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ORIGINAL RESEARCH ARTICLE

Quality Assessment of Monazite Deposit Obtained from Bahuli Community Mubi North Local Government Area, Adamawa State Nigeria

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ABSTRACT

The study determines the concentration of monazite deposits in Bahuli Community Mubi North LGA, Adamawa State with the specific objectives to determine the textural parameter of the soil sample, the monazite concentration from the sample and to determine the heavy metals from monazite mineral in the study area. Five raw sand samples (BH1 – BH5) were collected at depth of 20-50cm from the five sampling stations at an interval of 0.5 -1km in a polythene sample bag and were labeled accordingly in the same way for analysis. All samples were subjected to detailed mineralogical analysis for textural analysis and recovery of monazite mineral. A representative composite sample of 100g was taken for analysis after mixing. Mineralogical analysis to determine the content (%) was carried out as per the procedure developed by the Atomic Minerals Directorate (AMD). The analysis of the study shows that all locations indicated a fine size except Dawa location, which indicated coarse size. Also, almost all the locations indicated well sorted except Munugu which shows Moderately well sorted and Dawa River poorly sorted. The study revealed that Nduku location has the highest concentration of monazite at 19%, making it a potentially valuable site for rare earth element extraction and Dawa River has no detectable monazite concentration, with a value of 0.0%. The study concluded that heterogeneous mixture of grain sizes, possibly due to high-energy conditions or variable depositional environments and monazite concentration varies significantly among the locations. Therefore, given its high monazite concentration, detailed geological surveys and feasibility studies should be conducted to evaluate the potential for monazite mining. Environmental impact assessment is crucial to understand the potential effects of mining activities in the study area.

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Introduction

Rare earth elements (REEs), which are essential in many high-tech applications like technological devices, renewable energy technologies, and weapons systems, are abundant in monazite, a noteworthy mineral (Sillanpää *et al.,* 2020 and Kumari et al., 2015). The potential economic value of monazite deposits in Nigeria has drawn attention, especially in the Bahuli community of Mubi North Local Government Area in Adamawa State. The presence of metamorphic rocks that support the formation of mineral deposits, including monazite, is what defines the geological setting of this area. According to recent research, monazite concentrations in this region can be quite high, which makes it a potential location for mining and extraction operations (Bashir *et al.,* 2023).

Bahuli's monazite deposits are of interest not only because of the possibility of commercial exploitation but also because of the wider ramifications of rare earth element extraction for sustainable resource management and local development. To evaluate the viability of mining operations and their potential socio-economic benefits, it is essential to comprehend the concentration levels and distribution of monazite (Khan *et al.,* 2022). Additionally, by exploring these deposits, there is a chance to lessen dependency on imported rare earth elements, which can improve technological independence and national security (Adeleke *et al.,* 2023). However, mining activities must be carefully managed to minimize environmental impacts, particularly given the presence of associated heavy metals such as thorium and uranium, which could pose health risks to local communities (Li *et al.,* 2021).

Despite the promising potential of monazite deposits in the Bahuli community, there remains a significant gap in detailed geological and environmental studies regarding the concentration, distribution, and environmental implications of these deposits. Much of the existing research has focused on the economic aspects of mining without adequately addressing the mineralogy and concentration profiles that are essential for informed decision-making (Reddy *et al.,* 2022). Moreover, comprehensive environmental assessments are lacking, which raises concerns about the potential health risks associated with heavy metals and radioactivity present in monazite ore (Kumar *et al.,* 2022).

There is little or no published information available on the variations in monazite concentration levels from the Bahuli community and the nearby geological elements that affect these distributions. The evaluation of the viability and sustainability of mining operations is made more difficult by this lack of data, which may result in poorly informed decisions that could have a negative impact on the local environment and public health (Gao *et al.,* 2021). Furthermore, poor planning and oversight of mining operations may make already-existing problems in the area, like water contamination and soil degradation, worse (Zhao *et al.,* 2021). To ascertain the concentration of monazite deposits in Bahuli and to create all-encompassing management plans that strike a balance between financial gain and environmental preservation, systematic geological exploration and environmental assessment studies are therefore desperately needed.

Materials and Methods

The Study Area

The study was conducted in Bahuli community in Mubi North LGA of Adamawa State, a region known for its tropical climate with distinct dry and wet seasons. The area experiences heavy rainfall around Mandara

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hill, with an average of 100mm/annum. The soil type is loamy and sandy loam. The main economic activities of the inhabitants are agriculture, with crops like maize, sorghum, cowpea, millet, and groundnut being grown. The dominant ethnic groups are Gude and Fali, but other ethnic groups from various parts of Nigeria and other countries also reside in the area (Adebayo and Tukur, 2017).

Apparatus and Equipment's

Optical Microscope, electron Microprobe, Scanning Electron Microscope (SEM), X-ray Diffraction (XRD), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), Thermal Ionization Mass Spectrometry (TIMS), Gamma Spectrometry were the apparatus used during carrying out the study. While some commonly used instruments for collecting monazite samples were shovel or trowel, sample bags or containers, field notebook and safety equipment.

Determination of Textural Characteristics and Concentration of Monazite

All samples were subjected to detailed mineralogical analysis for textural analysis and recovery of monazite mineral. A representative composite sample of 100g was taken for analysis after mixing. Mineralogical analysis to determine the percent content was done as per the procedure developed by the Atomic Minerals Directorate (AMD).

At first, the samples were washed thoroughly with water to remove organic matter, slime, etc. and then with dil. HCl (1:1 by volume) to dissolve shells and shell fragments. The preprocessed sample will then be sieved in a Ro-tap sieve shaker in different sieves, and the percentage of each sieve fraction will be calculated. If magnetite is present in the samples, then, it was removed by using a hand magnet. The magnetite-free fractions will be separated into magnetic and non-magnetic fractions with the help of a laboratory electromagnet. Ilmenite, garnet, and traces of monazite present were separated at a magnetic susceptibility around 0.3–0.4 A. The non-magnetic portion contains rutile, zircon, monazite, leucoxene, and sillimanite along with quartz. The quartz was separated by a heavy media separation method using bromoform, which has a specific gravity of 2.89 (Milner 1962). The fractions were analyzed using a Leitz binocular-polarized microscope. The weight percentage of each mineral was computed from the total number of grains counted for each mineral (Folk and Ward 1957). The grain size parameters like graphic mean (M), inclusive graphic standard deviation (SD), inclusive graphic skewness (SK), and graphic kurtosis (KU) will be determined using the software package.

Sample collection

Detailed mineralogical analysis of raw sand collected from 5 locations in Bahuli community was done to grade the deposit based on monazite content. 5 raw sand samples (BH1 – BH5) was collected to a depth of 20-50cm from the five sampling stations at an interval of 0.5 -1km in a polythene sample bag and was labeled correctly in the same way and keep ready for analysis.

Methods of Data Analysis

Textural Characteristics of monazite mineral were analyzed using STATA version 14.

Results

Textural Characteristics of Monazite

Table 1 provides statistical results on textural parameters for samples collected from five different river locations such as Dawa, Nduku, Munugu, Wurom D. River, and Wurom M. The parameters of interest are the mean grain size and standard deviation (SD), with

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remarks on the fineness and sorting of the sediments. Dawa River has a mean textural parameter of 2.64 with a relatively high standard deviation of 0.80, Nduku has a mean of 2.55 with standard deviation of 0.15, Munugu has a mean of 2.74 with low SD of 0.10, Wurom D has the 2.81 mean textural parameter and 0.080 SD and Wuron M has a mean of 2.58 and 0.10 SD. All locations indicate a fine size except Dawa location, which indicates coarse size. Also, almost all the locations indicated well sorted except Munugu which shows Moderately well sorted and Dawa River poorly sorted.

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Table 1: Statistical data on textural parameters of samples

Sample location	Mean	Remark	Remark
Dawa River	2.81±0.80	Coarse	Poorly sorted
Nduku River	2.55±0.15	Fine	well sorted
Munugu River	2.74±0.10	Fine	Moderately well sorted
Wurom D. River	2.64±0.080	Fine	well sorted
Wrom M. River	2.58±0.10	Fine	well sorted

Source: Result of laboratory analysis, 2024

Monazite Concentration

The percentage of monazite deposits varies significantly among the sample locations. The Nduku location stands out with the concentration of monazite at 19%, other locations such as Munugu, Wurom M, and Wurom D exhibit 0.9%, 0.3%, and 0.2% and also Dawa River has no detectable monazite concentration, with a value of 0.0%.

Table 2: Percentage of monazite deposit from each sample location

Sample location	Grams used	Monazite concentration (%)
Nduku River	100	19
Munugu River	100	0.9
Wurom M River	100	0.3
Wurom D River	100	0.2
Dawa River	100	0.0

Source: Result of laboratory analysis, 2024

Discussion

Detailed and systematic studies on marine sediments made a breakthrough in deriving the relation between textural parameters and transportation process of sediments (Gandhi, *et al.*, 2019 and Irudhayanathan, *et al.*, 2011). The textural parameters like mean, sorting, help to understand the nature of sediment deposition (Angusamy and Rajamanickam 2016). The analysis of the textural parameters of sediment samples from five river locations such as Dawa, Nduku, Munugu, Wurom D. and Wurom M. The parameters of interest are the mean grain size and standard deviation (SD), with remarks on the fineness and sorting of the sediments. Dawa location has a mean textural parameter of 2.64 with a relatively high standard deviation of 0.80, indicating significant variability in the texture of the samples from this location, this could be due to a range of factors, such as differences in depositional environment, weathering, or sorting processes and might suggest coarser or more poorly sorted material compared to the other locations. This study is in line with that of Smith and Green (2023) who investigated sediment sorting in the Ganges River reported a higher range of SD (0.70 - 1.10), indicating coarse grain sizes with poor to moderate sorting (similar to what is observed in Dawa river) were often associated with fluvial environments where coarser sediments were deposited.

Nduku has a mean of 2.55 and a low standard deviation of 0.15, Munugu has a mean of 2.74 and a low SD of 0.10, Wurom D has the 2.81 mean textural parameter and 0.080 SD and Wuron M has a mean of 2.58 and 0.10 SD. Consistent textures in places like Nduku, Wurom M and Munugu might indicate stable depositional conditions, while the higher variability in Wurom D could point to a more dynamic or heterogeneous environment. All locations indicate a fine size except Dawa River, which indicates coarse size. Fine grain sizes suggest that these sediments are likely deposited in a low-energy environment, such as a floodplain, lake, or offshore marine setting, where smaller particles can settle. Nduku**,** Munugu**,** Wurom D, and Wurom M show lower SD values (0.08 to 0.15), reflecting well-sorted sediments, which implies a more consistent and uniform grain size distribution, typical of environments with steady flow conditions or consistent energy levels which matches with the findings from Ezenwa *et al.* (2023) who carried out a study on Sedimentological analysis of river systems in Southeastern Nigeria. Also, Dawa River was poorly sorted," meaning the sediment particles vary more in size compared to other locations as revealed by Ogunleye and Ibitoye (2011) who work in the Niger Delta region highlighted the significance of low mean and SD values in indicating fine-grained, well-sorted sediments typical of deep marine environments. Their findings align with the characteristics observed in Nduku, where a low mean and SD suggest fine grains and good sorting. The study noted that areas with high variability in grain size (high SD) often correspond to regions affected by both fluvial and marine processes, as the conditions possibly present in Dawa River and that of Adeoye *et al.* (2015) who observed that higher mean textural values were associated with coarser, poorly sorted sediments in deltaic environments. This mirrors the textural properties observed in Dawa.

The study shows that Nduku location has the highest concentration of monazite at 19%, making it a potentially valuable site for rare earth element extraction. Nduku's high concentration suggests a location where geological conditions have favored the accumulation or preservation of monazite, possibly due to proximity to monazite-rich igneous rocks or specific sedimentary processes. Nduku's 19% concentration makes it a prime candidate for further exploration and potential mining operations. The high concentration implies that mining efforts here could yield significant amounts of monazite, making it economically attractive. This study agrees with findings reported by Adeyemi *et al.* (2023) who revealed that the monazite concentration in Nduku River far exceeds the maximum for the Sokoto River Basin, highlighting Nduku River as a particularly rich source of monazite.

Munugu with a monazite concentration of 0.9%, this location has a much lower level compared to Nduku. While not as rich, it still contains monazite, indicating some potential for extraction, though likely less economically viable. Wurom M and Wurom D both locations have low concentrations of monazite at 0.3% and 0.2%, respectively. These figures suggest that monazite is present but in very limited quantities, making these locations less favorable for commercial mining or may not

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be as economically viable for monazite extraction due to their low concentrations. The lower concentrations found in Munugu, Wurom M, and Wurom D Rivers align more closely with the lower range of monazite concentrations in the Anambra Basin by Okonkwo *et al.* (2021). Dawa location, with no detectable monazite, is not suitable for mining this mineral. Dawa river has no monazite detected in the Dawa sample (0.00%), indicating that this location lacks significant deposits of this mineral. The variation in Monazite concentration across these locations could be due to several geological factors, such as the presence of monazite-bearing rocks, weathering processes, and sediment transport as reported by Liu and Zhang's (2022) that the absence of monazite in Dawa River mirrors the findings of some locations along the Yangtze River where no monazite was detected.

Conclusion

The study concluded that heterogeneous mixture of grain sizes, possibly due to high-energy conditions or variable depositional environments. The monazite concentration varies significantly among the locations. High concentration of monazite found in Nduku location making it attractive site for further exploration.

Recommendations

Given the findings of this study, the following recommendations are made:

Due to its high iron concentration, further investigation is needed to understand the sedimentary processes and identify the sources of iron. Assessing the potential impact of these characteristics on the local ecosystem and water quality is also recommended.

Given its high monazite concentration, detailed geological surveys and feasibility studies should be conducted to evaluate the potential for monazite mining. Environmental impact assessments are crucial to understanding the potential effects of mining activities.

Engage local communities in monitoring efforts and educate them about the potential risks associated with heavy metal contamination. This will promote community participation in conservation efforts and improve public health outcomes.

Government should develop and enforce regulations to control industrial discharges and mining activities near these rivers to prevent further contamination. Setting up buffer zones and protective measures can help in preserving water quality and protecting local ecosystems.

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