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Provenance and climatic condition of the quaternary Tista sand deposits, Rangpur, Bangladesh

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ABSTRACT

The present research work deals with the petrographic analysis of the Tista sand deposits which is exposed along the river bank and point bars. The constituent minerals of the sand deposits are quartz (73.18%), microcline (8.10%), orthoclase (0.15%), plagioclase (1.16%), lithic grains (1.37%), muscovite (6.59%), biotite (3.67%), heavy minerals, organic matters, minor amounts of matrix whereas fine-grained quartz and clay constitute the matrix materials. The heavy minerals include pyroxene, amphiboles, zircon, tourmaline, garnet, chlorite and opaque minerals. The major minerals and the lithic grains can be expressed as quartz>feldspar>lithic grains using the QFL ternary diagram. Among the heavy minerals, garnet is the most abundant mineral. The presence of magnetite was established using its magnetic susceptibility. Ninety-two percent of the sand specimens have the mineralogical index value ranging from 80 to 100, which suggests that the Tista sand deposits were derived from an extremely weathered condition. The QPK (Quartz-Plagioclase-K-feldspar) ternary plot reveals that all the sand samples fall near the Quartz-apex and the prevalence of more stable K-feldspar over the less steady plagioclase feldspar. The bivariate diagram of ln(Q/R) versus ln(Q/F) suggests the metamorphic provenance for the investigated sand deposits. The Q/(F+L) vs Qp/(F+L) plot indicates that the humid climatic conditions prevailed during the deposition these sand deposits.

Keywords: Quartz; Feldspar; Lithic grains; Ternary plot; Humid; Tista.

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INTRODUCTION

The Tista river basin is characterized by the clastic sedimentary deposits of Quaternary age. The upper part of the basin is filled by the recent alluvium deposits, whereas the basal part is composed of Late Pleistocene to Holocene Tista Gravel (UNDP 1982; Hossain 1999). The sediments as exposed along the banks and point bars. The textural analysis of sand deposits reveals their unimodal characteristics, which are indicative of a single source for these deposits (Saha et al. 2017). The research work of Mazumder et al. (1994) displays the poor sorting nature for the clastic deposits of the Tista River. The dominance of quartz in association with illite and/or mica was found in the finer fraction of the sedimentary sequences (Saha et al. 2020). The recent sediments from the Tista River basin show the presence of elevated amounts of silicon dioxide (Hossain et al. 2013). Aktar et al. (2003) performed the research work on the provenance of the sandstones of the Tista fan and showed that the amount of the feldspar minerals exceeds the amount of the rock fragments. The Tista River is flowing through the Tista fault (Sarker et al. 2009). The Tista or Teesta River finally falls into the Brahmaputra River (Fig. 1).

The present research work aims to describe the bulk mineralogical composition of the Quaternary Tista Sand deposits to reveal the provenance and climatic conditions for the deposition of these clastic sediments.

MATERIALS AND METHODS

Twenty-five sand samples were collected from the study area for the mineralogical analyses. The thin sections for petrographic analyses were prepared following the standard methods (Saha 2000; Roy et al. 2004). The quantitative analysis for mineralogical composition of sand deposits was done using the point counting methods. One hundred to six hundred fifty grains were counted for each petrographic slide using the standard methods (Gazzi 1966; Dickinson 1970). The number of point counts is inversely proportional to the particle size, i.e. larger the grain size, the fewer the number of grains per thin section slide, and vice versa.

Mineralogical Index of Alteration (MIA)

The mineralogical index of alteration (MIA) shows the relative abundance of stable quartz grains with comparatively less stable feldspar group of minerals and MIA is used to compute the weathering potential (Roy and Roser, 2013). The MIA can be measured by the following equation:

$$\mathbf{MIA} = \frac{Quartz}{(Quartz + Plagioclase + K - feldspar)} \times 100$$

The MIA is a count of weathering at the source area of the sediments and it is a factor that is not influenced by the sorting or frictional force (Nesbitt et al. 1996; Rieu et al. 2007). The total loss of feldspar is directly proportional to the numerical value of the MIA, i.e. the higher MIA values suggest more loss of feldspar group of minerals under humid and warm climatic conditions (Roy and Roser 2013). The Q-P-K ternary plot is also helpful to comprehend the climatic condition of the depositional basin.

RESULTS AND DISCUSSION

The petrographic study deciphers that the studied sand deposits of the Tista River basin are fine- to very coarse-grained grained occasionally laden with rock fragments or lithic grains. The framework grains are composed of quartz (both monocrystalline quartz and polycrystalline), microcline, orthoclase, plagioclase, muscovite, biotite, pyroxenes, amphiboles, zircon, tourmaline, tourmaline, garnet, chlorite, other opaque minerals, lithic grains or rock fragments and organic matter. The framework grains are sub-angular to sub-rounded in shape. The results of the petrographic analysis are shown in Table 1.

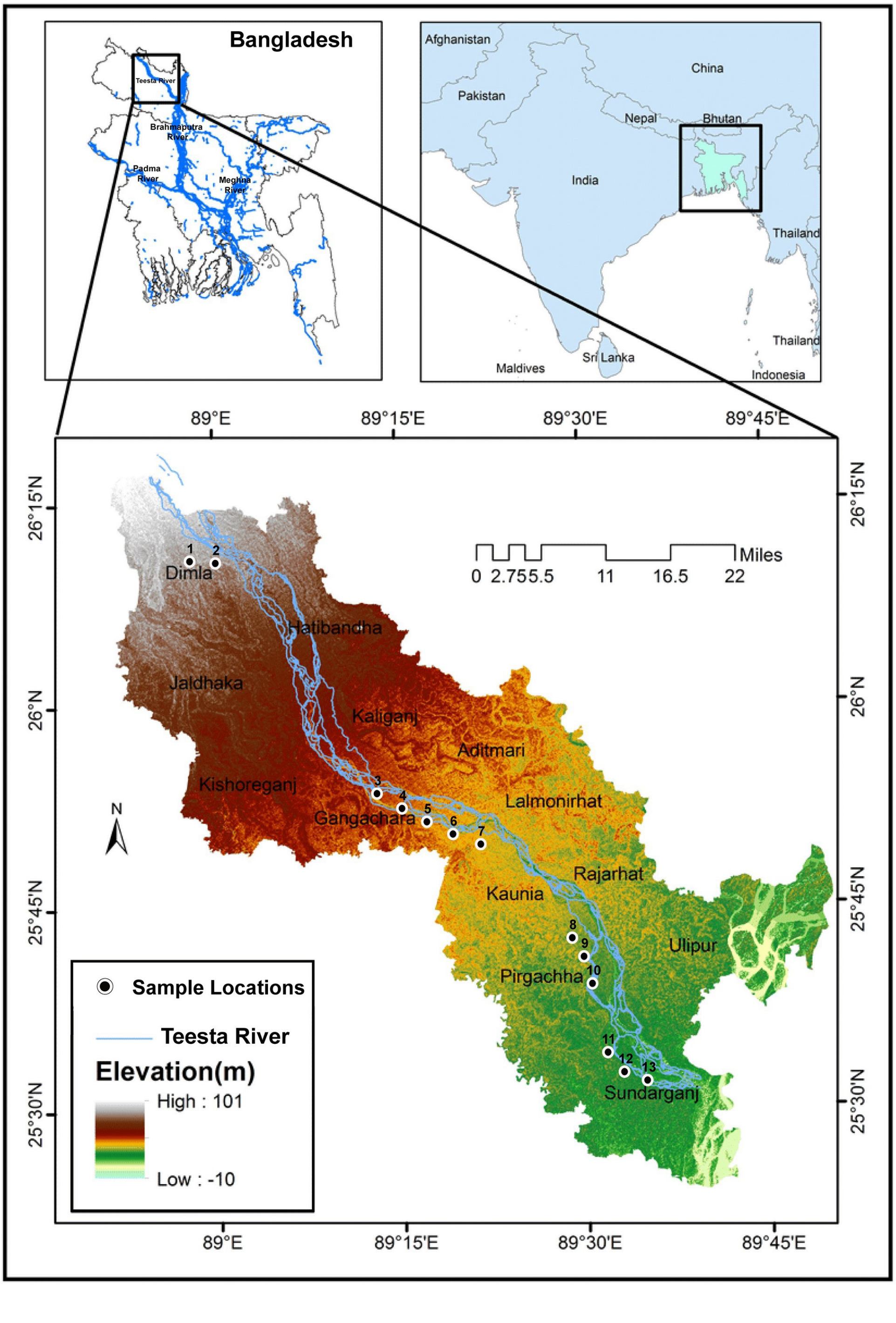

Fig. 1: Map of the study area (modified after Akter et al. (2019).

Table 1: Results of Statistical analysis of the microscopic analyses of Quaternary Tista sand deposits {n=25).

	Minimum	Maximum	Mean	Median	Std. Deviation	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis
Quartz	57.24	90.57	73.18	73.18	7.622	0.054	0.464	0.252	0.902
Microcline	0.00	18.42	8.10	7.62	4.622	0.285	0.464	-0.110	0.902
Orthoclase	0.00	0.77	0.15	0.00	0.241	1.347	0.464	0.484	0.902
Plagioclase	0.00	4.00	1.16	1.00	1.010	0.870	0.464	0.897	0.902
Lithic grains	0.00	9.92	1.37	0.90	1.972	3.677	0.464	15.638	0.902
Muscovite	2.69	16.67	6.59	5.80	3.290	1.405	0.464	2.406	0.902
Biotite	0.00	12.20	3.67	3.08	2.701	1.664	0.464	3.655	0.902
Pyroxene	0.00	0.71	0.13	0.00	0.249	1.517	0.464	0.587	0.902
Amphiboles	0.00	0.52	0.02	0.00	0.104	5.000	0.464	25.000	0.902
Zircon	0.00	3.86	0.44	0.00	0.847	3.071	0.464	11.074	0.902
Tourmaline	0.00	0.52	0.02	0.00	0.104	5.000	0.464	25.000	0.902
Garnet	0.00	5.24	1.31	1.09	1.128	1.963	0.464	5.296	0.902
Opaque	0.00	5.36	1.79	1.76	1.361	0.491	0.464	0.492	0.902
Chlorite	0.00	0.72	0.18	0.00	0.252	0.953	0.464	-0.656	0.902
OM	0.00	3.38	1.72	1.83	0.912	-0.425	0.464	-0.236	0.902
Chalcedony	0.00	1.16	0.17	0.00	0.313	2.029	0.464	3.620	0.902

Quartz: Quartz is the most component mineral in the investigated sand deposits (Fig. 2). The amount of quartz varies from 57.24% to 90.57% with an average value of 73.18%. The mineral quartz occurs as monocrystalline quartz and polycrystalline quartz. The quantity of monocrystalline quartz is greater than that of polycrystalline quartz (Fig. 2). The average amount of monocrystalline quartz is 69.22%, whereas the mean content of polycrystalline quartz is 3.96%. Polycrystalline quartz grains are composed of two or more crystals and crystal boundaries of polycrystalline quartz are often obscured due to recrystallization. The sandstones and sand deposits are characterized by the high content of quartz. The quartz grains are angular, subangular and subrounded. Elongated quartz grains are also observed (Fig. 3). Quartz is resistant to both mechanical and chemical weathering (Prothero and Schwab, 2003). Monocrystalline quartz grains having fluid-filled vacuoles are indicative of hydrothermal veins provenance. The quartz grains are characterized by uneven or undulose/undulatory/wavy extinction, which indicates distortion of their crystal lattice during tectonic activity, prior to their deposition in the sedimentary basin. Stresses in the sedimentary sequences are not enough to produce this type of deformation. Undulatory extinction of quartz characterizes their derivation from metamorphic origin. Nondulatory extinction of quartz is an indicative of volcanic igneous sources or grains recycled from older sandstones (Basu, 1985).

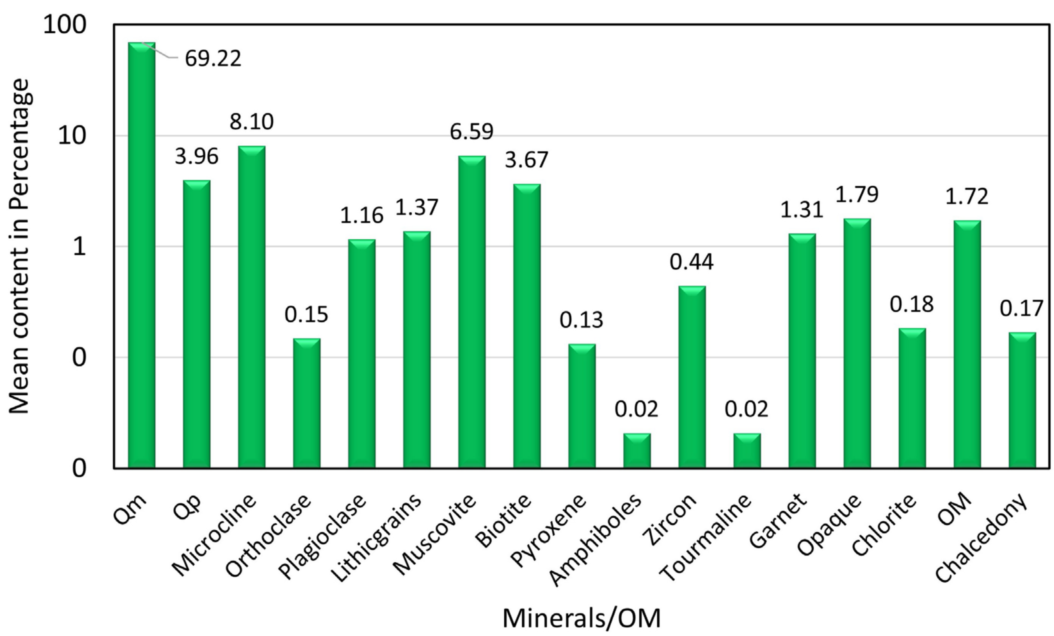

Fig. 2: The mean concentrations of framework mineral and organic matter (OM) grains of sand deposits (Semi-log).

The polycrystalline quartz grains are derived from the metamorphic rocks. The extinction may be straight or undulose. Inclusions of metamorphic minerals like micas and garnets may also be present (Basu et al. 1975). Polycrystalline quartz can develop from monocrystalline quartz during metamorphism (Young, 1976). Under the influence of increasing pressure and temperature, non-undulatory monocrystalline quartz transforms progressively into undulatory quartz, polygonized quartz and finally into polycrystalline quartz.

Feldspar: Microcline, orthoclase and plagioclase are the members of the feldspar group that are present in the studied sand deposits. Microcline is commonly present and comprises 8.10% on average (Table 1). The plagioclase feldspar is identified by its lamellar twinning (Fig. 3). The mean content of plagioclase feldspar is 1.16%. Orthoclase varies from zero to 0.77% and is distinguished by the Carlsbad twinning. Detrital feldspar from metamorphic origin is mainly microcline, while volcanic sources provide sanidine (Basu, 1976). The large amounts of microcline feldspar in the investigated area are suggestive of a metamorphic source.

Lithic grains: The amounts of lithic grains ranged from 0 to 9.92% with an average content of 1.37% in the studied sand specimens. The lithic grains are mainly of sedimentary and metamorphic origin. The pre-existing sandstone and schist grains are found in the thin sections.

Mica: Both the muscovite and biotite are reported in the sands of the Tista river basin. The average amounts of muscovite (6.59%) is higher than the average percentage of biotite (3.67%).

Heavy minerals: The heavy minerals comprise 3.89% of the total sediments and the include pyroxene, amphiboles, zircon, tourmaline, garnet, chlorite and opaque minerals (Table 1 and Fig. 2). Among the opaque minerals, magnetite was identified using its magnetic property.

Organic matter: The organic matter (OM) varies from 0 to 3.38% whereas the average value is 1.72%. In thin sections, organic matter is characterized by its dark yellowish to black colour with translucent edges. It is commonly found as an isolated grain.

Matrix: The amount of matrix is very low as the investigated sand deposits are relatively younger in age and the Tista is a fast flowing river. The matrix are mainly fine grained quartz and clay minerals.

Mineralogical Index of Alteration (MIA)

Ninety-two percent of the sand samples have the mineralogical index of alteration value varying from 80 to 100, which implies the Tista Sand deposits originated from extremely weathered sources. The ternary plot of Quartz, Plagioclase and K-feldspar (QPK) shows that the sand samples fall near the Quartz apex (Fig. 3). Figure 3 also shows the dominance of more resistant K-feldspar over the comparatively less stable plagioclase feldspar.

Paleoclimatic Conditions

The QFL diagram (Fig. 4a) shows that the higher percentage of quartz, relatively lesser amounts of feldspar and lithic grains. It is indicative of the source for the sediments of the Tista River from metamorphic rocks in humid climatic conditions (Suttner et al. 1981: Borgohain et al. 2019). The bivariate plot of ln(Q/R) versus ln(Q/F) (Fig. 4b) was constructed following the procedure as described by Weltje (1994), and it also suggests that the metamorphic rocks contributed more than the plutonic rocks for the formation of the Tista sand deposit. The bivariate plots of the Q/(F+L) vs Qp/(F+L) suggests the humid depositional conditions for the Tista sand deposits (Fig. 4c).

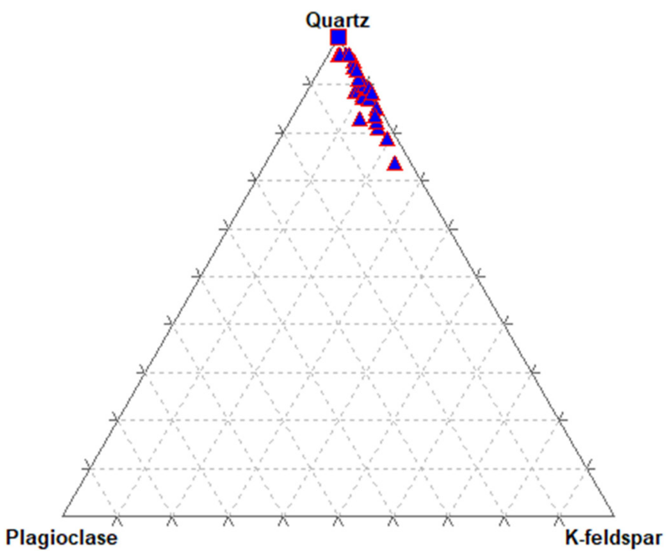

Fig. 3 The ternary plot of Quartz, Plagioclase and K-feldspar (QPK).

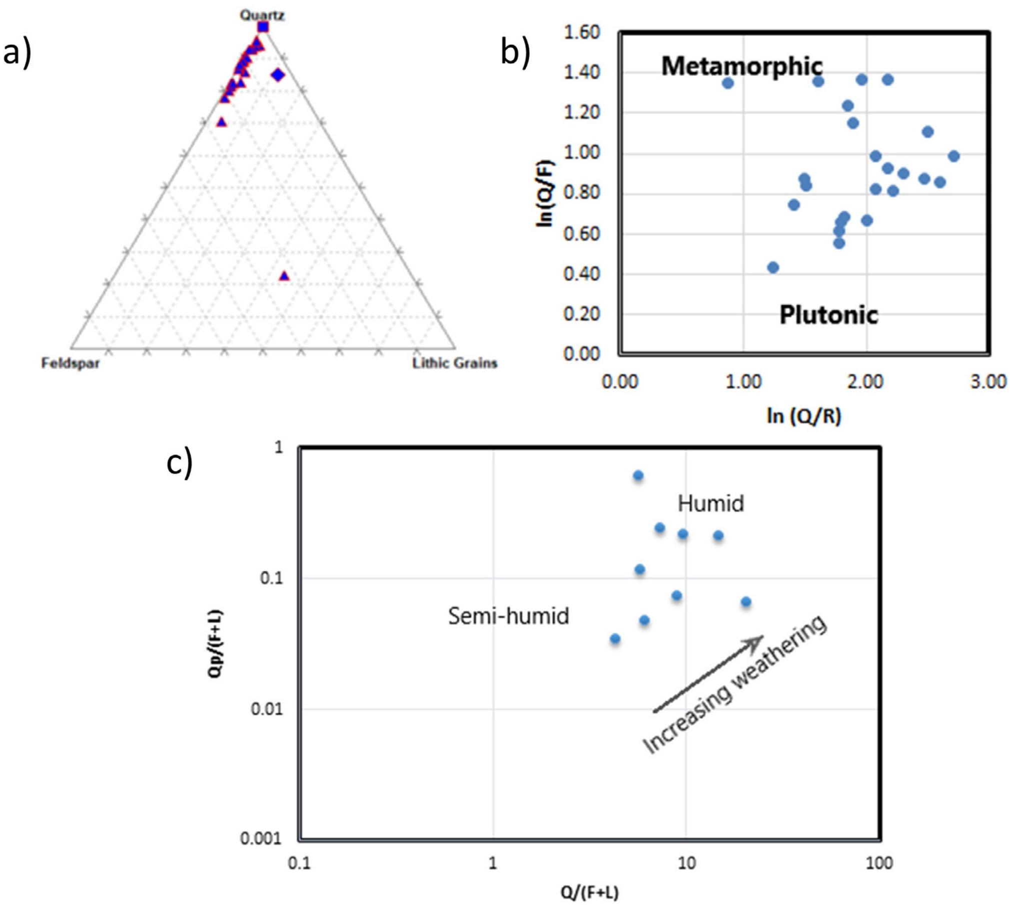

Fig. 4: a) The QFL plot of Tista sand deposits, b) the bivariate plot of ln(Q/R) versus ln(Q/F), and c) the bivariate plots of the Q/(F+L) vs Qp/(F+L)

CONCLUSION

The Tista river is flowing through the Tista alluvial fan and its path is bounded by the Tista fault. This research work is taken to study the petrographic characters of the exposed part of the Tista sand deposits along the river banks and medial point bars. Quartz, feldspars (chiefly microcline, orthoclase and plagioclase), muscovite, biotite and heavy minerals like pyroxene, amphiboles, zircon, tourmaline, garnet, chlorite, opaque minerals and lithic grains comprise the frame grains of the studied sands. From the opaque minerals, magnetite was identified easily using its magnetic property. The average amount of organic matter is 1.72%. The matrix materials are principally fine grained quartz and clay materials and the amount of matrix is very negligible as the sedimentary sequences are relatively younger and the finer particles are washed away by the fast flowing river. On the basis of the abundance of the major constituent minerals and lithic grains, it can disclose as quartz>feldspar>lithic grains and it is also approved by the QFL ternary diagram. The numerical value of mineralogical index of alteration (MIA) for most of the sand deposits vary from 80 to 100. The high values of MIA are an indication of the extremely weathered condition for the derivation of these sedimentary sequences. The K-feldspar predominates than the less stable plagioclase feldspar. The ternary plot of QPK shows that hundred percent of the sand samples fall close to the Quartz-apex. The metamorphic provenance is revealed for the Tista sand deposits from the bivariate plot of ln(Q/R) versus ln(Q/F). Humid climatic conditions were recognized at the time of deposition these sand deposits from the bivariate plot of Q/(F+L) vs Qp/(F+L).

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