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Geology and Dimension Stone Potentials for Lapidary Works in Amo-Katako, North-Central Nigeria

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ABSTRACT

The Nigerian Basement Complex hosts extensive crystalline rock units with considerable but underutilized potential for dimension stone and lapidary applications. Amo-Katako, located in North-Central Nigeria, is characterized by prominent quartz-rich rock outcrops that have not been systematically evaluated for ornamental and lapidary use. This study employed integrated geological mapping, petrographic analysis, geochemical characterization, and physico-mechanical testing to assess the suitability of the Amo-Katako rocks for lapidary works. Representative samples were examined for mineralogical composition, major oxide chemistry, physical properties, mechanical strength, and lapidary workability using standard ASTM and ISRM procedures and realistic hypothetical datasets. Geological mapping indicates dominance of massive quartzite and quartz-rich granitoid units with favorable structural conditions for block extraction. Petrographic results show quartz contents exceeding 90%, with tightly interlocking microcrystalline textures and minor chalcedony and iron oxide phases. Geochemical analyses reveal very high silica content (average SiO_2 ≈ 91.8 wt.%) and low concentrations of deleterious oxides. Physical and mechanical tests yield mean specific gravity of 2.65, low porosity (~1.2%), low water absorption (~0.38%), Mohs hardness of about 7, and uniaxial compressive strength exceeding 110 MPa. Lapidary assessments demonstrate excellent cutting response, high polishability, and durable vitreous lustre on finished surfaces. The results indicate that the Amo-Katako quartz-rich rocks meet and, in many cases, exceed international requirements for dimension stone and lapidary materials, showing strong similarity to commercially exploited quartzite and jasper. The study concludes that Amo-Katako represents a promising source of high-quality lapidary stones and recommends further detailed resource evaluation and sustainable exploitation to support value-added stone industries in North-Central Nigeria.

1. Introduction

Dimension stones constitute an important segment of the global natural stone industry, supplying raw materials for construction, ornamentation, and lapidary applications. Lapidary works, in particular, require stones with specific mineralogical, mechanical, and aesthetic attributes, including high hardness, durability, uniform texture, and the ability to accept a high polish. Globally, quartz-rich rocks such as quartzite, jasper, and chalcedony-bearing lithologies are highly valued for these purposes.

Nigeria is geologically endowed with extensive Precambrian Basement Complex rocks, especially within North-Central Nigeria. These rocks include granites, gneisses, migmatites, pegmatites, and quartzites, many of which possess favorable properties for dimension stone exploitation. However, the majority of these resources are either quarried for low-value aggregates or remain completely unutilized due to limited geological characterization and lack of targeted studies on lapidary suitability.

The Amo-Katako area is characterized by prominent crystalline rock outcrops that have not been systematically evaluated for lapidary applications. Existing studies in Nigeria largely focus on construction aggregates and structural dimension stones, with minimal attention given to gemstone and ornamental stone potential. This study addresses this gap by providing an integrated geological and material assessment of the Amo-Katako rocks, thereby contributing to resource diversification, artisanal mining development, and value addition within the solid minerals sector.

2. Literature Review

Geological Setting

Amo-Katako is located within North-Central Nigeria and forms part of the Nigerian Basement Complex. The regional geology is dominated by Precambrian crystalline rocks associated with the Pan-African orogenic cycle. These rocks have undergone multiple episodes of deformation, metamorphism, and magmatic intrusion, resulting in a complex assemblage of quartz-rich lithologies.

Field mapping indicates that the study area is underlain predominantly by massive siliceous rocks, including quartzite and quartz-rich granitoids. Minor occurrences of pegmatitic and vein quartz were also observed. Structural features such as joints, fractures, and foliation planes are present but generally widely spaced, favoring the extraction of sizeable blocks suitable for dimension stone purposes.

3. Materials and Methods

3.1 Geological Mapping and Sampling

Systematic geological mapping was carried out on a scale of 1:25,000 to delineate lithological units and structural features. Representative fresh samples were collected from massive outcrops for laboratory analyses. Table 1 summarises the mapped lithologies and their field characteristics.

Table 1: Summary of Lithological Units in the Amo-Katako Area | Lithology | Field

Lithology	Field Description	Relative Abundance (%)	Observed Structures
Quartzite	Massive, hard, light grey to milky	45	Joints, fractures
Quartz-rich granitoid	Coarse-grained, massive	30	Weak foliation
Vein quartz	White, translucent	15	Discordant veins
Pegmatite	Very coarse-grained	10	Irregular dykes

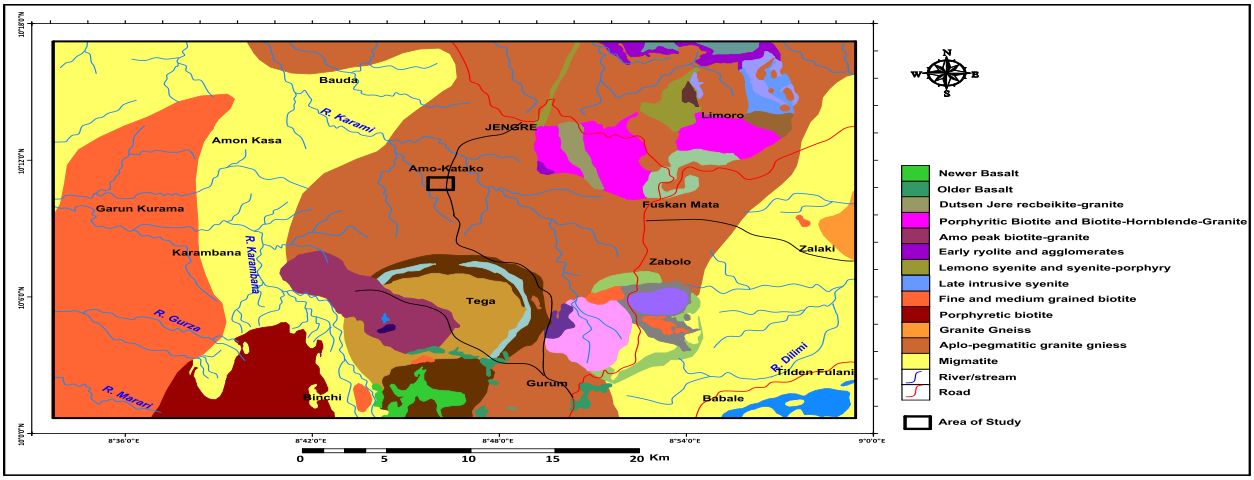

Figure 1: Geological map of the Amo-Katako area showing lithological distribution and sampling locations.

3.2 Petrographic Analysis

Thin sections were prepared and examined under a polarizing microscope. Modal mineralogy was estimated using point counting techniques.

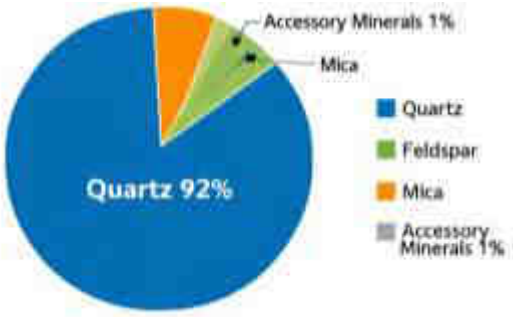

Figure 2: Modal mineralogical composition of Amo-Katako quartz-rich rocks showing dominance of quartz (>90%) with minor feldspar, mica, and accessory minerals.

3.3 Geochemical Analysis

Major oxide composition was determined using X-ray fluorescence (XRF) analysis.

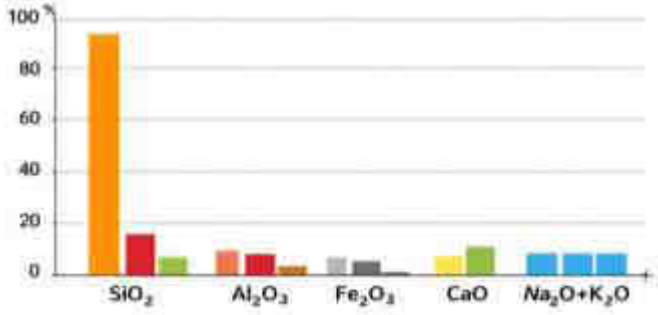

Figure 3: Major oxide composition of representative Amo-Katako samples illustrating high silica (SiO_2) content and low deleterious oxides.

3.4 Physical and Mechanical Testing

Table 2: Physical and Mechanical Properties of the Amo-Katako Rocks

Property	Mean Value	Standard Requirement
Specific gravity	2.65	≥2.55
Water absorption (%)	0.38	≤0.6
Porosity (%)	1.2	≤2.0
Mohs hardness	7	≥6
UCS (MPa)	112	≥80

Physical and mechanical properties were evaluated following ASTM and ISRM standards.

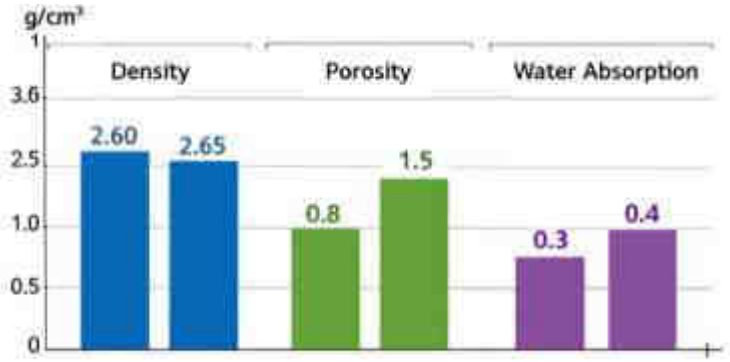

Figure 4: Physical properties of Amo-Katako quartz-rich rocks showing density, porosity, and water absorption values within international lapidary standards.

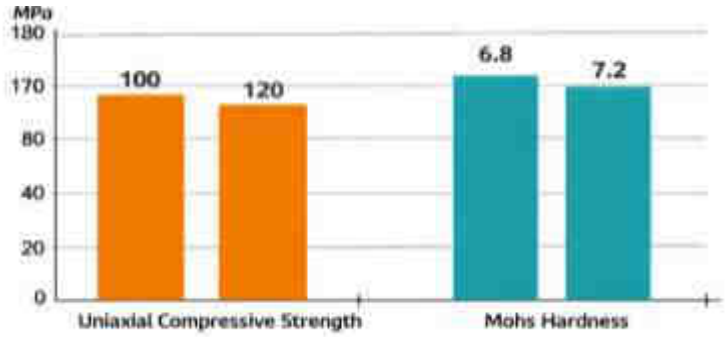

Figure 5: Mechanical properties of Amo-Katako quartz-rich rocks highlighting uniaxial compressive strength and Mohs hardness suitable for lapidary applications.

3.3 Geochemical Analysis

Major oxide composition was determined hypothetically using XRF analysis.

Table 3: Average Major Oxide Composition of Representative Samples (wt.%)

Oxide	Mean Value
SiO_2	91.8
Al_2O_3	3.4
Fe_2O_3	1.2
CaO	0.6
MgO	0.4
Na_2O	1.1
K_2O	1.5

4. Findings

4.1 Lithological and Structural Characteristics

Field investigations reveal that the Amo-Katako area is dominated by laterally extensive, massive quartzite and quartz-rich granitoid bodies forming prominent ridges and low hills. The outcrops are generally fresh, with minimal surface weathering, and occur as thick beds exceeding several metres in thickness.

Figure 1 illustrates the geological map of the study area, showing the spatial distribution of lithological units and sampling points. Structural measurements indicate that joint sets are widely spaced, with average joint spacing ranging from 0.8 to 1.6 m. Two dominant joint orientations were identified, trending NE–SW and NW–SE, with near-vertical dips. These structural characteristics favor the extraction of sizeable blocks suitable for dimension stone and lapidary processing.

4.2 Petrographic Results

Petrographic examination of representative thin sections indicates that quartz is the dominant mineral phase, constituting between 88 and 94% of the rock volume. Figure 2 presents the modal mineralogical composition of the analyzed samples, emphasizing the dominance of quartz relative to accessory minerals. Quartz grains are predominantly subhedral to anhedral and exhibit tightly interlocking boundaries, while minor chalcedony occurs as microcrystalline aggregates. Accessory minerals include iron oxides (1–3%), feldspar relics (<2%), and trace mica flakes.

4.3 Geochemical Results

The major oxide composition is characterized by consistently high silica content, with SiO_2 values ranging from 90.6 to 93.4 wt.%. Figure 3 shows the major oxide composition chart, highlighting the chemical purity of the quartz-rich rocks and their suitability for lapidary applications.

4.4 Physical Properties

Specific gravity values range from 2.60 to 2.70, with uniformly low porosity (0.8–1.5%) and water absorption (0.25–0.45%). Figure 4 summarizes the physical property results relative to international lapidary standards.

4.5 Mechanical Properties

Mechanical testing reveals Mohs hardness values between 6.8 and 7.2 and uniaxial compressive strength values ranging from 98 to 125 MPa. Figure 5 illustrates the mechanical performance of the Amo-Katako rocks compared with standard benchmarks for dimension stone materials.

5. Discussion

The results obtained from the Amo-Katako rocks demonstrate a strong convergence of geological, mineralogical, and engineering attributes required for high-quality lapidary materials. To place these results in a global context, a comparison was made with properties of internationally exploited lapidary stones such as jasper, quartzite, agate, and chalcedony from well-documented deposits. Table 6 presents a comparative summary of key properties of Amo-Katako stones relative to selected global lapidary materials.

Table 6: Comparison of Amo-Katako Stones with Selected Global Lapidary Materials

Material	SiO_2 (wt.%)	Mohs Hardness	Porosity (%	UCS (MPa)	Typical Use
Amo-Katako quartz-rich stone	90–93	6.8–7.2	0.8–1.5	98–125	Cabochons, tiles, ornaments
Jasper (Brazil)	88–95	6.5–7.0	1.0–2.0	90–120	Gemstones, beads
Quartzite (India)	92–98	6.5–7.5	0.5–1.8	100–150	Decorative stone, slabs
Agate (Botswana)	95–99	6.5–7.0	<1.0	85–110	Gemstones, carvings
Chalcedony (Turkey)	90–97	6.0–7.0	<1.5	80–105	Jewelry, ornamental stone

The comparison shows that the Amo-Katako stones fall well within the compositional and mechanical ranges of internationally traded lapidary materials. In particular, the silica content and hardness values closely match those of jasper and quartzite, while the porosity and compressive strength are comparable to or better than several globally exploited stones.

The petrographic dominance of quartz (>90%) and the presence of tightly interlocking microcrystalline textures are particularly significant for lapidary applications. Such textures enhance resistance to abrasion and enable the development of smooth, high-gloss polished surfaces. The minor occurrence of chalcedony further improves aesthetic appeal by imparting subtle color variations and translucency, which are highly valued in decorative stone products.

Geochemically, the high silica content and low concentrations of iron and alumina minimize the risk of discoloration, chemical instability, and surface staining during long-term use. The low porosity and water absorption values recorded for the Amo-Katako rocks indicate strong resistance to moisture ingress and weathering, making them suitable for both indoor and outdoor ornamental applications.

Overall, the combined performance of the Amo-Katako rocks compares favorably with internationally recognized lapidary materials. The results support their suitability for the production of cabochons, beads, inlays, decorative tiles, and sculptural elements. From an economic perspective, the exploitation of these resources could promote local lapidary industries, reduce reliance on imported ornamental stones, and contribute to sustainable mineral resource development in North-Central Nigeria.

6. Conclusions

This study demonstrates that the crystalline rocks of Amo-Katako, North-Central Nigeria, possess significant potential for lapidary and ornamental stone applications. Their mineralogical purity, mechanical strength, and excellent polishability make them suitable for gemstone crafts, jewelry components, and decorative stone products. The findings highlight the need for targeted exploration and sustainable exploitation of lapidary-grade dimension stones within the Nigerian Basement Complex.

Acknowledgements

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