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SAND MINERALOGY OF SOILS OF ASSAM
Soils developed on different land forms in North Bank Plain Zone of Assam. II. Sand mineralogy

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Abstract: The mineral assemblage in the fine sand fraction of the soils of North Bank Plain Zone of Assam was dominated by quartz (35.2-60.4%), feldspar (31.9-50.0%) and muscovite (5.3-32.4%) in the light fraction and biotite (27.6- 37.2%), chlorite (26.69-35.51%), zircon (18.84-32.23%), garnet (5.64-14.13%), hypersthenes (0.57-5.64%) and kyanite (0.83-4.81%) in the heavy fraction. The light mineral fraction is dominant and constituted 95.01-99.82 per cent of the fine sand fraction. The deficiency of ferromagnesian minerals and absence of opaque minerals was observed in these soils. The distribution and amount of light and heavy minerals and their shape and size indicated that the sand minerals in the North Bank Plain Zone of Assam are derived from sedimentary and partially metamorphosed rocks. The weathering ratio (Q/F) indicated more weathering of feldspars in the surface horizon of hill soils.

Additional key words: *Fine sand, mineralogy, light mineral, heavy mineral, weathering ratio*

Introduction

Study of mineral assemblage in the sand fraction of soils helps in understanding the nature and origin of parent materials, amount of weatherable minerals present and intensity of weathering of the soil. Chakravarty *et al.* (1979) reported mixed mineralogy of sand fractions of Brahmaputra alluvium, dominated by resistant minerals like quartz, zircon and weatherable minerals like mica, feldspars and chlorite. Karmakar and Rao (1999) reported that fine sand mineralogy of the soils of lower Brahmaputra valley zone of Assam was dominated by quartz, orthoclase, plagioclase and muscovite in the light fraction and zircon, biotite, chlorite, hypersthenes and kyanite in the heavy fraction. Dey (1999) observed that the distribution of mica, quartz and feldspars in fine sand fraction followed a definite trend in relation to pedogenic development of paddy and associated non-paddy soils of Assam. Dutta and Shanwal (2006) reported muscovite, biotite and K-feldspars as the prime K-bearing minerals in the sand and silt fractions of humid region of Assam. But the information on sand mineralogy of soils on North Bank Plain Zone (NBPZ) of Assam is very scanty. The present paper reports the fine sand mineralogy of soils developed on different land form units in the NBPZ of Assam.

Materials and Methods

The study area is located in Sonitpur district in the Northern Bank Plain Zone of Assam. Details of the study area and soil-site characteristics have been presented elsewhere (Karmakar 2014). Soil samples (<2 mm) from selected horizons were analysed for particle size distribution (Jackson 1979). The total sand fraction (2-0.05 mm) was separated by wet sieving and thereafter coarse sand (2-0.5 mm) and fine sand (0.5-0.05 mm) fractions were separated by dry sieving. The fine sand fraction was further separated into light and heavy mineral fractions using bromoform (specific gravity 2.82). These two fractions were washed with acetone, dried and percentage of light and heavy mineral fraction was calculated. Permanent slides of the light and heavy mineral fractions were prepared using Canada balsam as binding agent and studied under Leitz Panphot polarizing (petrographic) microscope following the procedure of Cady (1965).

Results and Discussion

The relative abundance of light and heavy minerals in the fine sand fraction is presented in Tables 1 and 2 respectively. The light mineral fraction constituted the bulk ranging from 95.01-99.82 per cent whereas the heavy mineral fraction constituted only <5 percent of the fine sand fraction.

Light minerals

Quartz was abundant in all the soils and constituted 35 to 60 per cent of the light mineral suit. It was generally observed that the amount of quartz increased in lower horizons except in hill (P1) and flood plain (P4) soils where the surface horizons contained higher amount (Table 1). The highest amount (51.5-60.4 per cent) of quartz was observed in the soils of P2 (monadnock) which is related to the siliceous (quartzite, sandstone) type of parent materials (Karmakar 2014). The outline of quartz was not distinct as there was little difference in refractive index between Canada balsam and that of quartz. Well developed quartz crystals were polygonal and angular whereas weathered crystals were subangular to round. Fresh grains of quartz observed in the flood plain soils (P4) were free from ferruginous coatings, inclusions and devoid of fractures. On the other hand well developed soils on low hill (P1) and monadnock (P2) contained quartz grains with needle-like and spherical inclusions and strain effect like oblique extinction indicating inheritance from metamorphic rocks. Some grains showed dirty appearance due to clay and / or iron oxide coatings. Thin grains showed sky blue polarization colour whereas thick grains exhibited concentric colour bands under polarized light.

Table 1. Light mineral assemblages (%) in fine sand fraction

Horizon	Depth (cm)	Light minerals (%)	Quartz	Feldspars				Muscovite
				Orthoclase	Plagioclase	Microcline	Total	
P1: Low Hill (Gamani) : *Ultic Hapludalfs*								
A	0-8	98.44	44.8	32.2 (83.6)*	4.6 (11.9)	1.7 (4.4)	38.5	16.7
Bt	52-140	99.58	35.2	26.2 (80.9)	5.5 (17.0)	0.7 (2.2)	32.4	32.4
P2: Monadnock (Baliparai) : *Ultic Hapludalfs*								
Ap	0-25	99.15	51.5	25.3 (73.1)	9.3 (26.9)	-	34.6	13.9
2Cg	162-220	99.37	60.4	27.3 (79.6)	7.0 (20.4)	-	34.3	5.3
P3: Alluvial plain (Ghoramari) : *Humic Endoaquepts*								
Ap	0-15	97.30	50.0	26.7 (53.4)	14.2 (28.4)	7.1 (14.2)	50.0	-
2Cg1	35-75	99.56	50.0	32.0 (80.0)	8.0 (20.0)	-	40.0	10.0
3Cg2	75-90	97.28	51.3	32.7 (87.9)	4.5 (12.1)	-	37.2	11.5
P4 : Flood plain (Na-Pam) : *Aquic Udifluvents*								
Ap	0-9	95.85	51.2	25.1 (78.7)	5.3 (16.6)	1.5 (4.7)	31.9	16.9
C2	73-101	99.82	42.7	37.7 (90.4)	4.0 (9.6)	-	41.7	15.6
2C3	101-108	95.01	47.0	37.8 (93.1)	2.4 (5.9)	0.4 (1.0)	40.6	12.4

*Figures in the parentheses represent as per cent of the total feldspar

Feldspar content in the fine sand fraction ranged from 31.9-50.0 per cent. The highest amount of feldspar (37.2-50.0%) was found in the soils on alluvial plain (P3) followed by that in the soils on flood plain (P4) (32-42%). Well developed soils on low hill (P1: Ultic Hapludalfs) and monadnocks (P2: Ultic Hapludalfs) contained lower amount of feldspar (Table 1). Orthoclase accounted for major portion (53-93 %) of feldspar followed by plagioclase (6-28 %) and microcline (1-14 %). Orthoclase feldspar varied from 25-38 per cent in the fine sand fraction. In general, subsurface horizons contained more amount of orthoclase feldspar than the surface horizons except in the soils on low hill (P1). This may be due to more hydrolysis of orthoclase in the surface horizon in presence higher organic matter. Orthoclase may react with a weak carbonic acid solution and form clay mineral kaolinite (Wade and Mattox 1969). On the other hand, the Bt horizon of P1 (low hill) contained less amount of orthoclase than the surface horizon. This may be due to non-uniformity of parent materials in these soils. This is also supported by wide sand/silt ratio between Bt and adjacent upper horizons (Karmakar 2014), which is taken as criterion for lithological discontinuinity (Sidhu *et al.* 1976). The relative distribution of feldspars within the profiles is mainly influenced by variations in the parent materials and the weathering activity (Mukesh *et al.* 2011). Weathered grains of orthoclase in the surface horizons exhibited pitted appearance due to partial alteration and those in the Bt horizon exhibited clouded appearance due to ferruginous coating. The grains showed typical blue interference colours with typical simple twinning.

Plagioclase feldspars constituted 2.4 to 16.2 per cent of the light mineral grains and characterized by the typical multiple lamellar twinning under cross nicols. Fresh crystals observed in the soils of P4 (flood plain) were clear and free from fractures and inclusions. Traces of alteration together with variations in lamellar thickness were observed in plagioclase grains in the soils of alluvial plain (P3).

Very small amount (0.4 to 7.1%) of microcline feldspars was present in the soils of low hill (P1), alluvial plain (P3) and flood plain (P4). Presence of microcline in these soils indicates that the parent materials are derived from metamorphic rocks as microcline is formed at lower temperature than is orthoclase (Huang 1977) and occurs in acid igneous rocks especially granite and pegmatites; also in feldspathic sandstones and arkoses derived from such rocks (Read 1973). This mineral could easily be identified by criss-cross twinning as a result of two sets of cleavages intersecting at right angles.

Muscovite mica ranged from 5.3-32.4 per cent. Muscovite was found as elongated, serrated flakes. It was colourless to light yellowish green in ordinary light and showed very bright polarization colours under cross nicols, as may be seen in metamorphic rocks – gneisses and mica-schists. The highest amount (32.4 %) of muscovite was observed in the Bt horizon of low hill (P1) soils which also suggests micaceous parent materials of these soils. Lower amount of muscovite in the surface horizon of P1 (Table 1) might be due alteration of this mineral to illite in the clay fraction. Mukesh *et al.* (2011) also reported high percentage of mica at the bottom and lower percentage at the top within profiles due to intense weathering at the surface.

Heavy minerals

Heavy minerals in the fine sand fraction were present as minute and fragmentary grains with varying shapes, sizes and colours. The heavy mineral suit consists of zircon (19-32 %), chlorite (27-35 %), biotite (27-37 %), garnet (6-14 %), hypersthenes (0.57-5.64 %) and kyanite (0.83-4.81 %) with traces of rutile in some profiles (Table 2).

The percentage of zircon increased in lower horizons except in P4 (flood plain) soils. This mineral was present as thin needle-like elongated crystals. Zircon showed bright interference colours, zoning and thick high relief. Pink and deep sky blue colours were observed in the transmitted and ordinary lights. As zircon is a resistant mineral, its higher percentage in the subsurface horizons indicates lower weathering of the soils.

Table 2. Heavy mineral assemblages (%) in fine sand fraction

Hori-zon	Depth (cm)	Heavy minerals (%)	Zircon	Chlorite	Biotite	Garnet	Hypersthene	Kyanite
P1: Low Hill (Gamani) : *Ultic Hapludalfs*								
A	0-8	1.56	32.18	28.16	27.59	7.47	0.57	4.02
Bt	52-140	0.42	32.23	28.93	37.19	-	0.83	0.83
P2: Monadnock (Baliparai) : *Ultic Hapludalfs*								
Ap	0-25	0.85	19.20	29.14	33.77	9.93	3.97	3.97
2Cg	162-220	0.63	28.00	30.00	29.20	8.00	1.60	3.20
P3: Alluvial plain (Ghoramari) : *Humic Endoaquepts*								
Ap	0-15	2.70	18.84	28.62	34.42	14.13	2.54	-
2Cg1	35-75	0.44	25.23	35.51	35.05	10.75	2.80	3.27
3Cg2	75-90	2.72	23.56	31.03	31.30	10.34	1.15	2.87
P4 : Flood plain (Na-Pam) : *Aquic Udifluvents*								
Ap	0-9	4.15	24.06	26.69	33.83	5.64	5.64	4.14
C2	73-101	0.18	20.27	35.40	30.24	8.25	1.03	4.81
2C3	101-108	4.99	21.63	29.81	32.69	9.62	3.37	2.88

Chlorite content in the surface horizons of the soils was less (27-29 %) and it increased (29-35 %) in the lower horizons. This may be due to more weathering at surface horizons as chlorite is mainly inherited from primary minerals found in metamorphic and igneous rocks (Barnhisel 1977). Chlorites exhibited pale to dark green colour and feeble pleochroism. They were platy with distinct basal cleavages and were grouped under secondary altered mica group.

Biotite constituted major portion (28 %) of the heavy minerals (Table 2). This suggests that the studied soils are derived from metamorphic rocks like biotite-gneisses, biotite-schists *etc*. It occurred as pale reddish brown to dark reddish brown flakes showing polarization on rotation of the microscopic stage to an angle of 360^{o}. Biotite was observed in fresh as well as in altered condition and alteration to pale green pleochroic chlorite was very common.

The soils of alluvial plain (P3) contained the highest amount (10-14 %) of garnet, and pink to pale pink garnets with polygonal to subrounded shape were observed. They possessed very high relief and basal sections were isotropic under cross nicols. The soils of flood plain (P4) contained the highest amount (1-5 %) of hypersthenes whereas the soils of low hill (P1) contained the lowest amount (0.57-0.83 %) of hypersthene. It showed a peculiar pleochroism - blue to reddish brown and sometimes schillerisation. Straight extinction was much more common than oblique extinction.

Kyanite was found as colorless, elongated grains with distinct prismatic cleavages and basal parting. The crystals were angular and splintery. The relief was fairly good and no pleochroism was seen. The mineral under polarized light was found in all the profiles amounting within 0.83 to 4.81 per cent of the heavy mineral grains. Presence of garnet and kyanite in the sand fraction of the studied soils indicates that the soils are derived from metamorphic rocks.

Pedological consideration

The amount and distribution of light and heavy minerals and their shape and size indicate that the sand minerals in the North Bank Plain Zone of Assam are derived from sedimentary and partially metamorphosed rocks. The reduction of size of quartz and presence of iron oxide coatings in low hill (P1) and monadnock (P2) indicated that the mineral in these soils has been subjected to considerable weathering. The abundance of orthoclase feldspars with subordinate amounts of plagioclase feldspars is attributed to the mineralogical composition of the parent rocks. The intense hydrolysis of orthoclase feldspars in presence of high organic matter might have decreased its amount in the surface horizons of monadnock (P2) and flood plain (P4) soils. These feldspars were unstable physically and chemically and hence weather rapidly. The weathering ratio (Q/F) indicated more weathering of feldspars in the surface horizons of low hill (P1) and flood plain (P4) (Fig. 1). Higher Q/F ratio in the C horizons of monadnock (P2), alluvial plain (P3) indicates siliceous nature (quartzite, sandstones) of the parent materials

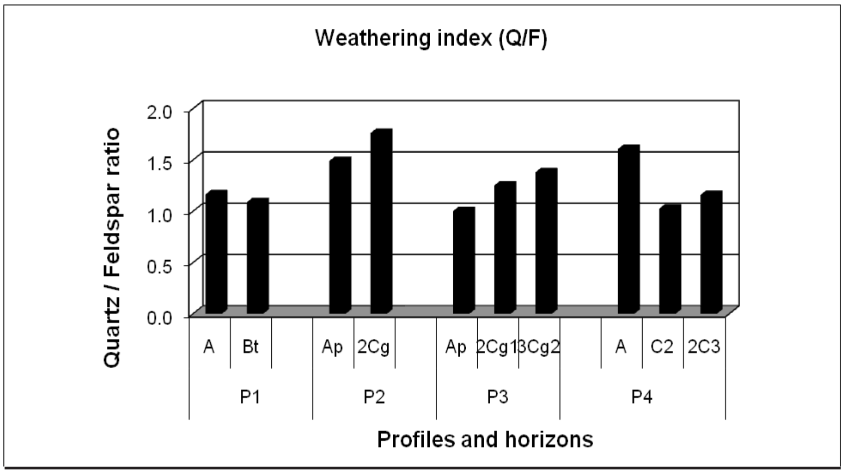

Fig. 1. Weathering index (Q/F) of soils

In the hill soils (P1), muscovite and biotite micas have been found to increase with depth while chlorite remained almost constant. The reduction of micas in the surface horizon of this profile may be due to alteration to illite under acid condition and higher weathering intensity. The amount and distribution of chlorite and bitite in the studied soils suggest that the soils are derived from metamorphic rocks with low-medium grade regional metamorphism (Barnhisel 1977; Read 1973). Presence of garnet and kyanite in the soils also suggests that these soils were derived from partially metamorphosed rocks. The distribution of feldspars, biotite and garnet in hill (P1) soils indicates stratigraphic nature of the parent materials. Higher amount of weatherable minerals like feldspars, chlorite, biotite and hypersthenes in the soils of alluvial (P3) and flood plain (P4) indicated that these soils are at initial stage of development.

The deficiency of ferromagnesian minerals and absence of opaque minerals in these soils may be ascribed to the acidic nature of parent materials. The parent materials of the study area are derived from the "Assam Himalayas" which have different stratigraphical and structural make-up of Cambrian to Tertiary age consisting of gneisses, schists (mica-schists, chlorite schists), sandstones etc. (Goswami 1960; Wadia 1966). The fine sand mineralogy in the present study also conforms this.

Conclusion

The fine sand mineralogy in the NBPZ of Assam area is dominated by light minerals with low amount of ferromagnesian minerals and absence of opaque mineral. The distribution and amount light and heavy minerals and their shape and size indicated that the sand minerals in this part of Assam are derived from sedimentary and partially metamorphosed rocks. The sand mineralogy indicated stratigraphic nature of the of the parent materials in low hill (P1) and therefore quantitative evaluation of minerals in all size fractions is warranted in order to ascertain the genesis of the soils developed on different landforms in NBPZ of Assam.

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