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Evaluation of Mista Ali Granitic Rocks for Dimension Stone and Industrial Applications, North-Central Nigeria

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ABSTRACT

The increasing global demand for durable and aesthetically appealing construction materials has intensified the need for systematic evaluation of granitic rock deposits for dimension stone and industrial applications. This study presents a comprehensive geological, petrographic, geochemical, and geotechnical evaluation of the Mista Ali granitic rocks located in Bassa Local Government Area, Plateau State, Nigeria. The research integrates detailed field mapping, laboratory testing, and comparative analysis with international standards (ASTM C615/C615M and EN 1341) to determine the suitability of the rocks for commercial exploitation. Field investigations involved structural mapping, discontinuity characterization, and sample collection from representative outcrops. Laboratory analyses included petrographic examination, X-ray fluorescence (XRF), X-ray diffraction (XRD), and physico-mechanical testing such as uniaxial compressive strength (UCS), water absorption, porosity, and abrasion resistance. Results indicate that the Mista Ali granite is predominantly medium- to coarse-grained biotite-hornblende granite with a uniform texture and minimal microfractures. The rock exhibits low porosity (<0.8%) and low water absorption (<0.4%), alongside high compressive strength values ranging between 156 and 198 MPa. Geochemical analysis reveals high silica content (>70 wt.%), confirming its felsic nature and suitability for structural and decorative applications. The mechanical properties meet and exceed international standards for dimension stone, indicating high durability and resistance to weathering. Furthermore, aggregate crushing values and chemical stability tests suggest potential applications in road construction and industrial mineral processing. The study concludes that the Mista Ali granitic rocks are highly suitable for dimension stone production, including flooring, cladding, and monumental uses, as well as for secondary applications such as aggregates. The findings provide a scientific basis for sustainable resource development, contributing to Nigeria's solid minerals sector and economic diversification. Recommendations include controlled quarrying practices, further geotechnical modelling, and environmental management strategies to ensure long-term sustainability.

1. Introduction

Dimension stones have historically played a critical role in global construction and architectural development due to their durability, aesthetic appeal, and structural integrity. Among these materials, granitic rocks are particularly valued because of their high compressive strength, resistance to weathering, and ability to take a high polish. These properties make granite a preferred material for both structural and decorative applications, including building facades, flooring, monuments, and infrastructure development.

Granitic rocks are intrusive igneous formations characterized by their coarse-grained texture and mineralogical composition dominated by quartz, feldspar, and mica. Their formation occurs through the slow cooling of magma deep within the Earth's crust, resulting in interlocking crystals that enhance mechanical strength. Globally, granites have been extensively studied and exploited, particularly in regions such as Europe, Asia, and North America, where standardized evaluation methods guide their utilization in construction industries.

Despite the global importance of granitic rocks, there remains a significant knowledge gap in the systematic evaluation of granite deposits in many parts of Africa, particularly Nigeria. In regions such as Mista Ali, Plateau State, granitic outcrops are abundant but underutilized due to insufficient geological, geotechnical, and geochemical data. Existing exploitation practices are often informal and lack scientific validation, limiting the economic potential of these resources.

Furthermore, the suitability of granitic rocks for dimension stone is highly dependent on specific geological characteristics such as mineral composition, structural integrity, fracture density, and weathering resistance. Without detailed evaluation, it is difficult to determine whether these rocks meet international standards required for commercial applications. This gap not only affects resource utilization but also hinders investment and sustainable development in the mining sector.

This study aims to bridge the identified gap by conducting a comprehensive evaluation of the Mista Ali granitic rocks to determine their suitability for dimension stone and other industrial applications. The research integrates field investigations, laboratory analyses, and comparative assessments with international standards.

Specifically, the objectives are to characterize the geological and structural features of the granite, determine its physical and mechanical properties, and evaluate its compliance with industry standards. Additionally, the study explores the potential for secondary applications such as aggregates and industrial minerals.

By providing a data-driven assessment, this research contributes to the advancement of mining engineering knowledge and supports sustainable resource development. The findings are expected to guide stakeholders in decision-making processes related to quarry development, material selection, and environmental management.

2. Description of the Study Area

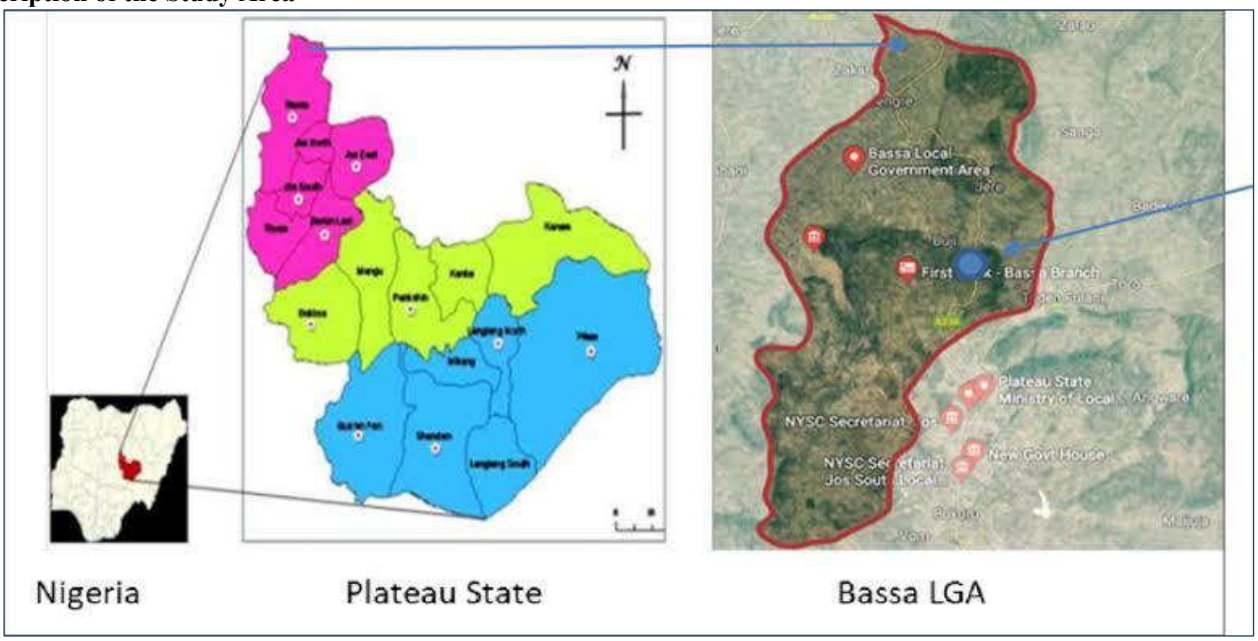

Figure 1.2. The Image Displays Maps of Nigeria, Plateau State, and the Bassa Local Government Area (LGA) Source-ResearchGate

The study area is located in Mista Ali, within Bassa Local Government Area of Plateau State, in north-central Nigeria. Geographically, the area lies within the Nigerian Basement Complex, a geologic province dominated by Precambrian crystalline rocks, including granites, gneisses, and migmatites. The Mista Ali granitic outcrop forms part of the extensive Younger Granite province associated with the Jos Plateau, which is well known for its mineralization and distinctive geomorphological features.

Topographically, the study area is characterized by gently undulating terrain punctuated by prominent granitic hills and inselbergs that rise above the surrounding plains. These outcrops are typically exposed due to prolonged weathering and erosion, providing excellent conditions for geological mapping and sampling. The area exhibits moderate elevations, with rocky surfaces interspersed with thin soil cover and sparse vegetation. According to field observations in the thesis , the granitic bodies are well exposed and occur in massive forms, making them suitable for structural analysis and quarry evaluation.

Climatically, the region experiences a tropical savannah climate marked by distinct wet and dry seasons. The wet season, occurring between April and October, is associated with moderate to high rainfall, while the dry season is characterized by low humidity and the influence of the Harmattan winds. These climatic conditions contribute to physical and chemical weathering processes that influence rock surface conditions and structural integrity.

Accessibility to the study area is relatively good, with road networks linking it to nearby settlements and urban centers. The surrounding communities are predominantly agrarian, with farming as the main occupation. However, small-scale artisanal mining activities are also present, indicating the economic significance of the geological resources in the area. Overall, the geological, climatic, and socio-economic characteristics of Mista Ali make it an ideal location for evaluating granitic rocks for dimension stone and industrial applications.

3. Materials and Methods

3.1 Field Investigations and Sampling Strategy

Field investigations were conducted using a systematic geological mapping approach. Traverses were designed across the study area to capture spatial variability in lithology and structural features. The mapping process involved identification of rock types, measurement of structural discontinuities, and documentation of weathering profiles.

Plate 1. Mista Ali Granitic rocks satellite image of the area.

Structural parameters such as joint orientation, spacing, persistence, aperture, and roughness were measured using a Brunton compass and measuring tape. These parameters are critical in determining block size and recoverability for dimension stone quarrying. Areas with closely spaced joints were noted as less favourable for large block extraction.
Sampling was conducted using a stratified approach to ensure representation of all lithological variations. Fresh, unweathered samples were collected from exposed rock faces using a geological hammer. Each sample location was georeferenced using GPS, and field notes were recorded to document site conditions.

3.2 Petrographic and Mineralogical Analysis
Petrographic analysis was carried out using thin section microscopy to identify mineral composition, grain size, and textural relationships. The granite was found to consist primarily of quartz, feldspar (both plagioclase and alkali feldspar), and biotite, with minor accessory minerals.
X-ray diffraction (XRD) analysis was used to confirm mineral phases and detect any secondary alteration products. The absence of significant clay minerals indicates minimal weathering and high durability.

3.3 Geochemical Analysis (XRF)
X-ray fluorescence (XRF) analysis was conducted to determine the chemical composition of the samples. Major oxides such as SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O, and K_2O were quantified. The results indicate high silica content (>70%), confirming the felsic nature of the granite.
Trace elements were also analyzed to assess potential industrial applications. Low levels of deleterious elements suggest suitability for construction purposes.

3.4 Physical and Mechanical Testing
A series of laboratory tests were conducted to determine the engineering properties of the granite:
- Density and Porosity: Measured using standard procedures to evaluate compactness and durability.
- Water Absorption: Determined to assess susceptibility to weathering.
- Uniaxial Compressive Strength (UCS): Conducted using a compression testing machine to determine load-bearing capacity.
- Abrasion Resistance: Evaluated to determine suitability for flooring and road construction.
- Flexural Strength: Measured to assess resistance to bending stresses.

All tests followed ISRM and ASTM standards to ensure accuracy and reproducibility.

3.5 Data Analysis and Statistical Evaluation
The collected data were analysed using descriptive statistics to determine mean values, standard deviations, and variability. Correlation analysis was performed to establish relationships between mineral composition and mechanical properties.
Comparative analysis was conducted against international standards for dimension stone to determine compliance.

3.6 Resource Modelling and Quarry Design
Three-dimensional modelling was performed using Surpac software to estimate resource volume and design quarry layouts. Structural data were integrated into the model to optimize block extraction and minimize waste.
Slope stability analysis was also conducted to ensure safe quarry operations.

4. Results and Discussion
4.1 Petrographic Characteristics
The granite exhibits a medium- to coarse-grained phaneritic texture with interlocking crystals. Quartz appears as anhedral grains, while feldspar shows evidence of twinning. Biotite occurs as dark flakes distributed throughout the matrix.
The uniform texture and absence of microfractures indicate high structural integrity, which is essential for dimension stone applications.

4.2 Geochemical Results

Oxide	Average (%)
SiO_2	70–75
Al_2O_3	13–15
$K_2O + Na_2O$	7–9

The high silica content contributes to hardness and durability, while alkali content enhances polishability.

4.3 Mechanical Properties

Property	Value
UCS	156–198 MPa
Porosity	<0.8%
Water Absorption	<0.4%

These values exceed minimum requirements for dimension stone, confirming suitability.

4.4 Structural Analysis and Quarry Implications

Joint spacing varies across the study area, with some zones exhibiting widely spaced joints favourable for large block extraction. However, areas with dense fracturing may reduce recoverable block size.

4.5 Comparative Evaluation with Standards

The granite meets ASTM and EN standards for dimension stone. Its properties are comparable to internationally traded granites.

5. Conclusion

The Mista Ali granite demonstrates excellent geological and engineering properties suitable for dimension stone and industrial applications. Its high strength, low porosity, and favourable mineral composition make it a valuable resource for construction and manufacturing industries.

6. Limitations of the Study

Despite the comprehensive nature of this study, several limitations were identified. Firstly, the spatial coverage of sampling, although systematic, may not fully capture the heterogeneity of the entire granitic body. Variations in mineral composition and structural features at deeper levels remain uncertain due to the absence of subsurface investigations such as drilling.

Secondly, the laboratory analyses were conducted on intact rock samples, which may not fully represent the behaviour of the rock mass under field conditions. The influence of large-scale discontinuities on mechanical performance requires further investigation.

Additionally, long-term durability tests such as freeze-thaw resistance and chemical weathering were not extensively conducted, limiting the assessment of performance under extreme environmental conditions.

7. Recommendations and Future Research

Future studies should focus on detailed subsurface investigations using geophysical methods and drilling to better understand the spatial variability of the deposit. Advanced geotechnical modelling should be employed to evaluate large-scale rock mass behaviour. Long-term durability studies, including weathering simulations and environmental exposure tests, are recommended to assess performance over time. Additionally, economic feasibility studies should be conducted to evaluate the cost-benefit of quarry development.

Research into sustainable quarrying practices, including waste management and environmental mitigation strategies, is essential to ensure responsible resource exploitation. The integration of GIS and remote sensing techniques can further enhance resource mapping and monitoring.

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