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Mineralogical Composition of Sand Deposits of an Estuarine Sequence, Bangladesh

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Abstract

The present study deals with the mineralogical composition of the sand deposits of the Jayanti estuary. The sands are composed of quartz (42.09%), feldspar (16.08%), rock fragments (0.79%), mica (4.75%), chlorite (0.75%), heavy minerals (8.45%), matrix (22.17%) and organic matter (4.48%) on an average. The relative abundance of the major minerals and lithic grains can be expressed as quartz>feldspars>lithic grains. The heavy minerals include hornblende, pyroxene, garnet, zircon, epidote, tourmaline, rutile, magnetite etc. The average matrix content of the sands is 22.17% that reflects the sands are wackes/dirty in nature. The presence of feldspar and clay particles in the sands are indicative of immaturity of the deposits. The sands might have derived from less resistant subcrustal plutonic rocks as the amount of total feldspars is higher than the lithic grains/rock fragments. The heavy mineral garnet indicates a high-grade metamorphic source while zircon, tourmaline and rutile suggestive of both igneous and metamorphic origin. The ZTR index varies from 27.69% to 50.08% with an average value of 37.58% which suggest that the sands are mineralogically immature.

Keywords: Quartz, feldspar, rock fragments, heavy minerals and ZTR index.

Introduction

The greywackes contain more than fifteen percent matrix and in some greywackes the amount of matrix may exceed fifty percent (Pettijohn et al, 1987). In some cases, greywackes contain less amount of quartz (Simpson et al, 2008). The heavy mineral study of the sedimentary rocks is a powerful tool in identifying provenance (Morton 1985). The heavy mineral concentrations of the river sands in Bangladesh varies from 6.25% to 8.26% (Rahman et al, 2017: Abedin et al, 2018). The ZTR index is higher in sediments of beach and littoral environments (Oni and Olatunji, 2017).

The study area lies in the two districts of Bangladesh, namely Shariatpur and Barisal. It is bounded by the latitude of 22°59´30" N to 23°11´30" N and longitude of 90°22´30" E to 90°28´30" E. The mean maximum and minimum temperatures are 33.9°C and 12.6°C respectively and the annual rainfall varies in between 2032 mm to 2286 mm (Rashid, 1977).

The area is drained by a river named as Jayanti river, that finally drains into the Meghna river. The area experiences semidiurnal tides. Numerous tidal creeks and khals fed the Jayanti river.

The Jayanti estuary is a funnel shaped water body. The geological map of the investigated area reveals the sediments of Recent age are the products of estuarine and deltaic environments (Alam et al, 1990). Previous studies show that the mud (silt and clay) dominates over the sand deposits. The sand deposits mainly occur as finely laminated sand and silt with minor amounts of clay particles (Roy et al, 2005). The colour of the sand varies from light yellowish brown to grey, medium to very fine sand rhythmically altered with steel grey silt (Figure I). This is the product of tide. Massive sand with crude laminations is found in two locations of the study area that might have resulted from storm/seasonal floods (Saha, 2000). The present study deals with the mineralogical study of these sand deposits.

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Figure I. Base: finely laminated sand and silt, middle: silty rhythmites and top: massive steel grey clay. Finning up sequences showing sharp erosional contact.

Methodology

Seven sand samples were collected from the field to study the mineralogical composition. The samples of the study area were found loose, impregnation was essential for each sample. At first slabs of loose samples were prepared with dimension of 3cm length, 2cm width and 1 cm thickness with adhesive glue. The adhesive glue was prepared by mixing araldite resin and araldite hardener in a ratio of 1:1 and was diluted with toluene (glue 30%: toluene 70%). Then the samples were sunk into it and kept 72 hours, allowing the solution to penetrate the samples. After evaporation of toluene, the samples became hard. These samples were then heated in an oven at 40°C temperature for 48 hours to increase their rigidity. One side of the impregnated slab was polished on a coarse grinding lap and further a glass plate using a 400 grade and after rinsing 600 grade carborundum powder with water unite a smooth and flat surface is achieved. The polished surface was then washed with running water to remove carborundum powder and was dried. The flat and smooth surface of slab was mounted on a clean microscopic slide applying araldite glue on the polished surface. Care was taken to remove any excess glue and any air bubble from the glue. Then it was placed at room temperature for 72 hours as the slab became fixed on the glass slide. The free face of the sample was grinded on a coarse grinding tap until light could pass through it. Then it was further grinded on a glass plate using 400 grade and after rinsing 600 grade carborundum powder. The thickness of the rock sample was checked regularly using a polarizing microscope until the required thickness of the rock samples (0.03mm) was gained. The washed and dried rockslide was then covered by thin cover slip after applying Canada balsam on the heated surface of the slide. Finally, the slide was washed with acetone and labeled.

The mineralogical composition of the sand samples was analyzed using polarizing microscope, MEIJI. From each slide at least 300-400 grains were counted. Photographs of representative mineral grains were taken using a camera attached with the high-level polarizing microscope. The ZTR index was calculated using the following formula:

$$\text{ZTR index} = \frac{(Zicon + tourmaline + Rutile) \times 100}{Total\ non-opaque\ heavy\ minerals}$$

Results

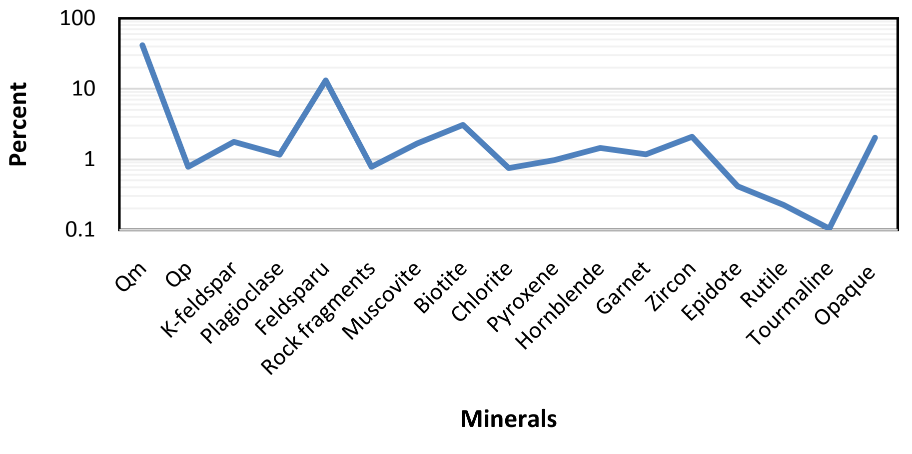
Table 1. Mineralogical composition of the sand deposits of the study area

Sample No.	A30	A27	A31	A18	A17	A4	A1
Monocrystalline quartz	36.84	41.03	40.58	45.4	46.44	43.12	35.71
Polycrystalline quartz	0.88	0.84	1.02	1.03	0.76	0.57	0.4
K-feldspar	2.63	2.34	2.53	2.48	1.02	0.28	1.09
Plagioclase	1.58	1.5	1.65	1.44	0.76	0.57	0.65
Undifferentiated feldspar	9.12	9.85	15.32	13	13.45	16.74	14.59
Rock fragments	0.53	0.43	1.05	1.65	1.27	0.57	0
Muscovite	0.88	2.34	0.95	0.41	1.27	1.13	4.79
Biotite	2.28	3.42	2.82	2.89	3.55	3.69	2.83
Chlorite	0.88	0.93	0.53	0.41	1.02	0.85	0.65
Pyroxene	1.58	1.01	1.48	0.41	0.76	1.13	0.44
Hornblende	2.11	1.85	1.33	1.65	1.27	0.85	1.09
Garnet	0.88	0.55	1.2	1.65	2.03	0.85	1.09
Zircon	1.75	1.92	1.89	2.06	2.28	2.27	2.4
Epidote	0	0.3	0.23	0.62	1.02	0.28	0.44
Rutile	0	0.25	0	0	0.76	0.57	0
Tourmaline	0	0.2	0	0	0.25	0.28	0
Opaque	1.23	2.14	1.95	1.86	3.05	1.99	1.96
Organic matter	1.75	7.94	5.47	1.03	3.05	4.26	7.84
Matrix	35	22	20	22	16	20	24
Total	99.92	100.84	100	99.99	100.01	100	99.97

The bulk mineralogical compositions of the sand are expressed as detrital and authigenic (chemical) components. The composition of the detrital mineral is dependent on the abundance of the minerals in the source area and chemical stability under sedimentary environments.

The Holocene sand as exposed along the study area are composed of quartz (42.09%), feldspar (16.08%), rock fragments (0.79%), mica (4.75%), chlorite (0.75%), heavy minerals (8.45%), matrix (22.17%) and organic matter (4.48%) on an average (Figure II).

Figure II. The mean concentration of minerals in sand deposits of the study area



The framework grains

Detrital framework grains of the sand sized particles of either monomineralic (i.e. quartz, feldspar, mica etc.) or polymineralic i.e., rock fragments constitute the framework structure of the sand. The petrographic study of the present study shows the following mineral compositions of the investigated sand deposits.

Quartz

Quartz is the most abundant mineral in the sand fraction. In thin sections, quartz grains were identified by their low refractive index (R.I), absence of cleavage, first order (pale gray to yellow) interference colour (Figure III), low birefringence and undulatory extinction.

Monocrystalline quartz grains constitute 41.30% of the total rock fractions and 98.13% of the total amount of quartz. Unstrained monocrystalline quartz grains are single crystals that extinguish as a unit under cross nicols when the stage of the microscope is rotated. Stained monocrystalline quartz grains termed as undulose quartz, are single crystals that never completely extinguish under cross nicols, but an irregular band of extinction merges across the crystal as the stage is rotated.

Polycrystalline quartz in the studied samples range from 0.40 to 1.03%. Crystal boundary of polycrystalline quartz may often be obscured due to recrystallization but extinction characteristics generally indicate the polycrystalline nature. Boundary between the polycrystalline quartz may be straight or sutured. Polycrystalline quartz grains result from the weathering of metamorphic rocks.

Feldspars

Feldspars are the second abundant minerals of the studied samples and constitute 13.33% to 19.50% of the total rock components. Both orthoclase and microcline are common feldspar and they comprise 0.28% to 2.63%. Microcline is identified by its distinct cross-hatching twinning, first order gray interference colour,

a	b
	
c	d

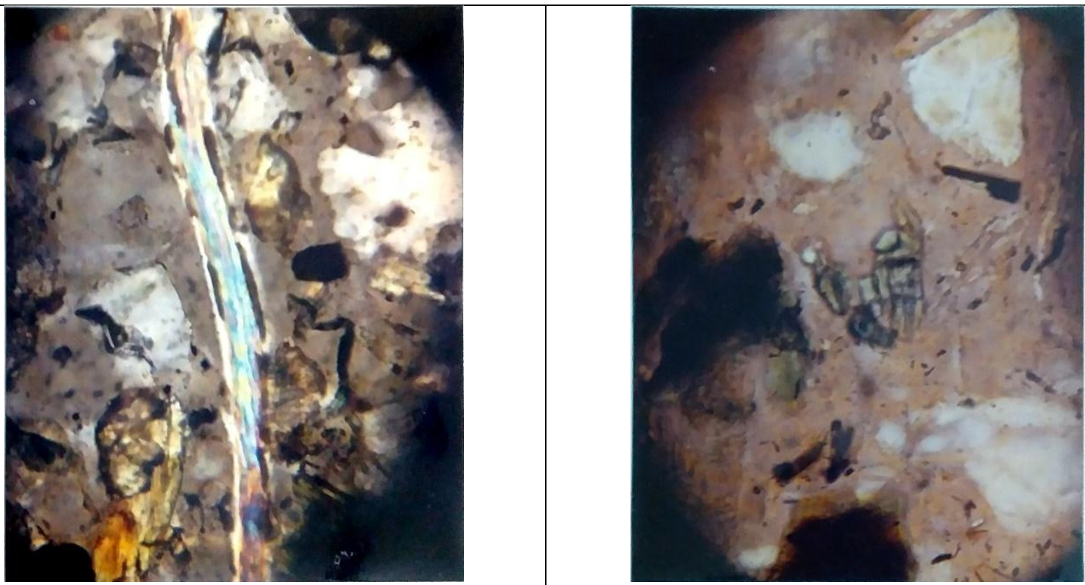


Figure III. Photomicrographs showing (a) cross nicols, quartz grains, (b) cross nicols, plagioclase feldspar, quartz, rutile (c) cross nicols, muscovite and (d) cross nicols, augite, muscovite and quartz.

low birefringence, two sets of cleavage and low refractive index. In thin sections orthoclase shows Carlsbad twins.

Plagioclase feldspars range vary from 0.57% to 1.65% and is generally identified by its characteristics lamellar or polysynthetic twinning i.e., combination of Carlsbad-albite twinning. Calcium poor varieties have first order white interference colour, while calcium-rich varieties show first order yellow. Plagioclase feldspars are less common as they are unstable to chemical weathering.

Two types of alterations were reported in feldspar minerals. These include vacuolization and sericitization. Vacuolization refers to such an alteration in which feldspars attain a grayish turbid or cloudy appearance. Sericitization means the alteration of feldspar minerals to sericite, very fine-grained white mica. Untwinned feldspar is also found in thin sections.

Micas

Mica minerals constitute 3.16% to 7.62% of the sediments. Both muscovite and biotite are common as detrital minerals and they occur as thin tabular crystals, flakes, lamellar grains.

Muscovite varies from 0.41% to 4.79% and is colourless in plane polarized light and have one set cleavage, low refractive index, high birefringence with higher order pink and blue interference colour (Figure 3) and parallel extinction.

Biotites range from 2.28% to 3.69%, with an average value of 3.07% and are yellowish brown to brown coloured in plane polarized light and strongly pleochroic. Reddish brown varieties usually have a high Ti and Fe content, and green ones usually have a high Fe^{3+} content. The mica content increases with the finning nature of the sand deposits.

Chlorite

Chlorite is another minor mineral in the sand samplesof the study area. The concentrations of chlorite vary from 0.41% to 1.02% (Table 1) with an average value of 0.75%. it is pale to darker green in colour. They are identified by their birefringence and pleochroism. Biotites and hornblendes often alter to chlorite.

Rock fragments

Rock fragments comprise trace to 1.65% with an average value of 0.79% of the total rock components. Sedimentary rock fragments are identified in thin sections, that include mainly sandstone and sandstone.

Heavy minerals

Heavy minerals occur as detrital grains and they comprise 7.42% to 11.42% of the total rock components.

Non-opaque minerals

Minerals capable of transmitting light are designated as non-opaque minerals. They were identified by their optical properties, such as relief, cleavage, crystal habit, interference colour, extinction angle and optic sign.

Garnet

Euhedral crystals of garnet having six sided sections are common and they are characterized by colourless too pale brown colour, lack of cleavage and isotopic nature. Garnet constitutes 1.18% of the total rock components.

Zircon

Zircon occurs as small euhedral or subhedral prismatic crystals. They are commonly colourless and have poor cleavage. High relief, lower order interference colour, high birefringence, crystal shapes and straight extinction are distinctive features of zircon and they range from 1.75% to 2.40% with the mean value of 2.08%.

Hornblende

Hornblendeconstitutes 1.45% of the total rock components and occur as euhedral prismatic crystals. They have perfect two directional cleavages and the angle between the two cleavages is always in the range 54°--56°. The mineral is characterized by its moderately strong green or blue green colour, inclined extinction (extinction angle varies from 12°--30°), second order blue interference colour and moderate birefringence.

Pyroxene

Pyroxene minerals comprise 0.97% on an average of the bulk mineral composition of the sand deposits and are usually euhedral or subhedral with a very elongate or acicular prismatic habit and colour varies from pale to dark yellowish green. Two set cleavages at 87°-90° angles are found in pyroxenes. Augite is the commonest mineral among the pyroxenes.

Epidote

Epidote ranges from 0%to 1.02% and occurs as colourless and pale green to yellowish green coloured grains. The mineral is slightly pleochroic. Epidote is found in aggregates of elongated prismatic crystals with pseudohexagonal cross sections. It is identified by its perfect (001) cleavage, high relief, moderate to high birefringence, second to third order yellowish green interference colour and straight extinction.

Rutile

Rutile usually occurs as small prismatic to acicular crystals and the colour of the mineral is yellowish to reddish brown in thin sections. High relief, high birefringence, high interference colour and parallel extinction are the distinguishing features of rutile and the amount of rutile varies from 0% to 0.76%.

Tourmaline

Tourmaline occurs as elongated prismatic crystals with a hexagonal or triangular in thin sections. They bear green to yellowish green colour and it is identified by its moderate relief, strong colour and pleochroism, lack of cleavage and crystal shape. They vary from 0% to 0.28%.

Opaque minerals

Minerals that are incapable of transmitting light are termed as opaque minerals. The opaque minerals comprise 2.03% of the rocks. Magnetite was identified from the sediment samples by using its magnetic property.

Organic matter

Organic matter is another accessory detrital component of the sand deposits. In the thin sections, the organic matter is identified by its dark yellowish brown to black colour with translucent edges and usually occurs as an isolated grain. The average concentration of organic matter is 4.48%.

Matrix

The average concentration of matrix is 22.7% of the studied sand deposits. Pettijohn et al, 1987 summarized that in graywackes the concentrations of matrix can exceed 50%. The size of the matrix materials ranges from silt to clay. The matrix comprises of silt size quartz particles, clays and micas.

Discussion

The quartz is used to correlate with the feldspar minerals. In terms of mineralogical maturity, an immature rock contains a mixture of stable (quartz) and unstable minerals (feldspars and clays) while the mature rocks contain only stable mineral, quartz (Oni and Olatunji, 2017). The sand deposits of the study area contain stable (quartz) and unstable (feldspars) and termed as immature sand deposits. The ratio of feldspar to the lithic grains are considered as an index of sands provenance. The sandstones that resulted from the weathering of supracrustal rocks (like volcanics) contain more lithic fragments than the feldspars. If a sandstone has more feldspars to the lithic grains, then the source rock is probably less resistant subcrustal rocks, like plutons. In the investigated area, the sands contain more feldspar than the lithic grains. The provenance of these sand deposits is probably less resistant subcrustal rocks, like plutons. The heavy mineral garnet indicates a high-grade metamorphic source while zircon, tourmaline and rutile suggestive of both igneous and metamorphic origin (Feo-Codecido, 1956).

The ZTR index is commonly high in beach or littoral zone depositional environments due to the long transport distances from their sources and are separated by the winnowing actions of the waves. The ZTR index of the study area varies from 27.69% to 50.08% with mean value of 37.58%. The ZTR index also reflects the maturity level of the entire heavy mineral assemblages (Oni and Olatunji, 2017). The present study reveals that the sands are mineralogically immature.

Conclusion

The sand deposits of the study area are deposited in estuarine environments and seasonal floods. The distribution major mineral and lithic grains can be expressed as quartz>feldspars>lithic grains. The presence of feldspar and clay particles are indicative of immature nature of the sands. The dominance of feldspars over the lithic grains in the sands reveals that the source rock is less resistant subcrustal plutonic rocks. The ZTR index varies from 27.69% to 50.08% with average value of 37.58%.The heavy mineral garnet indicates a high-grade metamorphic source while zircon, tourmaline and rutile suggestive of both igneous and metamorphic origin. Further research works can be taken on the Geochemistry of the sediments.

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