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Assessment of Physical and Mechanical Properties of Granitic Rock at University of Abuja

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ABSTRACT

A study on the assessment of physical and mechanical properties of granitic rock at University of Abuja was carried out. The research involved field work, laboratory testing and analysis of rock samples to determine their mineralogical properties, and compressive strength. The granitic gneiss outcrop at University of Abuja is a massive and elongated ridge trending NW-SE for about 2.8 km with a coarse-grained texture of gradual lineation of quartz and feldspar in places. Petrographic studies revealed biotite flakes in the granitic gneiss appeared thin as a result of deformation and are aligned in parallel to sub parallel style surrounding large crystals of feldspar to disclose some evidence of strain. Field occurrence of the gneisses revealed that the rocks have undergone intense heat and pressure, resulting in the formation of high-grade metamorphic rocks with bands of felsic to mafic minerals. Granitic gneiss predominates in the area having quartz, feldspar, muscovite and biotite mica ± hornblende and iron oxides. Correlation of mineralogical composition in granitic gneiss rocks with its compressive strength in the study area revealed that quartz is positively correlated with compressive strength, biotite is positively correlated with compressive strength and muscovite is also positively correlated with compressive strength while iron oxide and feldspar are negatively correlated with compressive strength. In gneiss, quartz, muscovite and iron oxides are positively correlated with compressive strength, while biotite and feldspar are negatively correlated with compressive strength.

Keywords: Granitic, Mineralogical, Petrographic, Mechanical, Gneiss, Biotite, Feldspar

1.0 INTRODUCTION

The assessment of physical and mechanical properties of granitic rocks is fundamental to engineering geology, particularly for foundation design, aggregate suitability, and slope stability analysis. Recent studies emphasize the critical link between a rock's petrographic characteristics and its engineering behavior, underscoring the need for site-specific investigations (Adegbuyi and Ogunleye, 2021; Faisal *et al*., 2024). The physical properties, such as density, porosity, and water absorption, are primary indicators of a rock's durability and resistance to weathering, directly influencing its mechanical strength (Hassan and Yusuf, 2022; Singh and Sharma, 2023). Porosity, in particular, has been identified as a key factor controlling uniaxial compressive strength (UCS) and tensile strength in granitic rocks (Khan *et al*., 2025; Li *et al*., 2020). Mechanical properties, including UCS, point load strength index, and Brazilian tensile strength, are crucial parameters for geotechnical design (Bello and Abubakar, 2023; Wang *et al*., 2021). Empirical correlations have been widely developed to estimate UCS from more easily measurable properties like point load index or Schmidt hammer rebound values, offering cost-effective alternatives for preliminary assessments (Díaz *et al*., 2020; Ojo and Olaniyi, 2022). However, the reliability of these correlations is highly dependent on the specific rock type and its geological context, making localized studies essential (Martínez-García *et al*., 2023; Zhao and Chen, 2024). Recent research has also highlighted the role of micro-cracks, mineral composition, and grain size in dictating the mechanical response of granite (Ersoy and Aydin, 2021; Nguyen *et al*., 2024). Furthermore, the influence of environmental factors, such as water saturation and temperature, on the degradation of these properties is a growing area of concern (Wang and Li, 2025; Zakaria and Bin, 2026). Given the specific geological setting of the University of Abuja campus, which is situated on the Precambrian basement complex of Nigeria, a detailed and localized characterization is imperative (Obiora and Okonkwo, 2020). Studies from similar geological terrains suggest significant variability in rock quality, necessitating comprehensive field and laboratory testing (Tunde and Adeleke, 2023; Taha and Omar, 2024). The findings from such assessments are vital for ensuring the long-term stability and safety of any infrastructural development on the campus (Salem and Hassan, 2022; Ibrahim and Musa, 2021).

1.1 Granitic Rock

Granitic rock is a type of igneous rock characterized by its mineral composition and distinctive texture. It holds significant importance in geological and engineering contexts due to its widespread occurrence, durability, and suitability for various applications. Granitic rock is predominantly composed of minerals such as quartz, feldspar, and mica, imparting its unique properties and appearance. Granitic rocks are formed through the solidification of magma deep within the Earth's crust. As magma cools and crystallizes, it forms the mineral grains that make up granitic rock. This slow cooling process allows large crystals to develop, giving granitic rock its coarse-grained texture (Blatt *et al.*, 2006). The engineering properties of granitic rock contribute to its versatility in construction. Its high compressive strength makes it suitable for load-bearing structures like bridges and buildings. The low porosity and impermeability of granitic rock also make it an ideal choice for foundations, as it minimizes water absorption and potential damage from freeze-thaw cycles (Bell, 2007). The durable nature of granitic rock is attributed to its resistance to weathering and erosion. This durability ensures that structures built from granitic rock maintain their integrity and appearance over time. Additionally, granitic rock's resistance to chemical weathering makes it well-suited for outdoor applications (Twidale, and Bourne, 2009). In the realm of construction aggregates, granitic rock plays a vital role. Crushed granitic rock, known as granite aggregate, is commonly used in the production of concrete and asphalt. Its hardness and durability enhance the strength of these construction materials, ensuring their longevity and performance. Granitic rock also holds geological significance. Its presence provides insights into the geological history and tectonic processes that shaped the Earth's crust. The occurrence of granitic rock formations can indicate areas of past magmatic activity and geological evolution (Marshaks, 2009). The composition of granitic rock, commonly referred to as granite, is a fundamental aspect that influences its distinct characteristics and wide-ranging applications in both geological and engineering contexts. Granite is primarily composed of several minerals, each contributing to its unique properties and appearance.

Table 1: Comparative Characteristics of Physical and Mechanical Properties

	Physical Properties	Mechanical Properties
Definition	Characteristics that describe the material's physical nature without changing its composition	Characteristics that describe how a material responds to applied forces and loads
What They Measure	State, structure, and appearance of the material	Strength, deformation, and failure behavior under load
Depends On	Composition, density, temperature, moisture Composition	microstructure, loading condition, temperature
Testing Method	Observation and basic instruments. No force required	Requires application of force, stress, or strain
Examples	Density, Specific Gravity, Porosity, Color, Texture, Electrical Conductivity	Thermal Conductivity, Melting Point Tensile Strength, Compressive Strength, Hardness, Ductility, Elasticity, Toughness, Fatigue Strength, Creep
Units	kg/m3, %, °C, W/mK, etc	MPa, N/mm2, %, J, GPa
Importance in Design	Used for material selection, durability, heat and electrical performance	Used for structural design, safety, and load carrying capacity
Changes With	Environmental conditions like temperature and moisture	Loading rate, temperature, and stress state

2.0 MATERIAL AND METHODS

2.1 Materials

The study areas lie within latitudes 8° 58′ 00″ N to 8° 59′ 00″ N and longitudes 7° 09′ 50″ E to 7° 11′ 30″ E in Abuja Municipal Area Council, Federal Capital Territory, Abuja. (Figure 1). The highway linking the University main gate is the Lugbe-Giri-Gwagwalada road which is connected to Gwagwalada-Lokoja highway at Giri. The materials used in this study were drawn from both field-based reconnaissance work and desk-based resources. They are categorized into field equipment, desk study resources, and analytical tools. The field equipment are Global Positioning System (GPS) receiver, Compass–clinometer, Measuring tape, Digital camera, Field notebook and Personal protective equipment (PPE): including safety helmet, boots, gloves, and reflective vest for safety during site visits.

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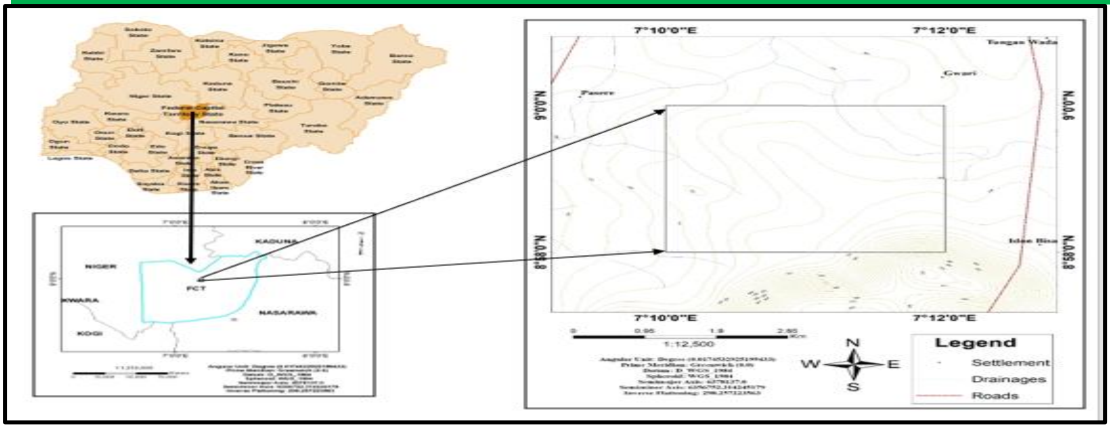

Figure 1: Location map of the study Area.

2.2 Methods

The study adopted a hybrid methodology involving both desk-based research and field reconnaissance. This approach enabled the integration of primary site observations with laboratory data. Field work was done to map the rock lithologies and to collect representative samples from the field by navigating to pre-selected observation points using a GPS receiver, measuring strike and dip of visible fractures with a compass–clinometer, recording lithological characteristics and wall-rock conditions in a field notebook and took photographs of fractures and lithologies. Spatial field data collected were plotted with ArcGIS 10.8 softaware to produce a spatial distribution map of observation points. Rose diagrams of fractures orientations were generated using GEOrient plotting software.

2.3 Petrographic Studies

Representative rock samples taken during the field mapping were prepared into thin section at the Department of Geology, University of Ilorin. The thin sections were prepared by cementing thin slices of rock to glass and carefully grinding using carborundum grit to produce a thin layer of rock to a standard thickness of 30 microns. Standard Olympus BX51 transmitted light microscopy (magnification range between 4x to 10x) was used to study the textures of the rocks and optical properties of individual minerals in the rocks under plane and cross polarized light and for microstructural observations to reconstruct the deformation features and mineralogical assemblages. The slides were examined with a microscope at the Edulong Digital School of Mines and Geosciences, Abuja for a clear photomicrograph.

2.4 Uniaxial Compressive Strength

The test procedure is in accordance with ISRM (1981) and ASTM (2001) D2938. The uniaxial compressive strength was determined using Equation 1.

$$Co = \frac{P}{A} = \frac{P}{(WXD)}$$

……………………………………………. Equation 1

Where C_o is Uniaxial compressive strength (MPa), P is the applied peak load, (kN), W is width of the sample (mm), D is height of the sample (mm).

3.0 RESULTS AND DISCUSSION

3.1 Geology of the study area

Two major rock types make up the geology of the study area (Figure 2), they are; Gneiss (mostly banded gneiss in places) and Granitic Gneiss

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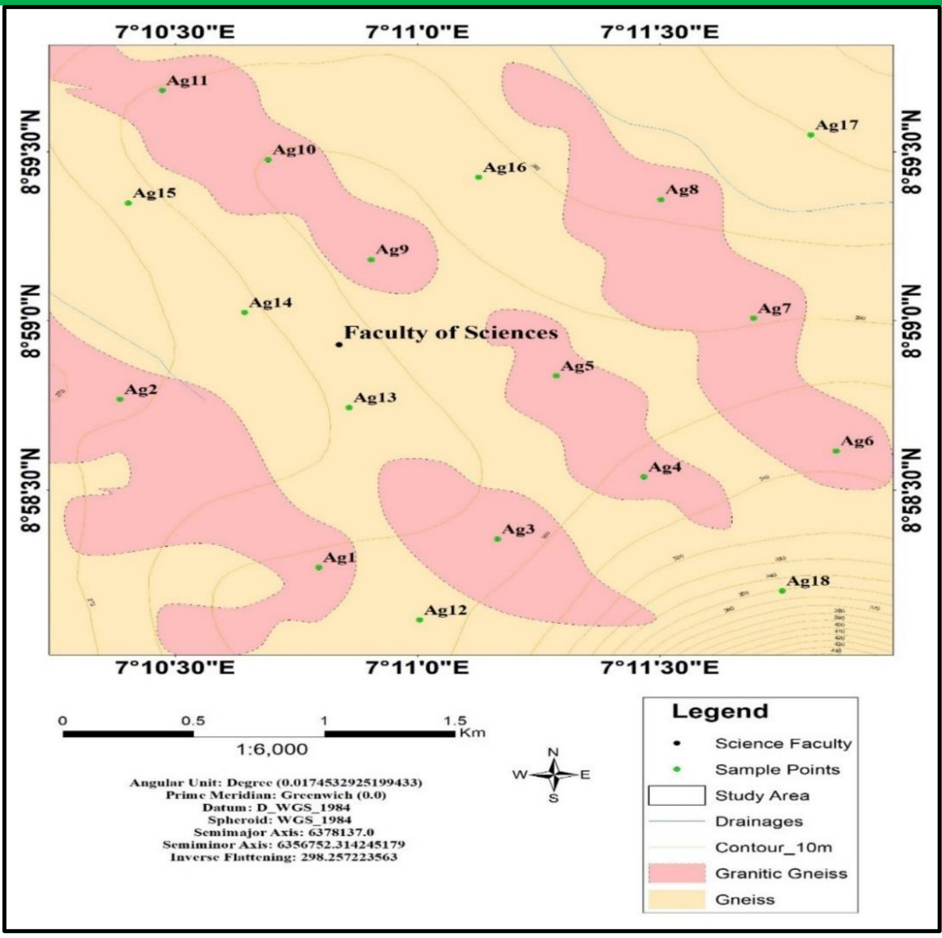

Figure 2: Geological map of the study area showing sample location points for geotechnical tests

Figure 3: (a) Outcrop of granitic gneiss in form of a ridge within the study area (b) Outcrop of low-lying gneiss within the study area

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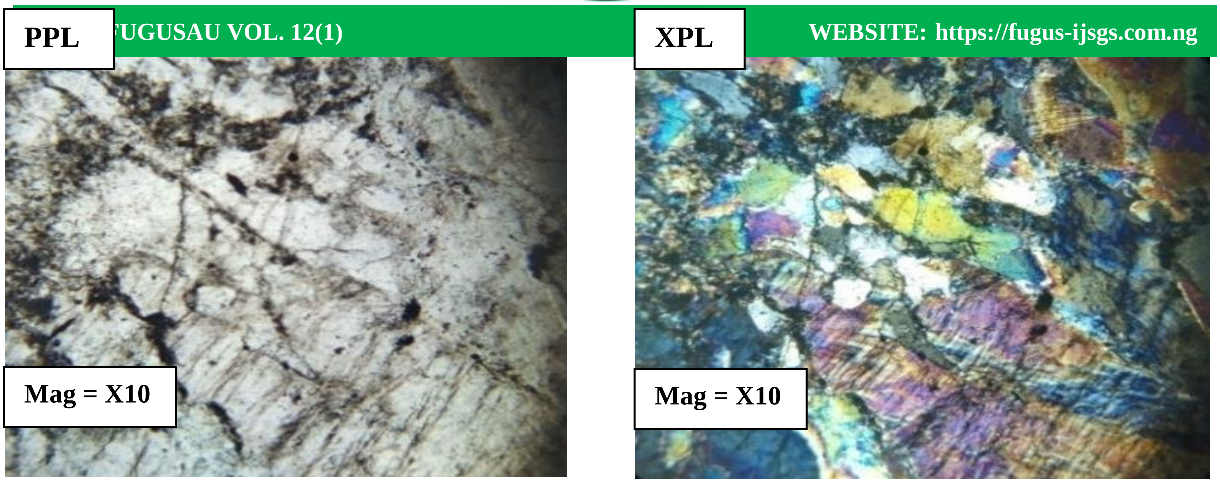

Figure 4: Photomicrograph of gneiss with alteration at the rims of the opaque mineral within the microfracture. It has traces of iron oxides, and dominant plagioclase feldspar (Pl), biotite (Bio), quartz (Qtz) and muscovite (Mus). PPL=Plane Polarized Light, XPL= Crossed Polarized Light.

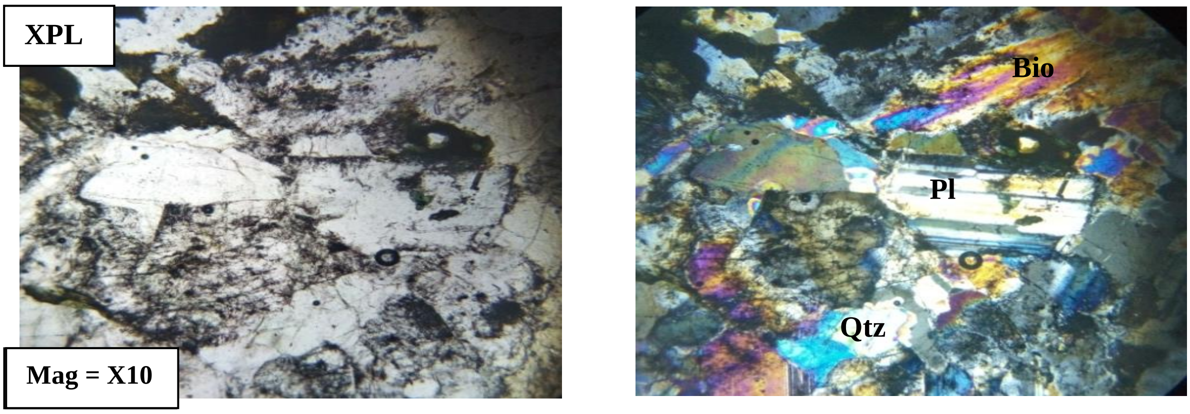

Figure 5: Photomicrographs of granitic gneiss under plane polarization (PPL) and cross polarization (XPL) in this study area. Plagioclase feldspar (Pl), biotite (Bio), quartz (Qtz).

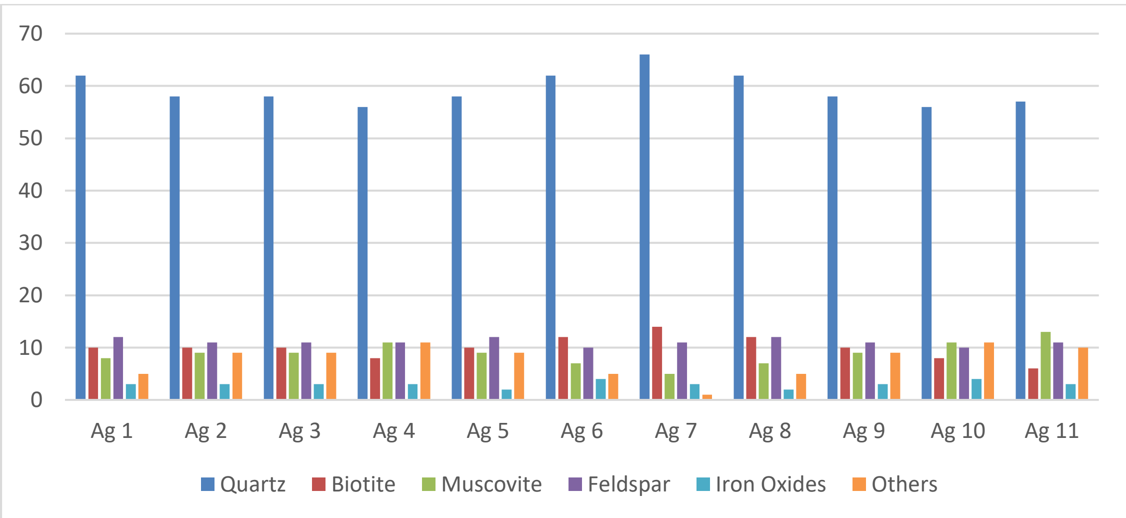

Figure 6: Histogram plot of mineralogical composition of granitic gneiss rocks in the study area

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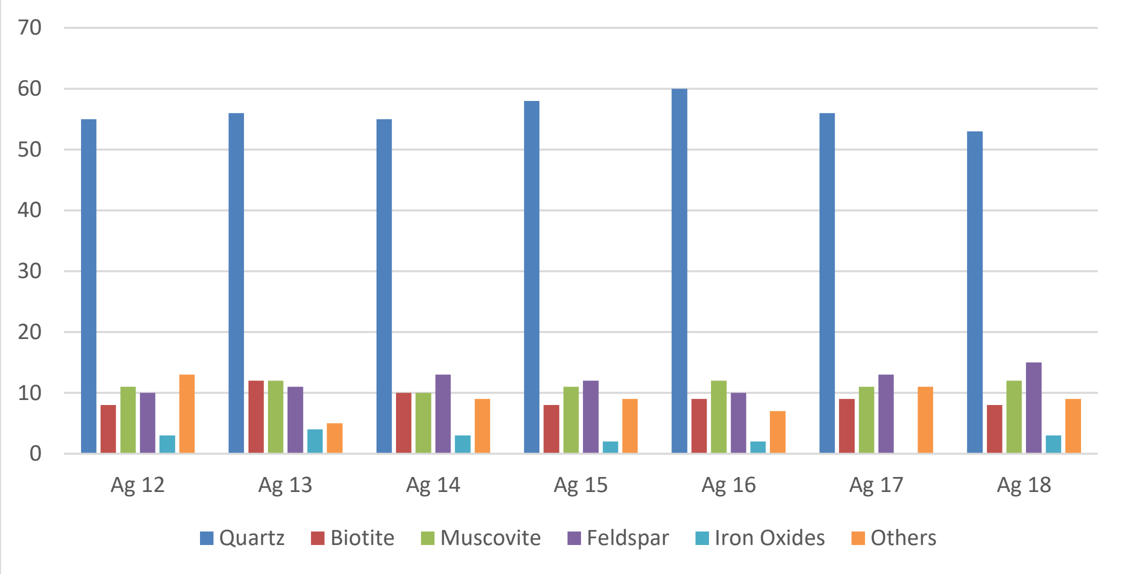

Figure 7: Histogram plot of mineralogical composition of gneiss in the study area

The assessment of physical and mechanical properties of granitic rock at University of Abuja was carried out to reveal mineralogical composition and uniaxial compressive strength of the two major rocks outcropped in the study area. The granitic gneiss is a massive and elongated ridge trending NW-SE for about 2.8 km with a coarse-grained texture of gradual lineation of quartz and feldspar in places, also with veins occurring as near circular to concave shape. From petrographic studies, biotite flakes in the granitic gneiss appeared thin, deformation and are aligned in parallel to sub parallel style surrounding large crystals of feldspar to reveal some evidence of strain. The gneisses are mostly low to flay lying outcrop of the Precambrian age covers a significant portion of the study area. Field occurrence revealed that the rocks have undergone intense heat and pressure, resulting in the formation of high-grade metamorphic rocks with bands of felsic to mafic minerals. Petrographically, the gneiss is composed of quartz, feldspar, muscovite and biotite mica ± hornblende and iron oxides depending of the sample location. The banding or foliation in the rock is a result of the recrystallization of minerals under directed pressure. The distribution of major minerals between the granitic gneiss and gneisses are fairly related in composition (Figures 6 and 7). Geotechnical evaluation suggests that the rock mass quality at study area ranges from (RMR 42–58.2) for granitic gneiss and (RMR 56.4–67.3) for the gneiss. The Uniaxial Compressive Strength (UCS) of the rocks are vital parameter for assessing its suitability for quarrying operations. The obtained UCS value of 67.3 MPa is crucial as it reflects the rock's ability to withstand vertical loads and stresses during extraction and processing (Franklin, 1985).

4.0 CONCLUSION

The research into an assessment of physical and mechanical properties of granitic rock at University of Abuja. The research was guided by the objectives of examining the geological and geotechnical characteristics of the rocks, estimating the strength of the rocks. Field work carried out on the area revealed two major rocks to include granitic gneiss and gneiss. The granitic gneiss forms a massive and elongated ridge trending northeast-southwest for about 2.8 km while the gneisses occurred as low to flat lying rocks within the study area. Geotechnical and mineralogical evaluation of the rocks indicated that the rock mass quality ranged from fair to good, with the gneiss being the most competent but not widely exposed/outcrop compared to the granitic gneiss which is massive with close strength to the gneiss. Although, the little variation in these rocks are attributed to rock heterogeneity resulting from various mineralogical composition especially the alteration of the biotite and feldspar to chlorite and sericite respectively.

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