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Characterization of clay minerals in the Brahmaputra river sediments, Assam, India

P. Kotoky[1,*], D. Bezbaruah[1], J. Baruah[1], G. C. Borah[1] and J. N. Sarma[2]

[1]Geoscience Division, Regional Research Laboratory, Jorhat 785 006, India
[2]Department of Applied Geology, Dibrugarh University, Dibrugarh 786 004, India

Characterization of clay minerals of the Brahmaputra river sediments within a selected stretch by X-Ray diffraction, differential thermal analysis and Fourier transform infrared spectra has revealed the association of dominant kaolinite with subordinate amount of illite and chlorite. The mineral assemblage, as evidenced from the study, may find its use towards effective understanding of related engineering properties and utilization in flood-management approaches, intimately connected with the lives and properties of the people of Assam.

Keywords: Brahmaputra river, clay minerals, flood management, sediments.

THE braided mighty Brahmaputra river that, occupies one-tenth of the Brahmaputra Valley represents a high-energy fluvial environment, characterized by steep valley gradients, non-cohesive banks and, consequently, high rate of bank erosion and bed load transport[1–3]. Despite gigantic efforts and colossal expenditure (>Rs 15,000 million)[4], the Brahmaputra continues to wreck havoc due to uncontrollable floods since time immemorial, putting in peril the lives and properties of the millions of people[5].

The recent study on its erosion activity[2,3] has established that the activity is not uniform throughout the stretch, with the bank, where Older Alluvium sediments and banks composed of higher clay contents are exposed, offering significant resistance to the erosive power of the river. It is therefore essential to understand the clay mineral component of the associated sediments of the river basin, as it has an intimate relationship with the engineering properties of the bank sediments in question, which, in turn, are related with the extent and nature of erosion mechanisms involved. It is expected that the present study will open up an avenue to understand and establish measures to be adopted towards flood-management approaches.

Forty-five bed sediment samples each about 2 kg were collected along a stretch (within 93°30′–94°30′E long. and 26°30′–27°15′N lat.) of the Brahmaputra river channel (Figure 1), which covers the world's largest river island 'Majuli' under extreme threat of erosion[1,6,7] and the world

*For correspondence. (e-mail: probhatk@yahoo.com)

heritage site 'Kaziranga National Park', the habitat for the endangered Asian one-horned rhinocerous species. From the bulk sediment samples representative fractions (100 g) were taken out by conning and quartering. The samples were then subjected to mechanical sieving for ten minutes. The 235 mesh size (62.5 μm) fraction was taken for the separation of clay for the present study. Following Lewis[8] and Tucker[9], X-ray diffraction (XRD) study of the clay fraction (≤ 3.9 μm) of the sediment samples was carried out. The XRD pattern of the samples was taken on a JDX-II P3A JEOL (Japan) X-ray Powder Diffractometer at 20 to 102° 2θ using Fe-filtered Co–K_α radiation. The patterns thus obtained were compared with standard dataset of the Joint Committee for Powder Diffraction Standards (JCPDS)[10], USA.

Thermal analysis (TA) of samples was carried out under dynamic conditions in an air atmosphere using α-Al_2O_3 as the reference material, up to a temperature of 1000°C in a computerized TA instrument, Model STD 2964 with simultaneous DTA and DTG.

The clay fraction (≤3.9 μm) of the samples was ground in an agate mortar and pellets were made out of it after mixing with KBr, for infrared study. The pellets were placed in the path of the infrared spectra and adsorption was recorded in the IR grating at 200 to 4000 cm^{-1}.

The XRD study of the clay fractions of Brahmaputra river sediment samples revealed dominant association of kaolinite (7.11 Å, 3.65 Å), illite (10.7 Å) and chlorite (7.15 Å). Presence of clays of different nature (Figure 2) indicates a significant change in physico-chemical conditions operating within the system. Weathering of alkali feldspar under acidic condition produces mainly the kaolinite group without any exchangeable cations, whereas illite and chlorite are developed by alteration of mica, alkali feldspars, biotite, etc. under alkaline conditions.

The study of Differential Thermal Analysis (DTA, Figure 3) indicates broad dehydration peaks within the temperature range of 60 to 100°C, with corresponding sharp endothermic peak at 60°C, which reveals the presence of illite in the sample. Weight loss due to dehydration mechanisms started at 200°C continued up to 679.06°C with weak endothermic inflexion at 670°C, which clearly indicates the presence of kaolinite in the studied samples. The broad range of temperature can be attributed to association of adsorbed and structural waters in different proportions in kaolinite samples[11]. The Older Alluvium samples collected from Majuli and Kaziranga areas indicate that typical flat kaolinite dehydration started at 400°C and thereafter a sharp loss in weight was observed

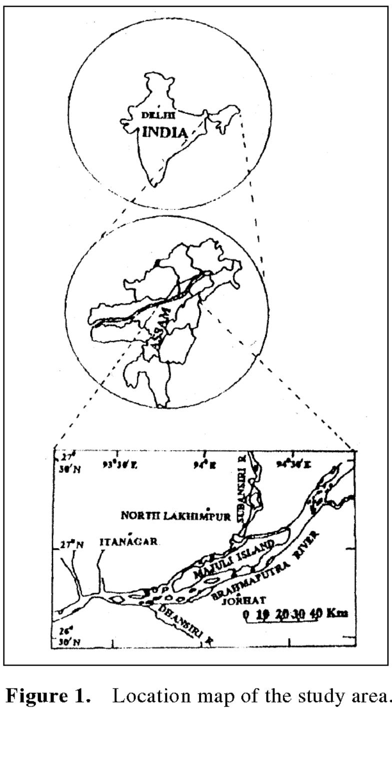

Figure 1. Location map of the study area.

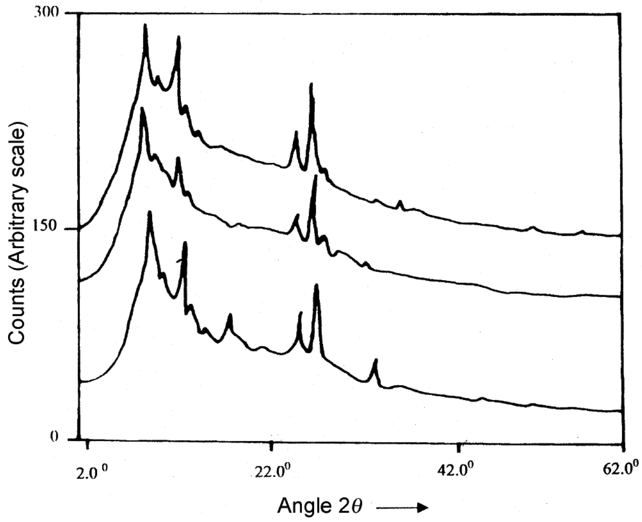

Figure 2. Representative XRD spectra of the Brahmaputra river sediments.

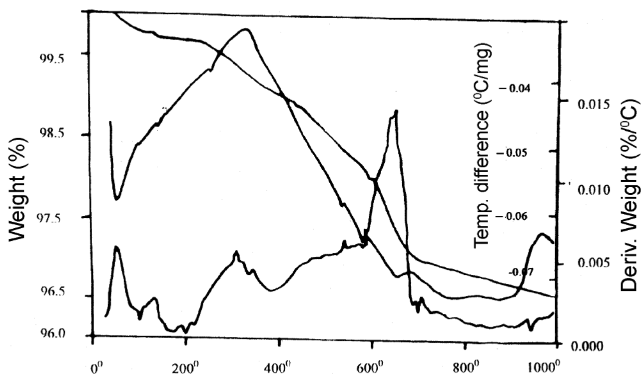

Figure 3. Representative thermo analytical curve of sample N1 of the Brahmaputra river sediments.

Table 1. Infrared spectra of clay samples of Brahmaputra river sediments and their assigned mineralogy

Sample number	Infrared bands (cm^{-1})	Assigned mineralogy
ASB-1	310	Almandine-spesssartine type of garnet
ASB-1	320	Almandine-spesssartine type of garnet
ASB-1	330	Almandine-spesssartine type of garnet
ASB-1	350	Almandine-spesssartine type of garnet
ASB-1	360	Albite
ASB-1, N1-d, SM1-C	380	Albite
ASB-1, N1-a, SM1-C	430	Si–O stretching vibration
ASB-1, N1-a, 1b, N1-d, SM1-C, 1a	470	Stretching vibration of S–S bond
ASB-1, N1-a, 1b, N1-d, 1a	530	Si–O bending vibration
ASB-1, 1a	590	Si–O bending vibration
ASB-1, N1-a	620	Chlorite
ASB-1	680	O–H bending vibration
ASB-1, N1-a	750	Illite
ASB-1, N1-a, N1-d, SM1-C	770	Albite
ASB-1, N1-a, 1b, N1-d, 1a	790	Well-crystallized kaolinite
ASB-1, N1-a	920	O–H deformation band
ASB-1, N1-a, 1b, N1-d, SM1-C, 1a	1010	Kaolonite
ASB-1, N1-a, 1b, N1-d, SM1-C, 1a	1075	Kaolinite
ASB-1	1340	Minor organic matter present
ASB-1	1375	Minor organic matter present
ASB-1	1580	Minor organic matter present
ASB-1, N1-a, 1b, N1-d, SM1-C, 1a	1630	O–H deformation vibration of adsorbed water or bonded OH group
ASB-1	2700	–
ASB-1	2800	–
ASB-1	2900	–
ASB-1, N1-a, 1b, N1-d, SM1-C, 1a	3410	Chlorite
ASB-1, N1-a, 1b, N1-d, SM1-C	3620	Kaolinite
ASB-1, N1-d	3700	Kaolinite

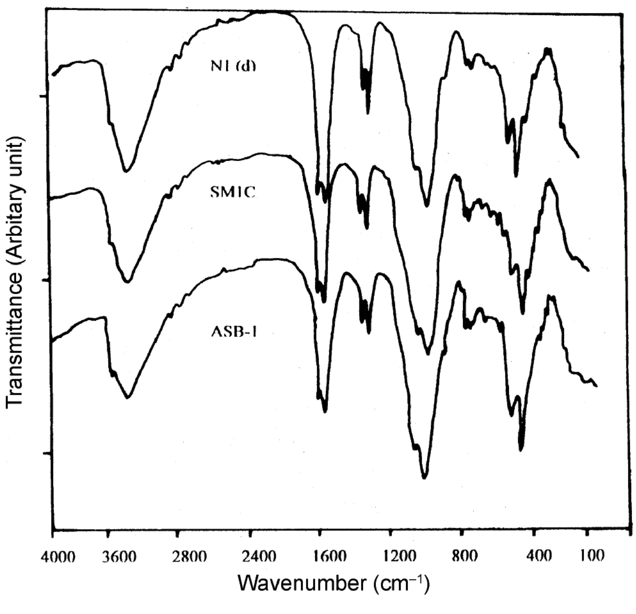

Figure 4. Representative FTIR spectra of the Brahmaputra river sediments.

up to a temperature of 760°C. It may be explained by variations in crystallinity, since the poorly crystalline material loses its hydroxyl water somewhat more easily than well-crystallized kaolonite[12]. A small amount of water (2 to 3%) is retained at about 525°C, and the moisture is lost up to 750–800°C, where dehydration is essentially complete. The small endothermic peak at 574.32°C indicates the presence of crystalline kaolinite in the sediment samples of the Brahmaputra river. The broad exothermic peaks with peak temperature at 965.64°C in case of Older Alluvium samples indicate changes of kaolinite to mullite phase[13]. Similar behaviour is observed in the case of rippledrift samples. Identical behaviour has also been reported by several workers[12–16], while they studied the exothermic nature of kaolinite up to 1000°C. The presence of chlorite mineral (7.15 Å), as evident from the XRD study, could not be differentiated in the thermogram because of the dominant occurrence of kaolinite mineral, characterized by peaks within 500–550°C and endothermic peak within 500–700°C. The heterogeneity in natural samples might have played a significant role in the identification of smaller fraction of mineral species in the samples.

Fourier Transform Infrared Spectra (FTIR) spectra obtained from the samples under study (Figure 4) indicate almost similar clay mineral assemblage with the spectra having broad band at 3420 to 3621 cm^{-1} and at 1620, 1580, 1375, 1340, 1075, 1010, 790, 770, 530, 470 and 430 cm^{-1}. Assignment of different peaks of the spectra is given in Table 1. The broad band within 362.09 to 3427.44 cm^{-1} can be attributed to OH-stretching vibration of the interlayer hydroxide sheets. In the region of OH-stretching vibrations of a polycrystalline compound, one can observe a complex adsorption band with intense components at 3554, 3513 and 3408 cm^{-1}. Moreover, the deformation vibration of adsorbed water lying at 1630 cm^{-1} is characteristic of molecular H_2O. The symmetric and asymmetric stretching vibrations of adsorbed water give rise to a broad band centred at 3400 cm^{-1}, compared to with ~3700 cm^{-1} in the free molecule, with reduction in frequency reflecting the formation of moderately strong hydrogen bond[17].

The most important silicate minerals observed are kaolinite, chlorite and illite. All are layered silicates and contain the planner hexagonal silicon-oxygen (Si–O) network. The Si–O stretching vibration in this study is located in the region 700 to 1200 cm^{-1}. Occurrence of a band at 1010 to 1075 cm^{-1}, coupled with 790 to 920 cm^{-1} and 3620 cm^{-1}, suggests the presence kaolinite mineral. Moreover, occurrence of the band resulting from OH deformation also confirms the presence of well-crystallized kaolinite mineral in the sediment samples of the Brahmaputra river. The stretching band of adsorbed water frequently masks the broad OH stretching doublet of chlorite in clay mineral. The band at 680 cm^{-1} due to OH deformation components from 2 : 1 layer, suggests the occurrence of trioctahedral chlorite in the samples. The broad band with a peak at 3410 cm^{-1} also confirms the presence of chlorite in the sample. The band at 620 cm^{-1} indicates the presence of high iron content in chlorite and this is also confirmed by the XRD study with *d*-spacing at 7.15 Å. Bands at 750 and 770 cm^{-1} indicate the presence of illite and albite minerals in the samples. The broad OH stretching vibration band at 3620 cm^{-1} coupled with doublet at 750 cm^{-1} is charateristic of illite mineral. The band at 470 cm^{-1} can be assigned to S–S stretching vibration of disulphide mineral. Minor bands at 310 to 350 cm^{-1} can be assigned to almandine-spessartine type of garnet mineral in the studied samples[17].

XRD, FTIR and DTA studies on clay fraction of the Brahmaputra river sediments revealed that kaolinite is the dominant mineral species with minor amount of chlorite and illite. This assemblage of clay minerals indicates a fluctuating nature of physico-chemical conditions operating within the studied stretch of the braided Brahmaputra river basin. Identification and characterization of clay minerals help in understanding the probable nature and mechanisms of active erosion processes, and may find use in flood mitigation and management approaches for this perennial flood-affected part of NE India.

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