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Heavy Mineral And Clay Mineralogy Of Recent Fluvial Sediments Along Brahmaputra River Of Dibrugarh District, Assam

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Abstract
This study area delves into the geological saga of the Brahmaputra River in Dibrugarh District, Assam, exploring its profound impact on regional evolution amidst extensive layers of contemporary alluvial sediments, including Older Alluvium, High-Level Terraces, and New Alluvium, visible in natural cut bank formations along the river's course. The recent fluvial sedimentary deposits were meticulously surveyed and sampled at Thirty distinct sites from Tingkhan – Nagakheliya Gaon, Oakland Ghat, Madhupur Ghat, and Dolphin View Point, Chabua, evenly distributed from north-north-east (NNE) to south-west-west (SWW) along the river. The primary objective of this study is to conduct a thorough analysis of heavy mineral percentages through microscopic slide analysis, aiming to assess the maturity of river sediments utilizing the Zircon-Tourmaline-Rutile (ZTR) maturity index and to elucidate clay mineralogy employing X-ray diffraction techniques of recent fluvial sediments. The findings of these analyses provide valuable insights like, heavy minerals derive from the sediments diverse NNE and SWW sources, with ultra-stable and unstable heavy minerals assemblages suggesting sediments source from high-grade metamorphic and acidic igneous rock regions. The ZTR maturity index of river sediments increase from NNE to SWW; the calculated ZTR index indicates that most sample depths exhibit below 20%, corresponding to generally very immature sediments. Also rounded Zircon-Tourmaline-Rutile grains imply reworked sediment contribution, while subrounded to sub-angular grains hint at potential first-cycle origin. X-ray diffraction analyses highlight peaks of clay matrix (Kaolinite, Chlorite), and the abundance of non-clay matrix (Garnet, Siderite, Pyrite specially Quartz). This sedimentary record resonates with a captivating amalgamation of influences from the northeastern Himalayas and Naga Hills, coupled with dendritic sediment depositions.

Keywords: *Heavy Minerals, ZTR Maturity Index, X-Ray Diffraction, Brahmaputra River, Dibrugarh District.*

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I. Introduction:

Minerals, intricate crystalline inorganic substances sourced from mountainous regions, settle naturally in sediments transported by rivers, glaciers, or atmospheric forces [6]. The classification of minerals into two categories, light minerals with a density below 2.9/103 kg·m−3 and heavy minerals exceeding this threshold [4], stems from the erosion of rocks and minerals, causing denser minerals to aggregate [2.9/103 kg·m−3].

The Brahmaputra River, characterized by its braided system and substantial sediment load, embodies a complex interplay of sediment supply and climatic influences, shaping diverse landscapes. With an annual sediment load of 800 million tons, it ranks among the world's most sediment-laden rivers. The river's braided nature brings both ecological wonders and challenges, with dynamic channels, islands, and floods becoming a canvas for nature's processes.[3]

This research focuses on the Brahmaputra's heavy mineral content, exploring its economic potential and sediment maturity in Dibrugarh District. By analyzing heavy mineral concentrations and clay mineralogy using XRD analysis, this study aims to unravel the geological story of the river's sedimentary evolution in Dibrugarh, Assam. Understanding these mineral dynamics is crucial for assessing resource viability and ecological impacts in this dynamic riverine ecosystem.

My Study Area:

The chosen site encompasses the geographical expanse comprising locations- a) Near Dolphin view point, Chabua; b) Near Oakland Ghat, Chabua; c) Near Tingkhan & Nagakheliya Gaon, Kumaronichiga; d) Near Madhupur Ghat, near Bogibeel Bridge within Dibrugarh district. This region is intricately traversed by the majestic Brahmaputra River, with coordinates extending from N27°33'55.9″, E95°13'30.9″, to N27°20'32.5″, E94°45'00.0″. The study's purview extends across stable sandbars, encapsulating an expansive area of 228 square kilometers along the Brahmaputra River's course in the Dibrugarh district of Assam, located in the northeastern reaches of India. (Figure-1)

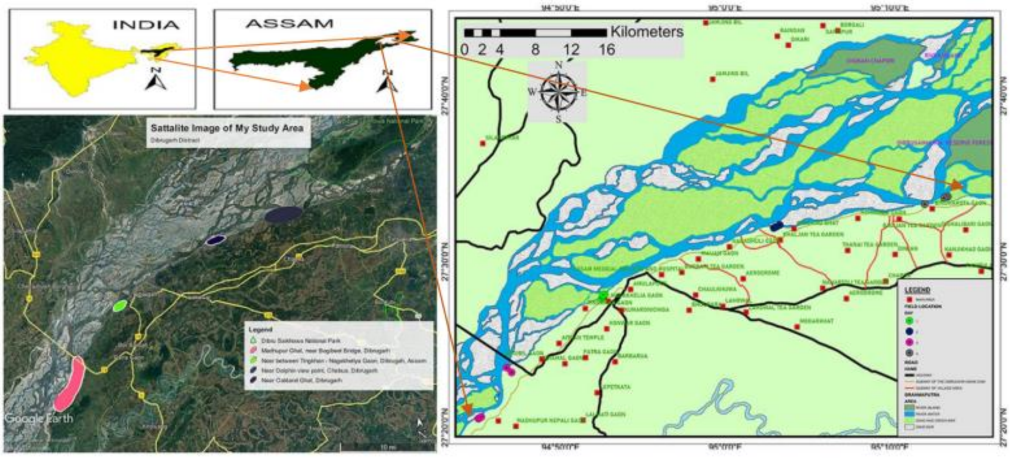

Figure 1: Location Map Of The Study Area

II. Materials And Methods:

Conducting a geological and mineralogical exploration, a heavy minerals study analyzes minerals with higher specific gravity in sedimentary, igneous, or metamorphic rocks and soil samples. These minerals, characterized by a specific gravity exceeding 2.85, resist weathering, concentrating in specific environments. Vital for stratigraphic correlation, they serve as indicators for provenance, revealing petrographic features of the source area and dispersal patterns. Integral to diagenetic history assessment and petrographic reconstruction, heavy mineral studies, especially those focused on sediments, play a paramount role according to [9]. The examination of heavy mineral assemblages in fossil-free sedimentary rocks aids in source rock composition analysis and sedimentary rock classification [10].

The research commences with meticulous sampling, involving diverse sand and clay specimens collected from riverbanks. Moving to heavy mineral analysis, sand fractions (80-230 mesh) undergo a rigorous extraction process using dilute hydrochloric acid (HCl) and stannous chloride ($SnCl_2$), followed by bromoform-based Funnel Separation [8][11]. Mineral grains are placed on microslides for detailed examination, including graphical representation for ZTR maturity index derivation and spatial distribution analysis. Hubert (1962) introduced ZTR percentages as a measure of mineralogical maturity, and categorizing heavy minerals into genetic suites aids in determining source rock lithology (Hubert's edition of Carver) [5].

Transitioning to clay mineral study, representative sand samples undergo air-drying and sieving with a 230-mesh sieve. Clayey samples are curated in vials and prepared for X-ray Diffraction (XRD) analysis at CSIC, Dibrugarh University. The diffraction pattern aids in identifying and quantifying mineral phases within the clay, contributing to a comprehensive understanding of sedimentological dynamics in the Brahmaputra region. This multifaceted exploration illuminates the geological tapestry of the Brahmaputra River.

III. Results And Discussion:

Heavy mineral analysis- from the given samples, 16 identical thin section slides are prepared and studies under the petrographic microscope. Following the gazzi-dickinson method [2] of point counting, the statistical measurements of the constituent heavy minerals i.e., epidote, opaque, hornblende, zircon, chlorite, kyanite, sillimanite, garnet, andalusite, muscovite, biotite, rutile, topaz, zoisite, gypsum, siderite, augite, monazite, serpentine, tourmaline, sphene (titanite), staurolite, clinozoisite, hypersthene, chloritoid & apatite (figure-2) are carried out. These values are expressed in percentage. (figure-3) (table-1)

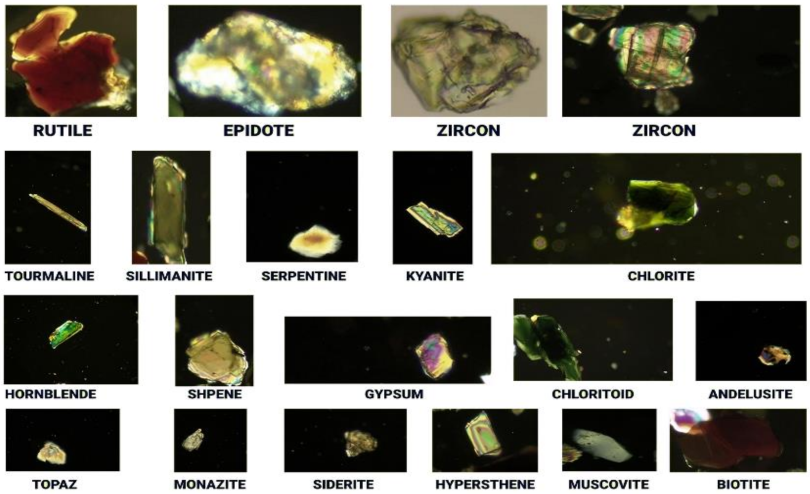

Figure 2: Heavy Minerals

HEAVY MINERALS	Location (Near Tingkhan & Nagakheliya Gaon, Kumaronichiga)	Location (Near Oakland Ghat, Chabua)	Location (Near Madhupur Ghat, near Bogibeel Bridge)	Location (Near Dolphin view point, Chabua)
	%	%	%	%
EPIDOTE	36.43812	33.93588	16.02825	52.04343
OPAQUE	7.584535	10.38376	8.712933	7.015016
HORNBLENDE	14.4891	8.815959	9.212595	13.23661
ZIRCON	6.648647	6.698257	12.7331	2.861201
CHLORITE	6.449447	10.00351	7.732077	9.563718
KYANITE	5.258084	3.732304	3.522952	5.085227
SILLIMANITE	3.924042	9.447759	4.007485	2.236201
GARNET	1.680206	2.047502	2.566731	0.324675
ANDALUSITE	3.635334	1.421551	3.950072	3.973214
MUSCOVITE	3.460357	2.673453	2.517299	0.793425
BIOTITE	1.768285	4.504505	3.035304	0.318588
RUTILE	1.351619	1.205101	2.871939	0.480925
TOPAZ	0.452755	0.649351	2.830487	0.318588
ZOISITE	0	0	1.714079	0
GYPSUM	1.650764	0.819001	3.027262	0
SIDERITE	0	0	1.03436	0
AUGITE	0.599718	0	1.86708	0.162338
MONAZITE	0.598291	0	2.56832	0
SERPENTINE	1.483861	0.4095	2.651162	0.162338
TOURMALINE	1.343544	0.625951	1.562666	0.15625
SPHENE (Titanite)	1.183288	0.819001	1.146703	0
STAUROLITE	0	1.158301	2.101336	1.268263
CLINOZOISITE	0	0	0.141844	0
HYPERSTHENE	0	0.649351	0.882153	0
CHLORITOID	0	0	1.298116	0
APATITE	0	0	0.283688	0

Table 1: Heavy Minerals (In Percentage) Observebed In My Study Areas

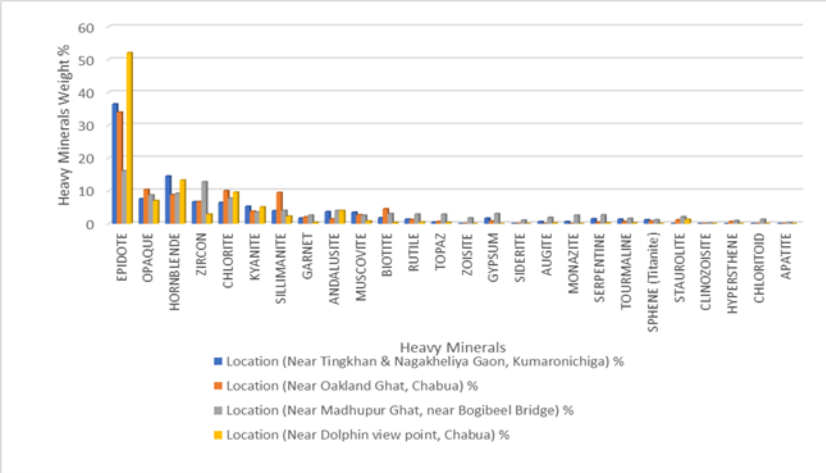

Figure 3: Heavy Minerals Distribution Bar Diagram In My Study Areas

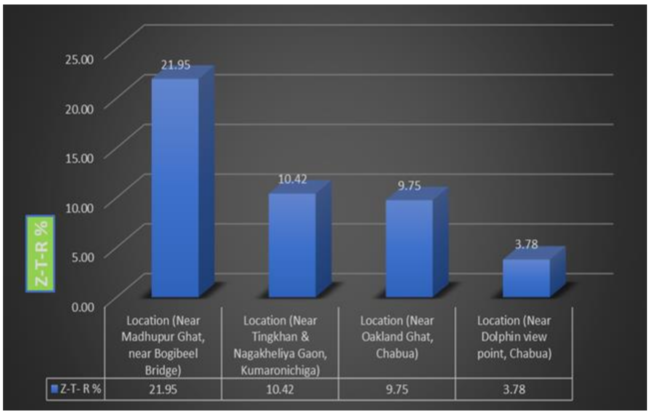

Figure 4: Z-T-R Maturity Bar Diagram (Dibrugarh West To East)

Z-T-R MATURITY INDEX- The evaluation of sandstone maturity in this study employs [5] 'ZTR index.' This quantitative measure assesses the mineralogical "maturity" of heavy mineral assemblages in sandstones through the transparent, non-micaceous, detrital heavy minerals —zircon, tourmaline, and rutile. Represented as a percentage, the ZTR index indicates the combined presence of these mechanically and chemically stable minerals. As sandstones evolve towards more quartzose compositions, these minerals, known for their stability, tend to concentrate alongside quartz, chert, and metaquartzite rock fragments. Within this area, the Z-T-R index, as reported by Bhuyan D. (2000), denotes a lower level of maturity. A discernible pattern emerges from the bar diagram, depicting a progressive rise in the Z-T-R index from the eastern to the western expanse. This trend implies a potential augmentation in the maturity of sedimentary rocks within the Brahmaputra Valley from east to west. The calculated ZTR index indicates that most sample depths exhibit below 20%, corresponding to generally very immature sediments. Remarkably, our study zones showcase substantial concentrations of Epidote and Hornblende, providing valuable insights into the identification of the source rocks for these sediments [1]. (Figure-4,5)

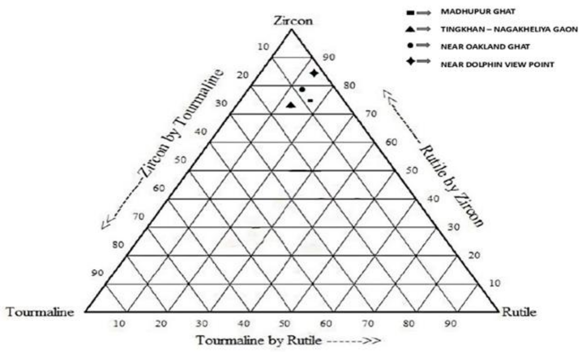

FIGURE 5: Z-T-R MATURITY INDEX DIAGRAM

X-RAY DIFFRACTION ANALYSIS- X-ray diffraction (XRD) is a prevalent method for discerning the mineralogical composition of clay-rich samples, revealing crystal structures and offering insights into geological and environmental implications. The three oriented slides produced from each sample undergo distinct runs—untreated, glycolate, and heated—to analyze peak characteristics, including position, intensity, shape, and breadth, providing valuable information about clay minerals. The Bragg law, expressed as $n\lambda=2d\sin\Theta$, governs peak position based on factors like atomic distance, X-ray wavelength, and angle of incidence [2].

Here, we have extracted 6 identical samples from our study areas. Specifically, SN 1 and SN 2 are sourced from the vicinity of Tingkhag & Nagakheliya Gaon, Kumaronichiga; SN3 originates near Oakland Ghat; SN 4 and SN 5 are obtained from Madhupur Ghat, near Bogibeel Bridge; and SN 6 is collected near Dolphin Viewpoint, Chabua. (table- 2)

Clay Minerals	Standard values for clay		Identified clay in sands	SN1	SN2	SN3	SN4	SN5	SN6
	2 θ	dÅ		2 θ (dÅ)	2 θ (dÅ)	2 θ (dÅ)	2 θ (dÅ)	2 θ (dÅ)	2 θ (dÅ)
KAOLINITE	12.38	7.17	KAOLINITE + CHLORITE	12.45 (7.1)	--	12.42 (7.14)	--	--	--
	24.49	3.57		24.277 (3.665)	--	--	--	--	--
CHLORITE	6.3	14+	CHLORITE	--	--	--	--	--	--
	12.62	7		12.45 (7.1)	--	12.42 (7.14)	--	--	--
	18.92	4.7		--	--	--	18.76 (4.72)	--	--
	25.45	3.5		--	--	--	--	--	--
NON CLAY MINERALS									
GARNET	30.62	2.920	GARNET (Iron, manganese)	--	--	--	--	30.56 (2.92)	--
	34.22	2.620		--	--	34.41 (2.6)	--	--	--
	37.63	2.390		--	--	--	--	--	--
	39.17	2.300		--	--	--	--	--	--
QUARTZ	20.85	4.26	QUARTZ	20.823 (4.263)	20.85 (4.25)	20.84 (4.25)	20.84 (4.25)	20.88 (4.25)	20.84 (4.26)
	26.66	3.343		26.63 (3.34)	26.63 (3.44)	--	26.64 (3.34)	26.65 (3.34)	26.63 (3.35)
	36.56	2.458		--	36.52 (2.45)	36.54 (2.44)	36.55 (2.45)	36.52 (2.45)	36.54 (2.46)
	39.49	2.28		39.456 (2.281)	39.45 (2.28)	39.44(2.28)	39.49 (2.28)	39.45 (2.28)	--
SIDERITE	24.80	3.59	SIDERITE	--	--	--	--	--	24.43 (3.62)
	32.08	2.79		--	--	--	--	--	--
	35.05	2.560		--	--	--	--	--	35.07 (2.55)
	37.10	2.423	PYRITE	--	--	--	37.40 (2.42)	--	--

Table 2: 2 Θ And Då Values For Different Clay And Nonclay Matix Identification

X-ray Diffraction (XRD) clay mineral analysis emerges as a potent instrument in the realms of geology, soil science, and environmental research, offering intricate insights into the mineralogical characteristics of clay-rich specimens. Within our study area, the river water exhibits a lower concentration of clay minerals in comparison to non-clay minerals. The analysis reveals a notably higher percentage of Quartz compared to both clay and non-clay minerals.

IV. Conclusion:

In our comprehensive exploration into the geological nuances of the Brahmaputra River's sedimentary realm has been nothing short of revelatory. The diverse heavy mineral suite, spearheaded by EPIDOTE, HORNBLENDE, ZIRCON, and their cohorts. The observation is supported by the presence of prismatic, long slender, and zoned grains of zircon. However, the existence of colorless zircon and zircons with opaque inclusions indicates their likely origin from igneous and metamorphic sources. Rounded zircon grains suggest some contribution from Reworked sediments. The sediments contain grains of different derivatives, indicating varied sources with diverse compositions. The higher percentage of hornblende suggests a metamorphic source for these sediments. Additionally, the presence of kyanite-epidote and garnet, known as a Himalayan assemblage, further supports a metamorphic origin for some of these sediments.

The dynamic variations in the ZTR maturity index, particularly this observed from Chabuwa to Madhupur, unveils a captivating narrative of sediment origins. This mosaic of sources, shaped by the ever-changing Brahmaputra River, reflects the geological vibrancy of the region, with influences stretching from the NNE to SWW. The calculated ZTR index indicates that most sample depths exhibit below 20%. So, these river sediments are corresponding to generally very immature sediments. The ZTR maturity index of sediments increases in the direction from NNE to SWW, indicated by ZTR maturity Index variations; rounded Zircon-Tourmaline-Rutile grains imply reworked sediment contribution, while subrounded to sub-angular grains hint at potential first-cycle origin.

The X-ray diffraction analysis reveals a minor peak corresponding to clay matrix, predominantly Kaolinite and Chlorite, alongside prominent peaks indicating a high abundance of non-clay matrix, including Garnet, Siderite, Pyrite. Additionally, the percentage of quartz is notably higher than both clay and non-clay matrix. The sedimentary record resonates with a captivating amalgamation of influences from the northeastern Himalayas and Naga Hills, coupled with dendritic sediment deposition, offering a captivating insight into the geological evolution of the area.

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