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Sand and silt mineralogy of some alluvium derived paddy and non-paddy soils of Assam

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Abstract

Paddy and the associated non-paddy soils developed in alluvium of Brahmaputra and Barak valleys of Assam were investigated for their fine sand and silt mineralogy. Light sand constituted the bulk of the fine sand fractions. Both fine sand and silt fractions were dominated by quartz followed by feldspars and mica. Potash feldspar and plagioclases represented the feldspars. The content of plagioclases was higher than that of K-feldspar in the silt fractions in most of the soils. Depth distribution of mica, quartz and feldspars in fine sand fraction showed definite trend in relation to the pedogenic development of soils. Heavy minerals were present in small amount and were commonly constituted by biotite, chlorite, amphiboles, augite, tourmaline, zircon, garnet, rutile, kyanite and goethite. The relative abundance of heavy minerals was determined by degree of weathering of soils. Mineral distribution indicated that the alluvium was derived from both igneous and metamorphic rocks. Paddy soils were characterised by lower amount of mica in both fine sand and silt fractions and of olivines in silt fractions as compared to that of non-paddy associates in their surface horizons.

Additional keywords: Pedogenesis, acid soils.

Introduction

Study of mineral assemblage in the sand and silt fractions of soils helps in understanding their pedological development with special reference to their parent materials. Mukherjee *et al.* (1971) observed dominance of quartz, mica and feldspars in the silt fraction of alluvial soils of north bank of Brahmaputra valley of Assam. 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. The present investigation was undertaken to study the sand and silt mineralogy of soils of both Brahmaputra and Barak valleys of Assam under different land use.

Materials and methods

The study area lies between 24°49'N to 27°14'N latitudes and 92°47'E to 94°11'E longitudes in the major river valleys of Assam viz. Brahmaputra and Barak valleys. Four soils under longterm paddy cultivation (50 to 100 years) were selected. The soils from North Lakhimpur (P1, P2), Titabor (P3, P4) and Kaki (P5, P6) were located in the Brahmaputra valley and soils from Cachar (P7, P8) were located in the Barak valley. Thus, P1, P3, P5, P7 represents paddy soils whereas, P2, P4, P6, P8 represents non-paddy soils. Pedons were exposed in the field and horizonwise samples were collected. The fine sand and silt fractions of selected horizons were separated by using size segregation procedure of Jackson (1969). The light and heavy mineral suites were separated by using bromo-form. The powdered samples were X-rayed by using Philips X-ray diffractometer with CuK_{α} radiation. Semi-quantitative estimation of minerals was made on the basis of intensities of strongest reflections of different minerals (Klages and Hopper 1982; Brown 1961). Few grains of quartz and mica were mounted on a slide and were studied under petrographic microscope for their morphological characteristics.

The soils of Brahmaputra valley are developed in alluvium derived from gneisses, granites and schists of Arachaen age, whereas, those from Barak valley, are derived from hard sand stone, mudstone, shale and argillaceous beds of the Pleistocene to Upper Eocene age. The area experiences humid subtropical climate with a mean annual rainfall ranging from 1169 to 2956 mm and mean annual temperature ranging from 23.1°C to 26.0°C.

The soils were classified as: P1 = Coarse loamy Typic Haplaquepts; P2 = Coarse silty Dystric Eutrochrepts; P3 = Coarse loamy Alfic Humaquepts; P4 = Coarse loamy Fluventic-Alfic Haplumbrepts; P5 = Fine clayey Vertic Humaquepts; P6 = Fine clayey Typic Haplaquepts; P7 = Fine clayey Vertic Ochraqualfs; P8 = Fine clayey Vertic Hapludalfs. All soils have mixed mineralogy and hyperthermic temperature regime.

Results and discussion

Light sand

The light and heavy sand mineral fractions identified in the fine sand fractions, are presented in the tables 1 and 2. The content of light sand fraction of the studied pedons ranged from 64 to 99 per cent of total fine sand. Minerals identified in the light sand fractions (Fig. 1) are quartz (4.22A°, 4.11A°, 3.36A°, 3.24A°, 2.46A°) (44-80%) followed by muscovite (10A°, 5A°, 3.30A°) (5-20%), K-feldspar (3.18A°) (3-18%) and plagioclases (3.22A°) (2-15%). Feldspars as a whole, are the second in order of abundance (9-27%). The content of kaolinite (7.02A°, 3.56A°) and 14A° minerals are very small (2-9%). Similar observation was also recorded by Chakravarty *et al.* (1979), in fine sand fractions of soils of the Brahmaputra valley.

Table 1. Relative abundance of minerals in light sand fraction (0.05 to 0.25 mm) in per cent

Horizon	Depth (cm)	Ls (%)	AF	PL	TF	K	14 A°	Mi	Q	Q:F
			Pedon 1 : Paddy soil, North Lakhimpur							
Ap	0-10	97.6	15	10	25	5	4	15	51	2.04
Bg2	17-30	98.0	9	15	24	6	6	9	55	2.29
Bg5	70-90	95.0	10	12	22	6	2	7	63	2.86
			Pedon 2 : Non-paddy soil, North Lakhimpur							
A	0-5	98.3	15	8	23	2	4	18	42	1.83
Bw2	53-105	97.6	12	15	27	5	6	8	44	1.63
BC2	153-155	95.3	12	11	23	6	6	8	47	2.04
			Pedon 3 : Paddy soil, Titabor							
Apg1	0-10	99.1	9	6	15	2	4	14	65	4.33
Bg2	20-39	99.0	12	3	16	2	6	10	67	4.19
Bg5	117-145	98.5	6	6	18	2	8	5	73	4.05
			Pedon 4 : Non-paddy soil, Titabor							
A1	0-5	99.1	9	6	15	2	6	16	61	4.07
Bw2	42-60	98.3	11	5	16	2	7	13	63	3.94
BC1	110-135	96.4	10	7	17	3	6	7	67	3.94

Horizon	Depth (cm)	Ls (%)	AF	PL	TF	K	14 A°	Mi	Q	Q:F
Pedon 5 : Paddy soil, Kaki										
Apg	0-20	93.4	8	5	13	3	5	12	67	5.15
Bg1	20-27	93.4	6	3	9	2	4	8	77	8.56
Bg3	105-130	76.2	18	6	24	2	5	7	62	2.58
Pedon 6 : Non-paddy soil, Kaki										
A	0-5	96.6	7	3	10	2	5	15	68	6.80
Bw1	5-28	90.0	5	4	9	2	4	5	80	8.89
Bw2	28-60	88.7	11	2	13	2	6	13	66	5.08
Bw4	91-130	64.0	7	3	10	2	9	7	72	7.20
Pedon 7 : Paddy soil, Cachar										
Apg	0-15	88.6	8	4	12	5	2	8	73	6.08
Btg2	65-75	95.1	10	6	16	7	2	16	59	3.69
BCg3	115-145	97.5	11	10	21	6	2	14	57	2.71
Pedon 8 : Non-paddy soil, Cachar										
A	0-10	97.9	3	7	10	7	3	10	70	7.00
Bt2	55-73	97.2	8	8	16	6	3	11	64	4.00
BC3	125-150	93.5	8	11	19	4	4	20	57	3.00

Ls = Light sand; AF = Alkali feldspar; PL = Plagioclases; TF = Total feldspars; K = Kaolinite; Mi = Mica; Q = Quartz; Q : F = Quartz:Feldspars ratio

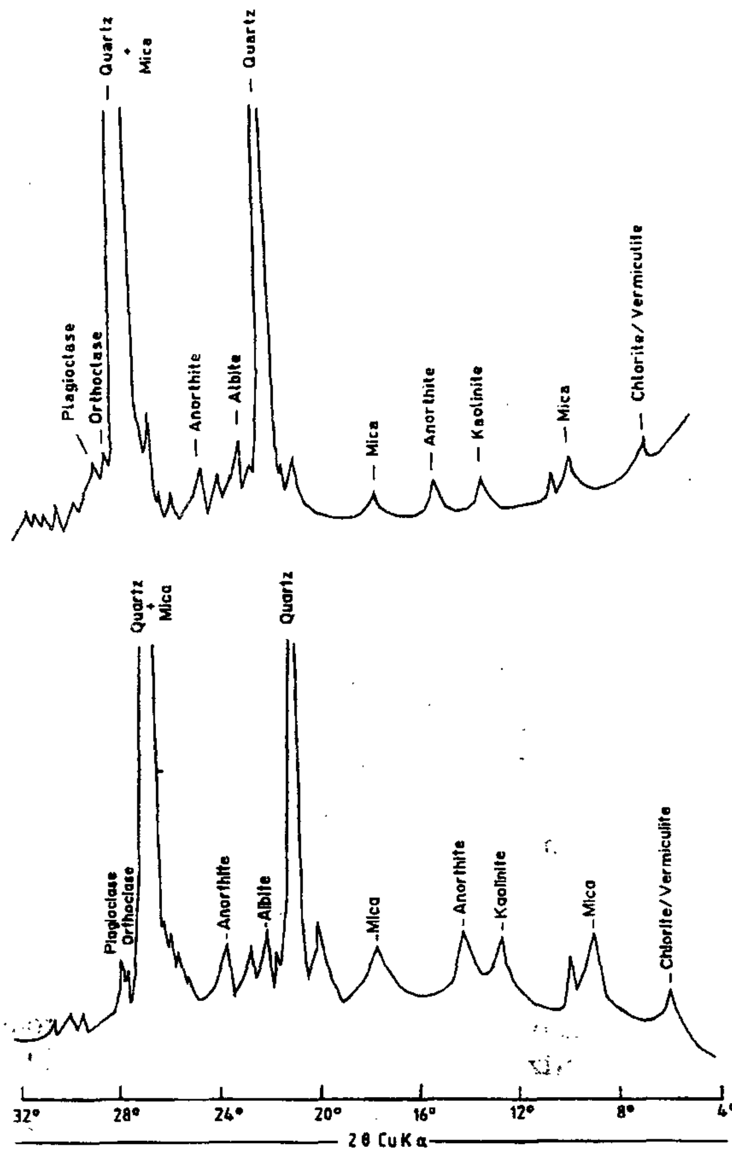

Fig. 1. Representative XRD pattern of light sand fraction of surface horizon of Cachar soils.

Table 2. Relative abundance of minerals in heavy sand fraction (0.05 to 0.25 mm)

Hori-zon	Heavy sand (%)	ZR	TR	RT	GR	BI	CH	AM	AG	OL
					Pedon 1 : Paddy soil, North Lakhimpur					
Ap	2.4	+	++	++	++	+++++	++	+++	++	-
Bg2	2.0	+++	++	++	+++	++++	++	+++++	++	-
Bg5	5.0	++	++	++	+	++++	+++	+++	+	-
					Pedon 2 : Non-paddy soil, North Lakhimpur					
A	1.7	++	++	++	+++	+++++	++	+++	++	-
Bw2	2.4	+++	+	++	+++	+++++	+++	+++	++	-
BC2	4.7	++	++	++	++	+++++	+++	++	++	-
					Pedon 3 : Paddy soil, Titabor					
Apg1	0.9	+	++	+++	+++	+	+	+	+	+
Bg2	1.0	+++	+++	++++	++	++	+	++++	+	+
Bg5	1.5	++++	++	+++	+++	++++	++	++	++	+
					Pedon 4 : Non-paddy soil, Titabor					
A1	0.9	++	++	++	+++	+	+	+	+	+
Bw2	1.7	++	+++	+++	++++	++	-	++	+	+
BC1	3.6	++++	++	+++	+++	++	++	++	+	+
					Pedon 5 : Paddy soil, Kaki					
Apg	6.7	++++	++	++	+	++	+	+++++	++	+
Bg1	6.6	++++	++	+	+	+	+	+	++	+
Bg3	23.8	+++	+++	+	+	+	+	+	++	+
					Pedon 6 : Non-paddy soil, Kaki					
A	3.4	+++	++	++	+	++	++	+++++	++++	+
Bw1	10.0	++	++	++	+	+	+	+	++++	+
Bw2	11.3	+++	++	++	+	+	+	++	++++	++
Bw4	36.0	++	++	++	+	+	+	++	++++	++
					Pedon 7 : Paddy soil, Cachar					
Apg	11.4	++++	+++	+++	+	++	+	+	+	+++
Btg2	5.9	+++++	++	++	++	+++	+	++	+	++
BCg3	2.6	++	++	++	++	+++	+	+	+	+
					Pedon 8 : Non-paddy soil, Cachar					
A	2.1	++++	+++	+++	++	++	+	+	+	+++
Bt2	2.8	++++	++	++	++	+++	+	++	+	++
BC3	6.5	+++	++	++	+	++	++	+	+	+

ZR = Zircon; TR = Tourmaline; RT = Rutile; GR = Garnet; BI = Biotite; CH = Chlorite; AM = Amphiboles; AG = Augite; OL = Olivines
+ = Traces; ++ = Fair; +++ = Moderate; ++++ = Abundant ; +++++ = More abundant;
All soils contained moderate to more abundant of quartz and kaolinite, and fair to moderate amount of kyanite and goethite

Morphologically, quartz of the studied soils is mostly milky quartz with extensive etching and internal fracture and round in shape indicating their pronounced weathering during transportation by flood water. The mica flakes were mostly muscovite. The biotite flakes, constituting small proportion of mica, were reddish brown in colour. However, mica from traditional paddy soils were not as reddish as those from non-paddy soils, because of pronounced oxidation and precipitation of haematite in non-paddy soils.

In both paddy and non-paddy soils of North Lakhimpur (P1, P2) and Titabor (P3, P4), the content of quartz was the lowest in the surface which decreased with depth and thus suggests relatively younger nature of the alluvium. The irregular depth distribution of both quartz and feldspars in Kaki soils (P5, P6) suggested their stratification and younger nature. On the other hand, soils of both paddy and non-paddy soils from Cachar (P7, P8), showed highest content of quartz in the surface which decreased with depth, and lowest content of feldspars in the surface which increased with depth, suggesting their advanced stage of weathering. The high content of mica, in the surface of both paddy and non-paddy soils of North Lakhimpur, Titabor and Kaki also suggested their young stage of weathering. The well developed soils from Cachar (P7, P8) had low content of mica in the surface.

The weathering ratio (quartz : feldspars) was the lowest in North Lakhimpur (P1, P2) (1.63-2.86), followed by Titabor (P3, P4) (3.94-4.19), Cachar (P7, P8) (2.71-7.00) and Kaki (P5, P6) (2.58-8.89). The vertical distribution of weathering ratio of soils indicates that it either increased with depth or it is irregular in North Lakhimpur and Kaki (P1, P2, P5, P6) soils and decreased with depth in Titabor and Cachar (P3, P4, P7, P8) soils. These observations suggest that soils of Titabor and Cachar are at an advanced stage of their pedogenic development as compared to that of North Lakhimpur and Kaki soils. Higher weathering ratio of Cachar as compared to that of Titabor suggests more advanced stage of development in soils of Cachar (P7, P8) than that of Titabor (P3, P4). The pedogenic development of studied soils thus varied in order : Cachar (P7, P8) > Titabor (P3, P4) > North Lakhimpur (P1, P2) = Kaki (P5, P6). Such pedogenic development is in tandem with physical and chemical characteristics of soils discussed elsewhere (Dey and Sehgal 1997a). Highest weathering ratio in young soils of Kaki (P5, P6) is attrributed to the fact that the alluvium of these soils originated from highly weathered soils from Assam Plateau. The observation suggested that weathering ratio alone does not indicate degree of profile development.

It was observed that surface horizon of paddy soils conntained lower amount of mica than that of associated non-paddy soils in all locations. Lower mica content in the surface horizon of paddy soils suggested an enhanced weathering of mica under repeated cycle of wetting and drying associated with paddy cultivation. This observation finds support from lower content of mica in the clay fraction of paddy soils than that of non-paddy soils reported earlier (Dey and Sehgal 1997b).

Heavy sand

Heavy sand fractions constitute 0.9 to 36.0 per cent of fine sand fractions (Table 2). Fine-textured soils from Kaki and Cachar (P5, P6, P7, P8) contained higher amount of heavy sand (2.6 to 36.0%) than that of medium texture red soils from North Lakhimpur and Titabor (P1, P2, P3, P4) (0.9 to 5.0%). Various minerals identified were zircon (3.30 A°, 4.43 A°), garnet (2.88 A°), tourmaline (3.99 A°, 2.96 A°), rutile (3.23 A°), kyanite (3.18 A°), biotite (10 A°), chlorite (14 A°), ambhiboles (8.40 A°), augite (2.95 A°), goethite (4.18 A°), kaolinite (7.20 A°) and olivines (3.88 A°) (Fig. 2). Weatherable ferromagnesian minerals like biotite, chlorite, amphiboles and augite constituted bulk of heavy sand fraction of North Lakhimpur (P1, P2) indicating their relative younger nature. However, resistant minerals like zircon, tourmaline, rutile and garnet dominated heavy sand fractions of moderately well to well developed soils from Titabor and Cachar (P3, P4, P7, P8). On the other hand, soils of Kaki (P5, P6) had dominantly resistant minerals, but presence of augite suggested their younger nature. Presence of kyanite and garnet in all the soils suggested that alluvium of these soils were derived from metamorphic rocks. Quartz and kaolinite were present in the heavy sand fraction as inclusionary material.

Mineral assemblage of heavy sand fraction did not show consistent difference between paddy and non-paddy soils.

Silt mineralogy

Silt fraction of soils had dominantly quartz (44-74%), followed by feldspars (9-29%) and mica (4-18%) (Table 3). Other minerals (kaolinite, amphiboles and 14 A°

minerals) occurred in minor amount (1-14%). Presence of high amount of quartz and appreciable amount of feldspars and mica in soils under study suggested that their alluvium are derived from igneous and metamorphic rocks such as granite, gneiss and schists. In Cachar soils (P7, P8) all minerals except quartz showed an increase from surface downwards whereas quartz showed a reverse trend suggesting the advanced stage of pedogenic development. This was also confirmed by absence of amphiboles in these soils. Relatively younger nature of soils of North Lakhimpur (P1, P2) and Kaki (P5, P6) was indicated by depth distribution of quartz, the content of which increased with depth

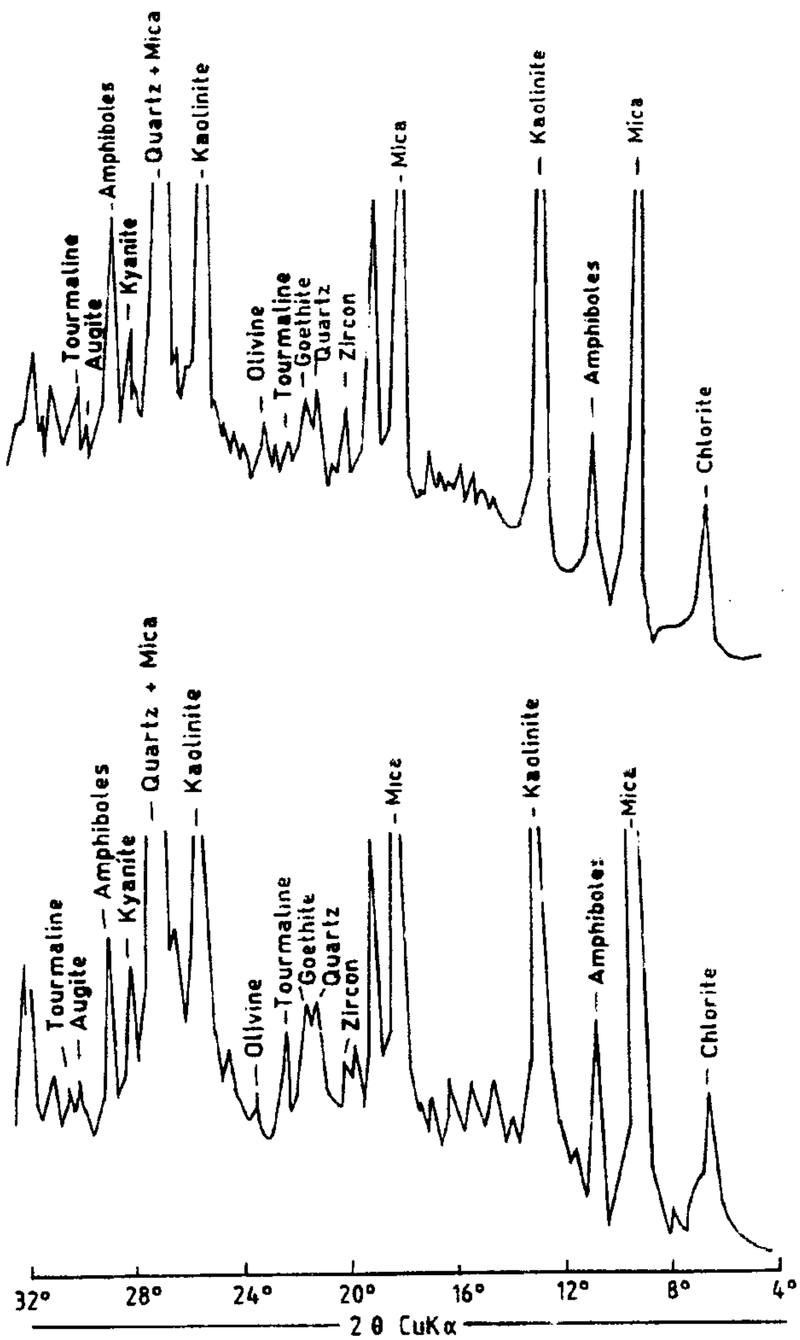

Fig. 2. Representative XRD pattern of heavy sand fraction of north Lakhimpur soils.

Table 3. Relative abundance of minerals in silt fraction in per cent

Horizon	Depth (cm)	Silt (%)	AF	PL	TF	K	14 A°	Mi	Am	Q
Pedon 1 : Paddy soil, North Lakhimpur										
Ap	0-10	66.1	12	15	27	6	4	4	4	51
Bg2	17-30	70.4	11	15	26	6	6	10	3	49
Bg5	70-90	82.0	9	12	21	8	4	11	4	52
Pedon 2 : Non-paddy soil, North Lakhimpur										
A	0-5	71.0	12	17	29	5	4	8	14	44
Bw2	53-105	80.5	10	12	22	6	7	9	6	50
BC2	153-155	87.3	6	11	17	7	4	8	2	62
Pedon 3 : Paddy soil, Titabor										
Apg1	0-10	69.0	5	10	15	2	5	4	1	73
Bg2	20-39	59.0	16	4	20	2	8	14	3	53
Bg5	117-145	39.8	4	5	9	4	3	14	3	69
Pedon 4 : Non-paddy soil, Titabor										
A1	0-5	51.5	5	4	9	2	3	14	3	69
Bw2	42-60	53.4	5	11	16	3	5	4	3	69
BC1	110-135	16.6	5	9	14	3	5	11	2	65
Pedon 5 : Paddy soil, Kaki										
Apg	0-20	42.3	8	5	13	2	3	15	1	63
Bg1	20-27	44.6	5	10	15	2	2	15	3	64
Bg3	105-130	47.0	5	5	10	3	3	17	3	66
Pedon 6 : Non-paddy soil, Kaki										
A	0-5	64.2	16	12	28	3	5	17	3	44
Bw1	5-28	59.2	10	7	17	4	7	10	3	59
Bw2	28-60	56.7	10	5	15	3	5	14	3	60
Bw4	91-130	56.7	10	5	15	3	5	14	3	60
Pedon 7 : Paddy soil, Cachar										
Apg	0-15	46.4	4	11	15	6	7	10	-	68
Btg2	65-75	57.1	4	14	18	7	4	10	-	66
Btg3	115-145	42.1	6	13	19	5	5	9	-	62
Pedon 8 : Non-paddy soil, Cachar										
A	0-10	50.3	4	8	12	6	7	16	-	58
Bt2	55-73	38.5	4	10	14	7	8	18	-	53
BC3	125-150	47.6	4	8	12	5	5	10	-	52

AF = Alkali feldspar; PL = Plagioclases; TF = Total feldspars; K = Kaolinite; 14 A° = Mostly chlorite with very small amount of vermiculite; Mi = mica; Am = Amphiboles; Q = Quartz

and that of feldspars decreased with depth. In Titabor soils (P3, P4) the content of quartz was higher in the surface than the subsurface. The distribution of feldspars and mica in the profile was irregular suggesting intermediate pedogenic development. The content of amphiboles in the surface was always lower in the paddy than the non-paddy soils. Similar variation in respect of mica was also observed in all soils. Lower amphiboles and mica contents in paddy soils as compared to the non-paddy soils was attributed to accelerated weathering of these minerals under repeated cycle of wetting and drying. Huizing (1971) also reported that ferromagnesian minerals in coarse fractions were increasingly attacked during soil formation in the seasonally wet paddy soils of Bangladesh.

The content of plagioclases was higher than that of K-feldspars in all except the Kaki (P5, P6) soils. This is in contrast to general observation in soils. This anomaly could be attributed to relative enrichment of plagioclase as compared to K-feldspars in their parent materials.

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