Shape Analysis, Quantitative Percentage Determination and Depositional Environment of Detrital Quartz Grains of the Atrai River Sand, Naogaon District, Bangladesh

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Abstract—The present study mainly embodies the shape (roundness and sphericity) analysis, quantitative percentage determinationand Depositional Environment of detrital quartz grains of the Atrai River sand, Naogaon district, Bangladesh.The study shows that, maximum grains are sub-angular moderately spherical shaped carried by both in traction and suspension population through an aqueous medium of moderate energy condition whereas the sub-rounded spherical grains traveled by traction population covering more or less a long distance. Presence of some angular grains with low sphericity witnessed a shorter distance of transportation. Conversely, a considerable amount of rounded and a few well-rounded grains having high sphericity indicates multi cycles of transportation covering a longer distance anddeposition of sedimentation took place in fluvial environment. These grains (sediments) derived mainly from crystalline igneous and older sedimentary rocks;whilethe contribution of metamorphic rock is insignificant. The quantitative study of detrital quartz grains within the depository is less than fifty percent (42.29%) which cannot be recognized as silica sand.

Keywords— Detrital Quartz Grains, Shape Analysis, Quantitative Percentage Determination, Depositional Environment, Roundness, Sphericity, Atrai River Sand.

1. INTRODUCTION

For the sand sized clastic sediments, shape (roundness and sphericity) is the fundamental properties of texture. It could be described in terms of geometric form and textural morphology of the detrital grains. The property is mainly controlled by the shape of the mineral grains in the parent rock, hardness, mineralogical composition, size, mode,the fluidity, distance of transport, energy condition of transporting agents, environment of accumulation and the digenetic changes experienced by the sediments (Krumbein and Sloss, 1963; Griffiths, 1967; Folk, 1976 and many others).

Pettijohn (1957) concluded that roundness of a particle is the sum of its abrasional history and sphericity more largely reflects the condition of deposition at the moment of accumulation; to a more limited extent, the abrasion process modifies sphericity.

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The shape, fluidity and energy factors interact in the process of sorting (Pettijohn, 1957) and in determining the settling velocity of a clastic particle in the sedimentary environment (Nevin, 1947; Krumbein and Sloss, 1963).On the other hand, the low sphericity reflects chemical action accompanying unusual episodes in early or late diagenesis (Griffiths, 1967). Weathering of rocks yields grains with wide range of roundness and sphericity. Farther, the energy and fluidity conditions determine the rigor of abrasion and thereby the degree of roundness of clastic particles in the depositional environments to some extent. Inasmuch as, the fluidity and energy conditions of different depositional environments differ, the clastic particles in them show a corresponding variation in their shape distribution. Studies of shape (roundness and sphericity) provide information on processes of erosion, transportation and deposition (Griffiths, 1967). The shape studies may, therefore, help to differentiate depositional environments (Shepard, 1964; Griffiths, 1967). Thus, the overall shape of the sediments reflects the genesis of the detrital grains and paleogeographic history of the terrain.

During the last decades, different aspects of shape analysis have been studiedby a number of sedimentologists including Beal and Shepard (1956); Krumbein and Sloss (1963); Ehrlich and Weinberg (1970); Sahu and Patro (1970); Patro and Sahu (1971, 1974, 1977); Blett *et al*. (1972); Whalley (1972); Pettijohn *et al*. (1973); Sahu (1973, 1976, 1982); Swan (1974); Patro (1975); Friedman and Sanders (1978); Reineck and Singh (1980); Verma and Prasad (1981); Leeder (1982); Oxford and Whalley (1983); Babu and Sinha (1987); Jahan *et al*. (1990); Rahman and Shine (1993); Rahman *et al*. (2004), Shine (2006) and many others.

The main objectives of this study is to determine the shape of the detrital grains. At the same time, to predict the mode and distance of transportation, energy condition of the transporting agents including the depositional environments of the detrital quartz grains. An attempt was also taken to determine the quantitative percentage of detrital quartz grains within the sediments. To fulfill these aims,32 sand samples were collected from six Upazilas of Naogaon district along the Atrai River, Bangladesh (Figure 1).

Figure 1: Location map of the study area.

2. METHOD OF STUDY

There are two types of techniques generally applied for the shape (roundness and sphericity) analysis of detrital quartz grains; one is visual comparison method (Figure 2) suggested by Krumbein and Sloss (1963) and another is direct measurement method. The first one was found suitable because in this method, various roundness and sphericity classes are well spaced and the variation in roundness and sphericity in each classes are correlated with the change inroundness and sphericity values (Figure 3 & 4). The same method was also favored by Griffiths (1967); Sahu and Patro (1970); Patro (1975);

Rahman and Shine(1993); Rahman *et al*. (2004), Shine (2006) and many others.

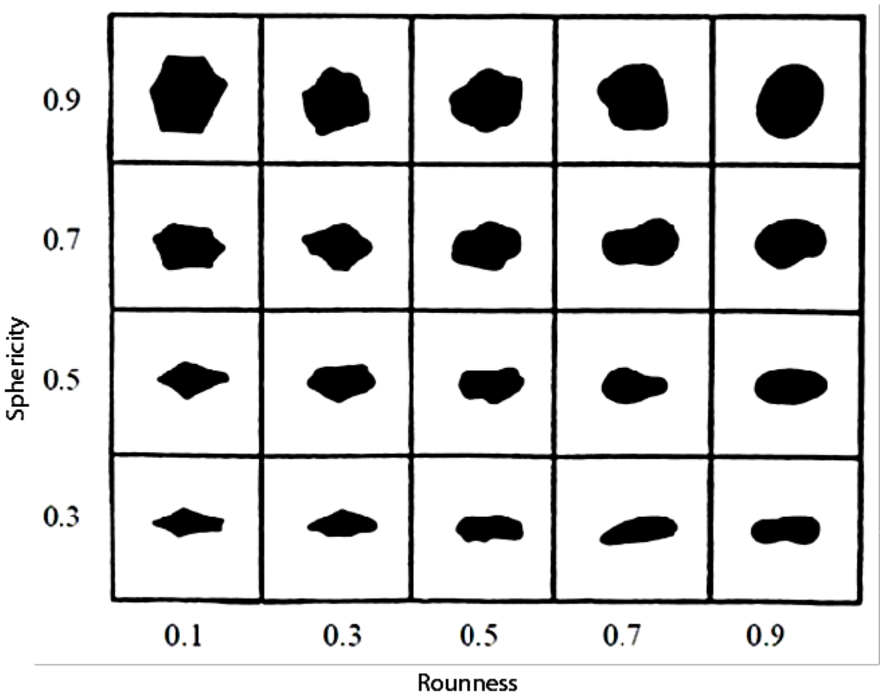

Figure 2: Chart for visual estimation of roundness and sphericity of sand grains(Krumbein and Sloss, 1963).

At first clay fractions were removed from the collected samples by repeated decantation in the laboratory. The sand sized fractions (1φ-3φ) having ferruginous coating were treated with dilute solutions of Hydrochloric acid (10%) and stannous chloride. Cleaned samples were washed with distilled water and dried in an oven at a temperature less than 40°C. Out of 32 collected samples from six Upazilas of Naogaon district considering the lithologic variation 14 representative samples (Figure 1) were finally prepared for14 slides with a view to determine the roundness and sphericity (shape) analysis through the microscopic observation (Plate A-L).

From 14 representative slide samples, 828 quartz grains were studied under the microscope (NPL-400B) and the individual grains were sketched on centimeter graph paper. The magnification was kept constant (140X) throughout the investigation. The roundness and sphericity of the sketched quartz grains were then estimated by comparing the chart provided by Krumbein and Sloss (1963). The sketching of the quartz grains has been recommended among others by Pettijohn (1957, 1977); Griffiths (1967); Sahu and Patro (1970); Patro (1975) mainly because of the abundance and stability of the mineral. Besides, it eliminates the variation caused by the hardness and mineralogical factors. The frequency percentage distribution of detrital quartz grains in various roundness grades and sphericity classes are shown in the table 1 & 2 and the average data have been represented graphically in figure 3& 4. The quantitative percentage of quartz grains has shown in table 3 and the data represented in figure 5.

3. DATA INTERPRETATION

3.1 Roundness

The roundness values of different localities of Naogaon district along the Atrai River (Table 1), majority of the quartz grains belong to sub-angular grade ranging from 34.68%-45.14% with an average of 40.12%. The sub-rounded and rounded grades attained the second and third highest positions varying from 24.15%-38.40% and 03.84%-27.58% with an average percentage of 32.65 and 14.55 respectively. The angular grade possesses maximum and minimum of 11.60% and 02.02% respectively while the grains of well-rounded grade are represented by 05.98% (Plate A-L).

3.2 Sphericity

The data of all 828 quartz grains of studied area reveal that, moderately spherical class ranges from 25.92%-55.81% with an average of 42.79% followed by spherical class which is reflected by the average percentage of 25.61 (Table 2). On the other hand, the poorly spherical class possess maximum and minimum of 30.76%-13.33% respectively with an average percentage of 23.20, whereas the highly spherical class is very low reflecting by only 08.39% (Plate A-L).

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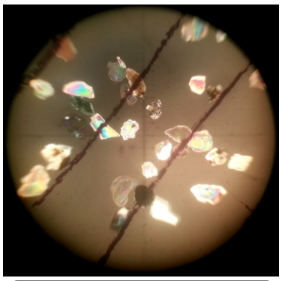

Plate:A
Sample No: DSS-3

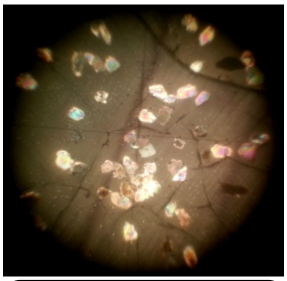

Plate:B
Sample No: DSS-5

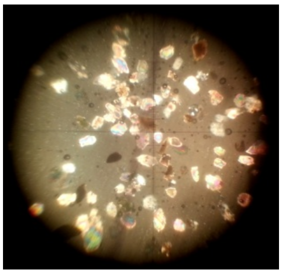

Plate:C
Sample No: PSS-6

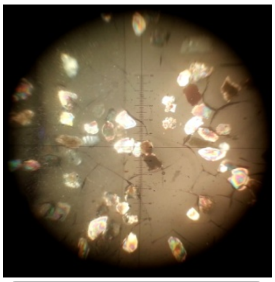

Plate:D
Sample No: PSS-8

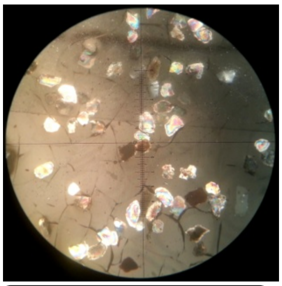

Plate:E
Sample No: MSS-9

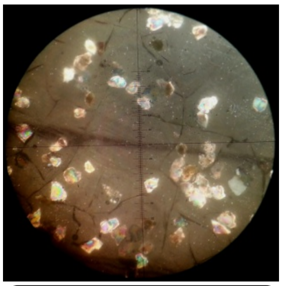

Plate:F
Sample No: MSS-12

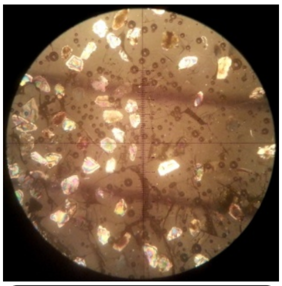

Plate:G
Sample No: MSS-15

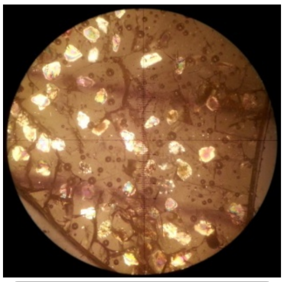

Plate:H
Sample No: MSS-18

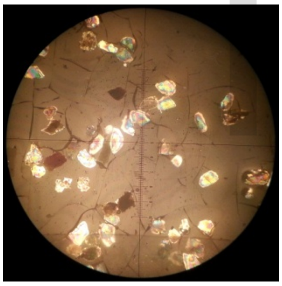

Plate:I
Sample No: RSS-21

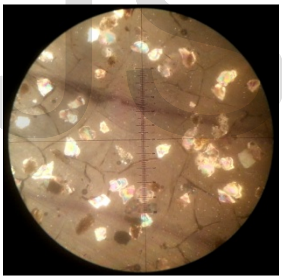

Plate:J
Sample No: RSS-23

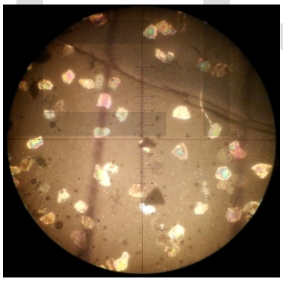

Plate:K
Sample No: ASS-24

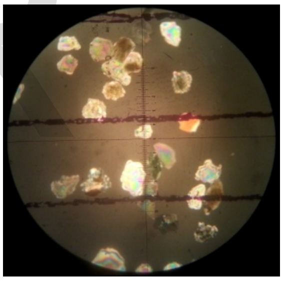

Plate:L
Sample No: ASS-3o

Plate (A-L): Showing the shape of the detrital quartz grains of the Atrai River sand of different Upazila of Naogaon district, Bangladesh.

TABLE-1: ROUNDNESS VALUE OF DETRITAL QUARTZ GRAINS OF THE ATRAI RIVER SAND OF NAOGAON DISTRICT, BANGLADESH

Sample No.	Angular 0.10 (%)	Sub-angular 0.30 (%)	Sub-rounded 0.50 (%)	Rounded 0.70 (%)	Well-rounded 0.90 (%)
Dhamoirhat Upazila Area					
DSS-3	11.60	45.14	38.40	03.84	01.02
DSS-5	11.54	45.11	37.31	04.00	02.04
Patnitala Upazila Area					
PSS-6	10.79	42.27	37.29	07.31	02.34
PSS-8	10.34	42.10	36.93	08.60	02.03
Mahadevpur Upazila Aea					
MSS-9	08.22	41.66	35.02	12.06	03.04
MSS-12	07.67	40.75	34.20	13.38	04.00

Manda Upazila Area					
MSS-15	07.12	40.00	32.39	14.63	05.86
MSS-17	05.72	40.73	31.75	15.78	06.02
MSS-18	04.87	39.81	31.80	17.26	06.26
Raninagar Upazila Area					
RSS-21	03.83	38.46	30.80	20.02	06.89
RSS-23	03.71	37.86	29.54	18.52	10.37
Atrai Upazila Area					
ASS-24	03.70	36.65	28.93	19.60	11.12
ASS-27	02.70	36.58	28.55	21.03	11.14
ASS-30	02.02	34.68	24.15	27.58	11.57
Average	**06.70**	**40.12**	**32.65**	**14.55**	**05.98**

TABLE-2: SPHERICITY VALUE OF DETRITAL QUARTZ GRAINS OF THE ATRAI RIVER SAND OF NAOGAON DISTRICT, BANGLADESH

Sample No.	**Poorly Spherical 0.30 (%)**	**Moderately Spherical 0.50 (%)**	**Spherical 0.70 (%)**	**Highly Spherical 0.90 (%)**
Dhamoirhat Upazila Area				
DSS-3	20.00	48.00	24.00	08.00
DSS-5	29.62	25.92	22.24	22.22
Patnitala Upazila Area				
PSS-6	13.79	41.37	37.95	06.89
PSS-8	30.10	50.00	17.28	02.63
Mahadevpur Upazila Aea				
MSS-9	27.58	31.03	37.95	03.44
MSS-12	17.54	49.12	24.56	08.77
Manda Upazila Area				
MSS-15	25.10	40.90	25.35	08.65
MSS-17	27.90	55.81	13.97	02.32
MSS-18	17.24	51.72	29.32	01.72
Raninagar Upazila Area				
RSS-21	30.76	42.30	19.25	07.69
RSS-23	26.62	25.92	25.24	22.22
Atrai Upazila Area				
ASS-24	13.33	43.33	36.68	06.66
ASS-27	21.84	48.70	21.48	07.98
ASS-30	23.47	44.85	23.37	08.31
Average	**23.20**	**42.79**	**25.61**	**08.39**

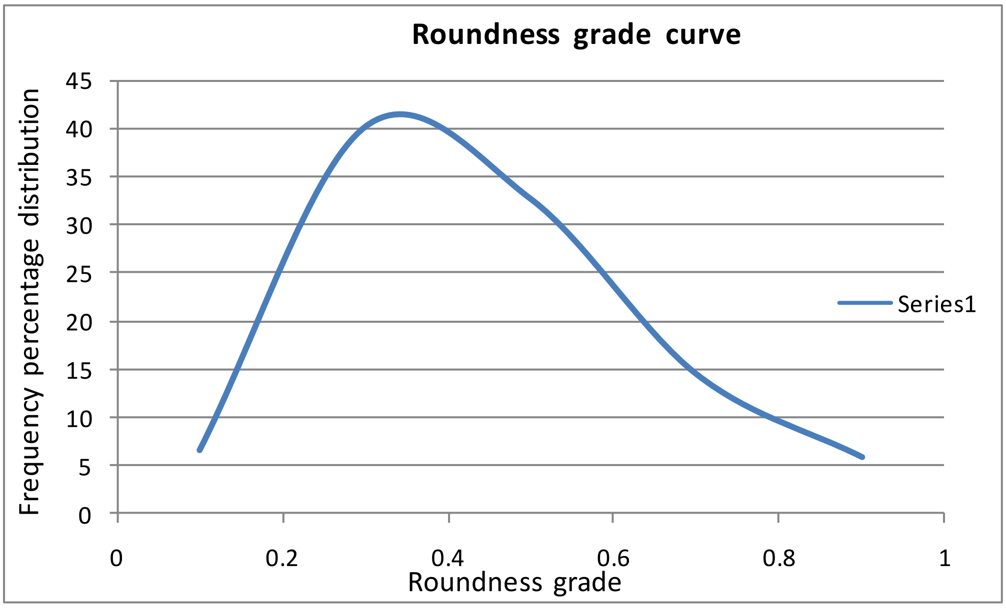

Figure 3. Average roundness value of detrital quartz grains of the Atrai River sand of Naogaon district, Bangladesh.

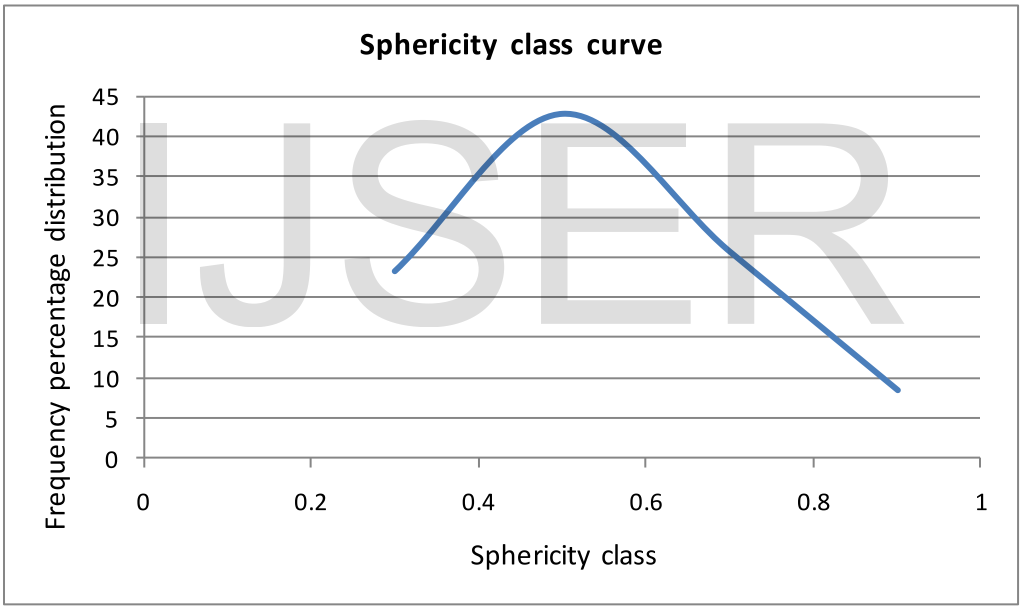

Figure 4. Average sphericity value of detrital quartz grains of the Atrai River sand of Naogaon, Bangladesh

TABLE-3: PERCENTAGE OF DETRITAL QUARTZ GRAINS OF THE ATRAI RIVER SAND OF NAOGAON DISTRICT, BANGLADESH

Sample No.	Detrital grains within slide	Number of quartz grains within slide	Percentage of quartz grains
Dhamoirhat Upazila Area			
DSS-3	143	51	35.66
DSS-5	120	44	36.66
Patnitala Upazila Area			
PSS-6	85	37	43.52
PSS-8	129	63	48.83
Mahadevpur Upazila Aea			
MSS-9	120	53	44.16

MSS-12	145	56	38.62
Manda Upazila Area			
MSS-15	133	58	43.60
MSS-17	186	85	45.69
MSS-18	135	57	42.22
Raninagar Upazila Area			
RSS-21	208	81	38.94
RSS-23	115	43	37.39
Atrai Upazila Area			
ASS-24	140	69	49.28
ASS-27	148	62	41.89
ASS-30	151	69	45.69
Total grains	**1958**	**828**	-------
Average percentage of 14 representative slides			**42.29**

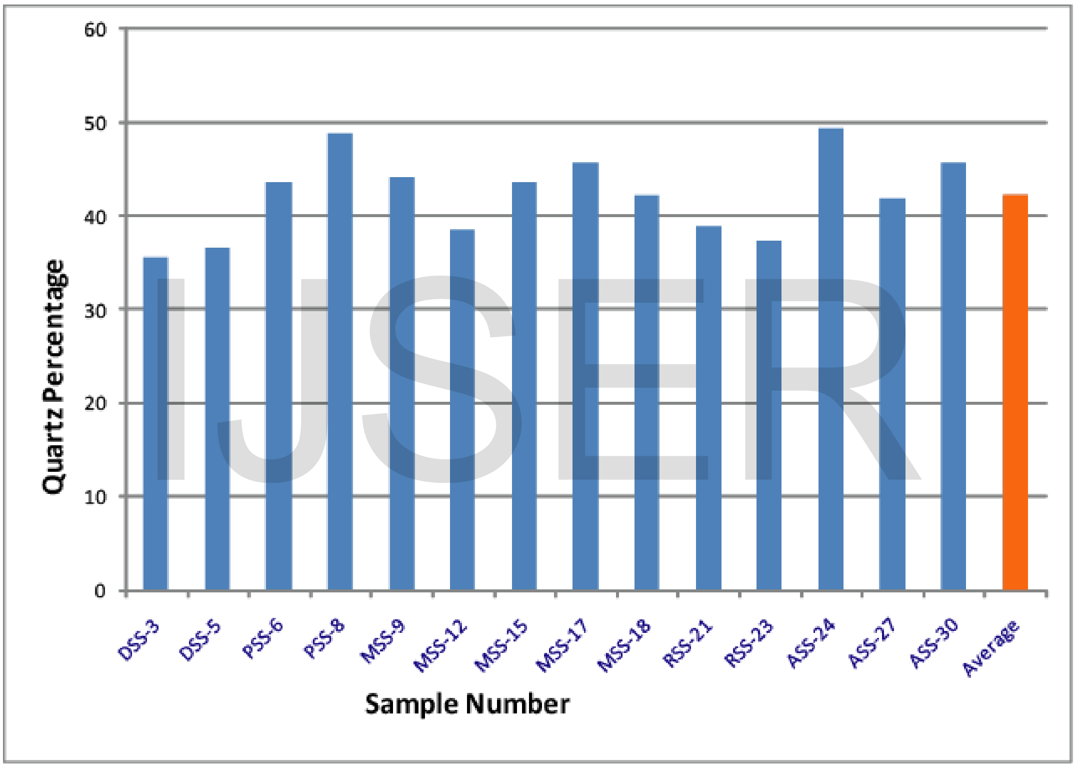

Figure 5: Percentage of detrital quartz grains of 14 representative samples of the Atrai River sand of Naogaon district, Bangladesh

4. DISCUSSION AND CONCLUSION

The statistical data (Table 1 & 2) reveal that, sub-angular and sub-rounded quartz grains dominate the clastic sediments of the Atrai River sand Naogaon district, Bangladesh. Such high abundance of quartz grains are attributed largely to their original outline of grains in the source rock and partly to the moderate distance of transportation which are the clear indication of first cycle of sediments with a significant proportion. This evidence is also supported by the presence of angular and nearly angular quartz grains; whereas, the considerable amount of rounded and a few well rounded grains owe their shape largely to a longer distance of transportation and/or the multi-cycle origin of clastic sediments.

On the other hand, moderately spherical to spherical classes of the quartz grains within the clastics are the indication of derivation of sediments from crystalline and older sedimentary rocks exposed in regions far from the basin of deposition. The impact of wind and turbulent water might be farther change the shape of the detrital grains; whereas, the fractions containing low sphericity might have been contributed by the metamorphic origin.

According to the Griffiths (1967), sphericity constitutes an important parameter for environmental discrimination. Roundness and sphericity frequency distribution of sand grains differ markedly from environment to environment. The variation in roundness and sphericity frequency distribution seemingly correspond to the difference in the existing energy and fluidity conditions among the different environments (Patro and Sahu, 1974). The roundness and sphericity parameter of the quartz grains of the investigated area indicate that the detrital sediments witnessed a moderate to long distance of transportation by wind and/or wave action. The frequency distribution of roundness and sphericity parameter (Figure 3 & 4) of the studied area shows that majority of the grains are indicative of dominantly single media of transportation through traction population. A minor deviation from unimodal distribution might have occurred in environments where the sediments were deposited by water (Patro and Sahu, 1974). Moreover, some digenetic changes might have occurred to modify the shape of quartz grains but no significant differences of depositional environments have been observed.

Considering all the circumstances, it could be concluded that, the dominating sub-angular moderately spherical grains are transported both in traction and suspension population through an aqueous medium of moderate energy condition. The sub-rounded spherical grains traveled through traction population covering more or less a long distance. The poorly spherical with a few angular grains comparatively covered a shorter distance; on the other hand, a considerable amount of rounded and a few well-rounded grains with highly spherical properties show multi-cycles of transportation covering a long to very long distance of transportation indicating deposition of sediment took place in fluvial environment. Crystalline igneous and the older sedimentary rocks are the chief sources of quartz grains while the role of metamorphic rock is insignificant. The presence of detrital quartz grains within the sediment is only 42.29% (Table 3) which indicates that the sediments cannot be recognized as silica sand in and around the Atrai River, Naogaon district, Bangladesh.

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