CHAPTER III
TEXTURE

INTRODUCTION

The textural study of the Patherwa Formation Sandstone included grain size, roundness and sphericity to understanding the hydrodynamic conditions and environments of deposition. A large number of workers have studied this aspect and produced voluminous literature. Reviews of grain size parameters and their relationship with depositional processes have published by Folk (1966), Visher (1969) and Friedman (1979). These workers have been used the statistical measures such as mean size, standard deviation, skewness and kurtosis to beach, dune, aeolian flat and fluvial environments.

Doeglas (1946) observed that (1) grain size distributions are mixtures of two or more component distributions or populations, and (2) these distributions were produced by varying transport conditions. Inman (1949) recognized three fundamental modes of transport, surface creep, saltation, and suspension on the basis of shape and size of the particles. Relationship of grain size distributions to depositional processes is given by Moss (1962; 1963). He employed shape and size of grains to distinguish subpopulations produced by three fundamental modes of sediment transport and found that these three populations could be intermixed in the same sample. His data, illustrated the subdivision of three subpopulations and showed that the position of truncation, sorting and mean size of these populations were different in different samples.

Visher (1969) and his coworkers (Visher and Howard, 1974; Freeman and Visher, 1975; Sagoe and Visher, 1977) demonstrated that each cumulative curve, comprises a number of straight line segments of different slopes separated by sharp ‘breaks’. The straight line segments were interpreted as to represent truncated Log-Gaussian subpopulations. In the case of unidirectional flows, the three subpopulations recognized were associated with bed load ‘surface creep’ (coarsest population), saltation (intermediate), and suspension (finest). The nature of the straight line segments and breaks were accordingly related to the importance of the three transport
mechanisms operating during deposition presumed distinctive in different depositional environments. The Visher’s technique was employed in the recognition of ancient depositional environments by several workers (Holmes and Oliver, 1973; Glaister and Nelson, 1974; Amaral and Pryor, 1977; Moshrief, 1980). In the present study textural analysis of the sandstones was undertaken to discriminate the depositional and hydrodynamic conditions of the Patherwa Formation. The methodology followed and the results obtained are given in the following sections:

**METHODS OF STUDY AND DATA PRESENTATION**

There are 93 thin sections were used in this study for grain size analysis, estimation of roundness and grain sphericity. Thin section showing least modification of texture by diagenetic and compaction effects were selected. These constraints limited the textural study to ninety-three samples of sandstones.

Grain size measurements were carried out with the help of a micrometer eye piece. Chayes (1949) point counting technique was employed and in each thin section a minimum of 200-250 grains were measured. The size data was grouped into half-phi class intervals. Cumulative frequency curves of grain size data were plotted on log probability paper. The grain diameter in phi units represented by $\Phi_5$, $\Phi_{16}$, $\Phi_{25}$, $\Phi_{50}$, $\Phi_{75}$, $\Phi_{84}$, $\Phi_{95}$ percentiles were read from the size frequency curves. These values were then converted to their sieve equivalents with the help of Friedman’s (1958) graph. The statistical parameters of grain size were calculated according to formulae given by Folk (1968, 1980) and included graphic mean ($M_Z$), inclusive graphic standard deviation ($\sigma_I$), inclusive graphic skewness ($Sk_I$) and graphic kurtosis ($KG$) (Appendix 2).

**GRAIN SIZE PARAMETERS**

The statistical parameters of grain size (Folk, 1968; 1980) of the sandstones under study are described below:
Graphic Mean Size (Mz): It is a function of size range of available sediment and the amount of energy imparted to the sediments which depends on the current velocity or the turbulence of the transporting medium. It has been calculated with the help of Folk’s formula:

\[ Mz = (\Phi_{16} + \Phi_{50} + \Phi_{84})/3 \]

Inclusive Graphic Standard Deviation (\( \sigma_1 \)): It depends upon the competency and stability of the currents. Relatively constant strength currents produce very well sorted to well sorted sediments but fluctuating currents will give rise to poorly sorted sediments. This parameter is derived by the formula:

\[ \sigma_1 = (\Phi_{84} - \Phi_{16})/4 + (\Phi_{95} - \Phi_{5})/6.6 \]

Inclusive Graphic Skewness (SK\( \ell \)): It measures the degree of asymmetry of the frequency distribution and is determined by the relative importance of the tail of distribution. The skewness or asymmetry is also determined by the position of the mean with respect to median. The comprehensive formula is given below:

\[ SK\ell = [(\Phi_{16} + \Phi_{84} - 2\Phi_{50})/2(\Phi_{84} - 16\Phi)] + [(\Phi_{5} + \Phi_{95} - 2\Phi_{50})/2(\Phi_{95} - \Phi_{5})] \]

Inclusive Graphic Kurtosis (KG): Inclusive Graphic kurtosis reflects the peakedness of the distribution and measure the ratio between sorting in the central portion. If the central portion is better sorted than the tail, the curve is said to be excessively peaked or leptokurtic. When tails are better sorted than the central portion, the curve is flat peaked and platykurtic. The graphic kurtosis is calculated with the help of the following formula:

\[ KG = (\Phi_{95} - \Phi_{5}) / 2.44(\Phi_{75} - \Phi_{25}) \]

Skewness and Kurtosis were referred to as indicators of selective action of transporting agents by Krumbein and Pettijohn (1938). Folk and Ward (1957) suggested that sands deposited near the source are characteristically leptokurtic and positive skewed. Mason and Folk (1958) made comparative textural studies of recent beach sands, dune and aeolian flat environments. These studies indicate that beach sands are normal or negative-skewed and leptokurtic, dune sands have positive skewness and are mesokurtic, and aeolian flat sands are positively skewed and
leptokurtic. Duane (1964) studied recent sediments in Western Pamlico Sound, North Carolina and found that: (i) the sign of skewness can be related to environmental energy and therefore to environment. Where winnowing is a dominant force (high energy), as in tidal inlets, the littoral zone and beaches, most of barrier Islands, the sediments are very dominantly negative skewed, (ii) the areas where energy levels are low, are characterized by positive skewness, as in sheltered lagoon and dunes. Friedman (1961) showed that beach sand generally has negative skewness but both, dune and river sands usually have positive skewness.

**Roundness:** Roundness of detrital grains was estimated by Power’s (1953) method of comparison with two-dimensional images of grains. The Power’s scale of roundness has the advantage of having a geometric scale and suitable class limits.

**Sphericity:** The most commonly used method of determining the sphericity is through visual comparison. For the present study the comparison chart given by Krumbein and Sloss (1963) was used for classification of sandstones into three classes, high, medium and low sphericity.

- $> 0.9$ High Sphericity
- $0.3 - 0.9$ Medium
- $0.0 - 0.3$ low sphericity

**Bivariant plot of textural parameters:** Bivariant plots are used to show the interrelationship of the various textural attributes of the sandstones of Patherwa Formation. Different textural parameters of sediments are plotted against each other and their relationship is determined statistically by computing their correlation coefficient values, which throw light on type of transportation, sediment character and depositional environment. Different plots which are used include mean size versus standard deviation, mean size versus skewness, mean size versus roundness, mean size versus sphericity, roundness versus sorting and sphericity versus sorting.
HARDI SECTION

The graphic mean size values of sandstones of Hardi section ranges from 2.24 \( \Phi \)-4.52\( \Phi \), average being 3.45\( \Phi \), indicating that most of the samples are fine grained followed by medium grained (Appendix 2). Inclusive graphic standard deviation values range from 0.22\( \Phi \) -0.91 \( \Phi \), average being 0.52\( \Phi \), indicating overall moderately well sorted sediments. Most of the sediments are moderately well sorted followed by very well sorted. Inclusive graphic skewness values ranges from 0.21 - 0.76, average being 0.36. Most of the sediments belong to the strongly fine skewed class. The graphic kurtosis values range from 0.68 - 1.25, average being 0.96, suggesting most of the samples are platykurtic followed by leptokurtic and mesokurtic. The grain roundness values ranging from subrounded to subangular. In most of the samples, majority of the grains are subangular (average 39 %), and subrounded (average 44 %). The mean roundness of individual samples range from 0.38 to 0.50, average being 0.41 (Appendix 3). The mean sphericity values of the studied samples range from 0.36 to 0.43, average being 0.39 (Appendix 4).

**Bivariant plots of textural parameters:** The mean size values of the Hardi sandstones are plotted against their sorting values and their correlation coefficient value is computed as 0.10 (Figure 8a). The mean size versus skewness plot gives a correlation coefficient value of 0.08 (Figure 8b). The mean size versus roundness plot gives a correlation coefficient value 0.20 (Figure 8c). The mean size versus sphericity diagram has a correlation coefficient value -0.40 (Figure 8d). Plot of the roundness versus sorting gives a correlation coefficient value of 0.14 (Figure 8e). The plot of sphericity versus sorting has a correlation of 0.03 (Figure 8f).

**Observations:** The textural study of seventeen samples of sandstones of Hardi section shows that they are fine grained followed by medium grained, moderately well sorted, strongly fine skewed and platykurtic to leptokurtic. Majority of the grains shows low sphericity and are subangular to subrounded. Bivariant plots of different parameters indicate that mean size versus sorting has poor relationship. Mean size versus skewness has poor relationship whereas mean size versus roundness has moderate relationship. Mean size versus sphericity has moderate inverse relationship. Sorting versus roundness, mean sphericity versus sorting has poor relationship.
Figure 8. Bivariate plots of (a) mean size versus standard deviation, (b) mean size versus skewness, (c) mean size versus mean roundness, (d) mean size versus mean sphericity, (e) mean roundness versus sorting and (f) mean sphericity versus sorting.
OBRA SECTION

The graphic mean size of sandstones of Obra section of Patherwa Formation ranges from 2.62Φ -4.12Φ, average being 3.31Φ, indicating the sandstones are mostly fine grained followed by medium grained (Appendix 2). Inclusive graphic standard deviation values range from 0.21Φ-0.86Φ, average being 0.47 Φ, indicated that most of the samples are moderately well sorted followed by well sorted. Inclusive graphic skewness values ranges from 0.65-0.68, average being 0.27 Φ, indicated that most of the samples are strongly fine skewed to fine skewed. The graphic kurtosis values range from 0.53-1.38, average being 0.92. Most of the studied samples are platykurtic followed by mesokurtic and leptokurtic. The mean roundness of the individual samples range from 0.35-0.43, average being 0.40 (Appendix 3). The mean sphericity values ranges from 0.35 to 0.43, average 0.38 (Appendix 4). Majority of the studied samples show low sphericity followed by medium sphericity (Appendix 4).

Bivariant plots of textural parameters: The mean size values of the studied samples are plotted against their sorting values and their correlation coefficient value is computed as -0.18 (Figure 9a). The mean size versus skewness plot gives a correlation coefficient value of -0.28 (Figure 9b). The mean size versus roundness plot gives a correlation coefficient value -0.15 (Figure 9c). The mean size versus sphericity diagram has a correlation coefficient value 0.15 (Figure 9d). Plot of the roundness versus sorting gives a correlation coefficient value of -0.42 (Figure 9e). The plot of sphericity versus sorting has a correlation of 0.03 (Figure 9f).

Observations: The textural study of twenty two samples of Obra section shows that they are fine grained, moderately well sorted, strongly fine skewed, platykurtic, mesokurtic and leptokurtic. Majority of the sediments shows low sphericity and are subangular to subrounded. Bivariant plots of different parameters indicate that mean size versus sorting has negatively poor relationship. Mean size versus skewness has moderate inverse relationship, mean size versus roundness has poor relationship, mean size versus sphericity, roundness versus sorting and sphericity versus sorting has moderate inverse to poor relationship.
Figure 9. Bivariant plots of (a) mean size versus standard deviation, (b) mean size versus skewness, (c) mean size versus mean roundness, (d) mean size versus mean sphericity, (e) mean roundness versus sorting and (f) mean sphericity versus sorting.
KEWTA SECTION

The mean size values of Kewta section ranges from $0.4 \Phi - 3.55 \Phi$, average being $2.3\Phi$. Most of the samples are medium grained followed by coarse grained (Appendix 2) and fine grained. Inclusive graphic standard deviation values range from $0.20 \Phi - 0.86 \Phi$, average being $0.51\Phi$. Most of the samples are moderately well sorted followed by well sorted. Inclusive graphic skewness values ranges from $-0.43 - 0.52$, average being 0.24. Most of the samples belong to the strongly fine skewed to fine skewed class. The graphic kurtosis values range from 0.59 - 1.48, average being 0.99. Most of the samples are mesokurtic followed by platykurtic. The grain roundness values ranging from subangular to subrounded. In most of the samples, majority of the grains are subangular (average 45%), and subrounded (average 40%). The mean roundness of individual samples range from 0.36 to 0.43, average being 0.40 (Appendix 3). The mean sphericity values of sediments range from 0.34 to 0.43, average being 0.38 (Appendix 4).

Bivariant plots of textural parameters: The mean size values of the sandstones of Kewta section of Patherwa Formation plotted against their sorting values and their correlation coefficient values is computed as 0.09 (Figure 10a). The mean size versus skewness plot gives a correlation coefficient value of -0.03 (Figure 10b). The mean size versus roundness plot gives a correlation coefficient value 0.20 (Figure 10c). The mean size versus sphericity diagram has a correlation coefficient value 0.13 (Figure 10d). Plot of the roundness versus sorting gives a correlation coefficient value of 0.08 (Figure 10e). The plot of sphericity versus sorting has a correlation of 0.03 (Figure 10f).

Observations: The textural study of twenty seven samples of Kewta sandstones shows that they are medium grained, well sorted, strongly fine skewed and leptokurtic. Majority of the grains show low sphericity and are subangular to subrounded. Bivariant plots of different parameters indicate that mean size versus sorting has poor relationship. Mean size versus skewness has negatively poor relationship whereas mean size versus roundness has negatively poor relationship. Mean size versus sphericity, sorting versus roundness has poor relationship. Sphericity versus sorting has poor relationship.
Figure 10. Bivariant plots of (a) mean size versus standard deviation, (b) mean size versus skewness, (c) mean size versus mean roundness, (d) mean size versus mean sphericity, (e) mean roundness versus sorting and (f) mean sphericity versus sorting.
MARKUNDI SECTION

The graphic mean size values of sandstones of Markundi section of Patherwa Formation ranges from 1.5 Φ – 4.99 Φ, average being 2.56 Φ. Most of the samples are medium grained followed by fine grained (Appendix 2). Inclusive graphic standard deviation values range from 0.24 Φ, 0.92 Φ, average being 0.59Φ. Most of the sediments are moderately well sorted followed by well sorted. Inclusive Graphic skewness values ranges from 0.24 -1.01, average being 0.50 and are strongly fine skewed. The graphic kurtosis values range from 0.38 - 1.12, average being 0.81. Most of the samples are platykurtic followed by mesokurtic. Roundness values of the studied sandstones ranging from subangular to subrounded. Majority of the studied grains are subangular (average 42 %), and subrounded (average 42 %). The mean roundness of individual samples range from 0.38 to 0.47, average being 0.41 (Appendix 3). The mean sphericity values of the studied samples range from 0.36 to 0.47, average being 0.39 (Appendix 4).

Bivariant plots of textural parameters: The mean size of the sandstones of Markundi section of Patherwa Formation are plotted against their sorting values and their correlation coefficient values is computed as 0.27 (Figure 11a). The mean size versus skewness plot gives a correlation coefficient value of 0.13 (Figure 11b). The mean size versus roundness plot gives a correlation coefficient value -0.39 (Figure 11c). The mean size versus sphericity diagram has a correlation coefficient value -0.07 (Figure 11d). Plot of the roundness versus sorting gives a correlation coefficient value of -0.06(Figure 11e).The plot of sphericity versus sorting has a correlation of 0.10 (Figure 11f).

Observations: The textural study of twenty seven samples of sandstones of Markundi section of Patherwa Formation shows that they are medium to fine grained, moderately well sorted to well sorted, strongly fine skewed and platykurtic to mesokurtic. Majority of the grains shows low sphericity and are subangular to subrounded. Bivariant plots of different parameters indicate that mean size versus sorting mean size versus skewness and mean size versus roundness has moderate to poor relationship. Whereas mean size versus sphericity, mean roundness versus sorting and mean sphericity versus sorting has poor relationship.
Figure 11. Bivariant plots of (a) mean size versus standard deviation, (b) mean size versus skewness, (c) mean size versus mean roundness, (d) mean size versus mean sphericity, (e) mean roundness versus sorting and (f) mean sphericity versus sorting.
INTERPRETATION OF TEXTURAL ANALYSIS

Skewness and Kurtosis were referred to as indicators of selective action of transporting agents by Krumbein and Pettijohn (1938). Folk and Ward (1957) suggested that sands deposited near the source are characteristically leptokurtic and positive skewed. Mason and Folk (1958) made comparative textural studies of recent beach sands, dune and aeolian flat environments. These studies indicate that beach sands are normal or negative-skewed and leptokurtic, dune sands have positive skewness and are mesokurtic, and aeolian flat sands are positively skewed and leptokurtic. Duane (1964) studied recent sediments in Western Pamlico Sound, North Carolina and found that: (i) the sign of skewness can be related to environmental energy and therefore to environment. Where winnowing is a dominant force (high energy), as in tidal inlets, the littoral zone and beaches, most of barrier Islands, the sediments are very dominantly negative skewed, (ii) the areas where energy levels are low, are characterized by positive skewness, as in sheltered lagoon and dunes. Friedman (1961) showed that beach sand generally has negative skewness but both, dune and river sands usually have positive skewness.

The characteristics of size statistics revealed by mean size indicate fluctuations in the depositing media with fine grained sand deposited in low energy environment. The moderately well sorted to well sorted sediments deposited under fluctuation of currents. The fine skewness character of the sands indicates deposition in the distal part of the basin. Most of the kurtosis values are platykurtic to mesokurtic indicating that samples from four stratigraphic levels (central portion of the curves) was better sorted than the samples from the one stratigraphic levels (tails of the curves). The presence of subangular to subrounded grains indicates long transportation of the sediments. However, these features may remain so even after short distance of transport (Pettijohn, 1975) because of winnowing. Bivariant plots of various parameters representing samples from one stratigraphic level in all four sections indicate that, mean size versus sorting has poor relationship, which reflects fluctuating hydrodynamic condition during deposition. Mean size versus skewness has poor relationship from one stratigraphic level in four sections and the samples are strongly fine skewed to fine skewed, in narrow range of mean size from one stratigraphic level in four sections indicating fluctuation in energy condition of depositional
medium. Mean size versus mean roundness has moderate relationship from one stratigraphic level in four sections indicating increase in roundness with decrease in grain size. Mean size versus mean sphericity has poor to moderate relationship from one stratigraphic level in four sections giving hint of a decrease in sphericity with increase in grain size. Mean roundness versus sorting has poor to moderate relationship from one stratigraphic level in four sections indicating of increase in roundness with sorting and mean sphericity versus sorting has poor relationship from one stratigraphic level in four sections giving hint of increase in sphericity with sorting.