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Petrographic properties and physical-mechanical characteristics of Salang marbles located in Parwan province, Afghanistan

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Abstract

This research examines Salang marble's petrographic properties and physical-mechanical characteristics in Parwan province, Afghanistan. Situated in the western Hindu Kush zone, these marbles are part of the Afghanistan-North Pamir Folded Region, surrounded by faulted structural units.

Despite the lack of detailed information from the Afghanistan Geological Survey, including maps and reserve estimates, there has yet to be a comprehensive evaluation of the marble's quality, physical-mechanical properties, or material composition. Furthermore, research and exploration efforts in this area have been limited.

The paper aims to discuss and provide conclusions and suggestions regarding petrographic properties, mineral paragenesis, and physical-mechanical characteristics. The marbles predominantly comprise calcite, constituting around 99% of the composition. Spectrometry analysis reveals the presence of elements and oxides such as calcium, aluminum, iron, magnesium, sodium, silicon, and strontium.

The physical-mechanical properties of the Salang marbles, including specific gravity (2.70), bulk density (2.69 g/cm^3), marble durability index (98.52 MPa), and resistance to impact value (16.38 GPa) of marble aggregates, are analyzed.

This research involves collecting specimens from the mine area and conducting mechanical tests and petrographic studies following established norms and standards. The findings contribute to a better understanding of the Salang marbles and can inform future exploration and utilization of these valuable resources.

Keyword: Marble, petrographic, chemical, composition, spectrometer.

1. Introduction

This study focuses on the marble quarry in the Koklami area of Salang district, Parwan province. It aims to discuss the mineralogy, mineral paragenesis, and physical-mechanical properties of these rocks. Marbles are hard metamorphic rocks composed of calcite and dolomite. The formation of these rocks occurs through the crystallization of carbonate volumes under heat and pressure during geological processes (Bucher & Frey, 2002). This results in the formation of marble, characterized by a dense crystal structure and low porosity.

Marble's unique structural characteristics make it highly suitable for architectural and sculptural uses, offering various decorative possibilities (Siegesmund & Török, 2010). Its limited porosity, especially in polished form, makes it less susceptible to water-related damage (Toniolo & Poli, 2002). The transformation of calcium carbonate into marble leaves it vulnerable to various chemical agents such as chloride, nitrite, sulfate, and others (Basu, Orr & Aktas, 2020). Different sharpeners can affect aragonite and marble differently, necessitating attention to their specific characteristics during the production of various marble products.

Marble is generally classified into two types: calcite marble, with calcite as the dominant mineral, and dolomite marble, with dolomite as the primary mineral (Reedy, 2008). Dolomite marble exhibits more excellent resistance to chemical agents compared to calcite marble. The colour variation in marble stones is influenced by elements such as aluminum, magnesium, iron, etc. (Lazzarini, 2004). In the absence of water, iron oxide imparts a red or similar hue, while iron hydroxide results in brown or yellow colouration. Gray, bruised, or black shades are observed in marbles containing charcoal and manganese materials. Some marbles display streaks or foliation, while others are speckled or undulating.

It is essential to consider their mineralogy, mineral paragenesis, and physical-mechanical properties as they contribute to their overall characteristics and potential applications.

2. Research Goals:

The main objective of this research is to accurately evaluate the physical-mechanical properties and petrographic composition of the Salang marbles and explore their potential for effective utilization.

3. Research Methodology:

A combination of library research, fieldwork, and laboratory analysis was conducted to accomplish the research goals.

The library research involved studying geological information, reports, and archives related to Afghanistan's western Hindu Kush zone. The "Afghanistan Directorate of Survey and Geology" archives and resources available at the Polytechnic University library and private libraries were extensively explored. Unfortunately, no specific reports or documentation regarding the Salang marble mine in Parwan province were found in any of these sources. Therefore, this research represents the first scientific study on the Salang marble mine. Despite potential limitations due to the unavailability of expert teams, sufficient time, and additional security measures, it is hoped that future researchers and engineers will conduct further studies on this mine.

Field research involved on-site inspections of the quarry, studying the marbles and their associated rocks in the study area, and establishing their geological relationships. Various samples were collected during the fieldwork to enable petrographic studies and determination of the physical-mechanical properties of the marbles.

The laboratory component is the leading and crucial part of this research. Samples were carefully labelled and registered in the laboratory, followed by preparing thin sections from each rock sample for petrographic analysis. The study and examination of thin sections were conducted using the LEICA DM750P polarizing microscope from Germany.

Petrographic composition analysis of the rocks employed the spectrometry method, with two samples analyzed to determine their petrographic composition. Additionally, physical-mechanical properties such as specific weight, water absorption, aggregate abrasion, aggregate impact resistance, aggregate crushing value, and durability against sodium sulfate and magnesium sulfate solutions were determined to assess the quality of the marble aggregates.

These tests were conducted in private companies operating building material testing departments in Kabul, following the ASTM standards. The obtained results were compared with standard tables, leading to conclusive findings.

4. Research subject:

This research focuses on the "marble mine in the Koklami area of Salang district, Parwan province." Since the Salang marble is located within the Western Hindu Kush zone, the geological characteristics of this mine are examined by the broader geology of the Western Hindu Kush region. The sediments in the Western Hindu Kush zone exhibit variations in age and composition. The oldest sediments belong to the Proterozoic formations, known explicitly as Fulol member, which have a limited distribution. Additionally, there are dry and Sinozoic sediments present in the region.

Field samples were collected and analyzed as slides in the Department of Geological Survey and Mines within the Department of Geological Engineering and Mining Exploration. Due to the similar chemical composition of the mentioned marbles, only one slide was utilized for the study.

4.1. Description of Slide Number $M_{1\text{-}1}$:

The observed slide predominantly consists of acceptable to medium-grained calcite minerals, constituting up to 99% of the composition. There is a minimal presence of organic matter in the form of black spots. The particle size of this stone generally ranges from 0.2 to 1.5 mm. The schematic representation of this sample PPL (Plane polarized light) and XPL (Cross polarized light) is presented in Figure 1.

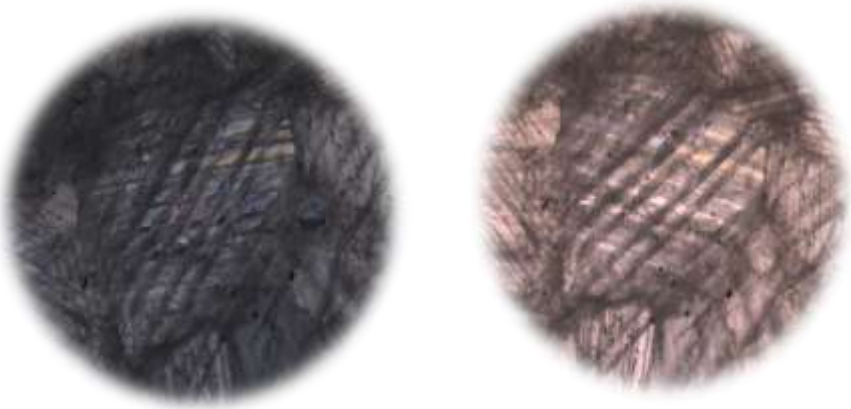

Fig 1: Zoom in of 10x10, Ø=2mm, displaying a massive texture, granoblastic structure, and identified as calcite marble.

Table 1: The macroscopic properties of the sample Number M_{1-1}

Macroscopic properties	
Degree of erosion	Low
Porosity	Very low
Reaction against acid (HCl)	Severe boils
Color	White

Table 2: Geological properties of sample number M_{1-1}:

Geological properties	
Sample name	Calcite marble
Petrographic class	Metamorphic rock
Geological formation	Metamorphic

4.2. Description of Slide Number M_{3-1}:

This particular slide exhibits a mineral composition including feldspar, quartz, calcite, muscovite, and biotite as primary constituents. Additionally, hornblende is present as a secondary mineral, and there are accessory minerals of various sizes. The schematic representation of this sample under Plane polarized and cross polarized light is presented in Figure 2.

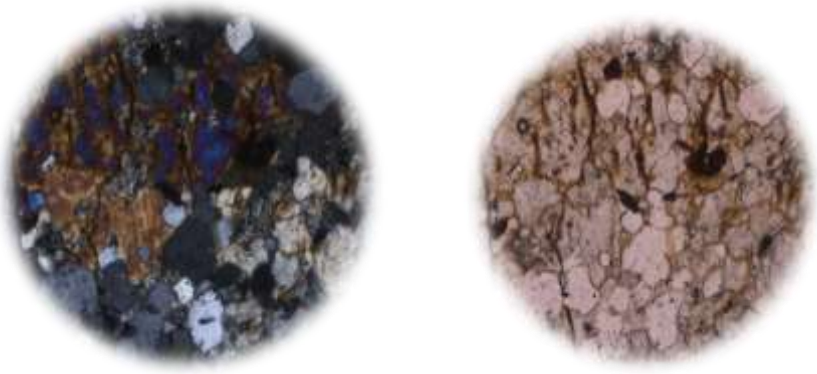

Fig 2: Displaying the mineral composition under PPL and XPL.

Zoom in of 10x10, Ø=2mm, displaying a massive texture and granoblastic structure, and identified as calcite marble.

4.3. Geochemical Analysis:

Geochemistry is concerned with the distribution, formation, and abundance of chemical elements in the Earth's crust. Various analytical techniques and instruments are employed to determine the elemental composition and percentage in geological samples. Two samples were collected from the marble mine in the Salang district for geochemical analysis using a spectrometer. The results are presented in Table 3.

Table 3: Geochemical Analysis Results.

No	Laboratory No	Field No	oxides	percentage
1	56	M_{1-3}	CaO	52.54
1	56	M_{1-3}	SiO_2	0.86
1	56	M_{1-3}	Al_3O_2	0.1
1	56	M_{1-3}	MgO	0.89
1	56	M_{1-3}	Fe_2O_3	0.08
1	56	M_{1-3}	P_2O_5	0.10
1	56	M_{1-3}	K_2O	0.003
1	56	M_{1-3}	Na_2O	0.54
2	56	M_{3-1}	CaO	23.99
2	56	M_{3-1}	SiO_2	42.41
2	56	M_{3-1}	Al_3O_2	3.14
2	56	M_{3-1}	MgO	0.99
2	56	M_{3-1}	Fe_2O_3	2.22
2	56	M_{3-1}	P_2O_5	0.30
2	56	M_{3-1}	K_2O	0.70
2	56	M_{3-1}	Na_2O	0.89

The analysis and spectrometric examination of the samples indicate that calcium oxides constitute a significant portion of the stone's composition. Additionally, minor amounts of aluminium, iron, magnesium, sodium, silicon, and strontium oxides are present in these marbles.

Therefore, the composition of these marbles can be classified as primary calcite. Aluminium and strontium oxides suggest the occurrence of clay materials in the marbles, although their proportion is negligible.

4.4. Physical and Mechanical Tests:

Similar to soil, stones possess pores that can be filled with water under certain conditions, leading to erosion and disintegration. Porosity also affects stones' compressive and tensile strength, directly influencing their mechanical properties and overall quality. To evaluate the physical-mechanical properties and suitability of Salang marbles from Parwan Province for construction materials and infrastructure., a series of mechanical tests were conducted following international and American ASTM standards. The results are presented in Table 4.

Table 4: Results of Physical-Mechanical Tests.

No	Test	description	Percentage (%)
1	Specific gravity, bulk density and water absorption according to the (ASTM D 6473) Standard	Water absorption	0.07 %
		Specific gravity	2.7
		Bulk density	2.69gr/cm^3
2	Resistance of salang marble agrigates by impact and percussions in Los Angeles device (ASTM C-131)	The average percentage of abrasion material	49.92 M pa
3	Durability (ASTM D 4644; Index slake durability)	Average durability	98.52 M pa
4	Aggregate impact value of Salang marble (BS-812 Aggregate impact value)	Aggregate resistance to impact	16.38 G pa
5	Determining the health of marble aggregates against sodium sulfate and magnesium sulfate	Erosional aggregates	6.82%

The durability index tests demonstrate that the marbles from the Salang district mine exhibit exceptionally high durability. According to the global standard table, an index above 98 megapascals falls within the category of extremely high durability. Notably, the durability index of Koklami marble measures 98.52 Megapascals. Therefore, the marbles from the Koklami mine in the Salang district are of outstanding quality from both petrographic and physical-mechanical perspectives, positioning them among the finest marbles worldwide.

5. Results and Suggestions:

The research on the marble of the Koklami area of the Salang district yielded the following outcomes:

1. Petrographic analysis and examination of the physical-mechanical characteristics confirmed that Salang marbles consist predominantly of calcite mineral, with negligible amounts of dolomite mineral.
2. Salang marbles exhibit variations in colour, with some being white and suitable for decorative and sculptural purposes, while others display a grey colour due to the presence of foreign minerals and occasional streaks. These marbles can be utilized for diverse construction applications.
3. It is noteworthy that Salang marbles are prone to significant cracking due to the pressures exerted during regional metamorphism, indicating limited suitability for block extraction.
4. The numerous marble mines in the Salang district possess high economic value, primarily due to their proximity to the paved Salang highway.

Suggestions:

1. Given the presence of numerous marble minerals in the Salang Valley, it is recommended to conduct comprehensive studies on these deposits and prepare detailed 1:25,000 scale geological maps for these areas.
2. Considering that all mines, including the marble mines in the Salang Valley, are national assets, it is advisable to implement measures to prevent unauthorized extraction by residents and influential individuals.
3. Marbles with white colour and suitable characteristics for sculpting and decorative purposes should receive significant attention and protection from the government.

6. Conclusion:

In conclusion, this study focused on the marble quarry in the Koklami area of Salang district, Parwan province, with the aim of evaluating the mineralogy, mineral paragenesis, and physical-mechanical properties of the marbles. The research findings revealed that the marbles in the Salang district predominantly consist of calcite mineral, with varying colors and characteristics. The marbles exhibited excellent durability, making them suitable for diverse construction applications.

The petrographic analysis and physical-mechanical tests conducted on the Salang marbles provided valuable insights into their composition and quality. The marbles displayed a range of colors, from white to gray, due to the presence of foreign minerals and occasional streaks. However, it was noted that the marbles are prone to cracking, limiting their suitability for block extraction.

The economic value of the marble mines in the Salang district is significant, mainly due to their proximity to the paved Salang highway. To further explore and utilize these deposits, it is recommended to conduct comprehensive studies and prepare detailed geological maps of the area. Additionally, measures should be implemented to prevent unauthorized extraction by residents and influential individuals, as these mines are national assets.

Marbles with white color and favorable characteristics for sculpting and decorative purposes should be given special attention and protection by the government. Overall, the Salang marbles from the Koklami mine demonstrate outstanding quality, both petrographically and in terms of their physical-mechanical properties, positioning them among the finest marbles worldwide.

In light of this research, future studies by researchers and engineers are encouraged to expand the knowledge and understanding of the Salang marble mine and its potential applications. By conducting further investigations, it is possible to unlock the full potential of these marbles and contribute to the development of the marble industry in the Salang district and beyond.

7. References:

1. Bucher, K., & Frey, M. (2002). Petrogenesis of metamorphic rocks. Springer Science & Business Media.
2. Siegesmund, S., & Török, Á. (2010). Building stones. In Stone in architecture: properties, durability (pp. 11-95). Berlin, Heidelberg: Springer Berlin Heidelberg.

3. Basu, S., Orr, S. A., & Aktas, Y. D. (2020). A geological perspective on climate change and building stone deterioration in London: Implications for urban stone-built heritage research and management. Atmosphere, 11(8), 788.

4. Reedy, C. L. 2008. "Thin-Section Petrography of Stone and Ceramic Cultural Materials." Archetype Publications, London.

5. Toniolo, L., Poli, T., Castelvetro, V., Manariti, A., Chiantore, O., & Lazzari, M. (2002). Tailoring new fluorinated acrylic copolymers as protective coatings for marble. Journal of cultural Heritage, 3(4), 309-316.

6. Lazzarini, L. (2004). Archaeometric aspects of white and coloured marbles used in antiquity: the state of the art. Periodico di Mineralogia, 73(3), 113-125.

7. Abdullah, S., and Chmyriov, V.M., editors, 2008, Geology and mineral resources of Afghanistan, Book 1, Geology: Ministry of Mines and Industries of the Democratic Republic of Afghanistan, Afghanistan Geological Survey, 15, p. 488. British Geological Survey Occasional Publication.

8. Risen, J. (2010). US identifies vast mineral riches in Afghanistan. New York Times, 13, 17.

9. Hofmann, P., Marschallinger, R., Unterwurzacher, M., & Zobl, F. (2013). Marble provenance designation with object based image analysis: State-of-the-art rock fabric characterization from petrographic micrographs. Earth Sci, 106(2), 73-82.

10. Attanasio, D., Armiento, G., Brilli, M., Emanuele, M. C., Platania, R., & Turi, B. (2000). Multi-method marble provenance determinations: the Carrara marbles as a case study for the combined use of isotopic, electron spin resonance and petrographic data. Archaeometry, 42(2), 257-272.

11. Attanasio, D., Bruno, M., Prochaska, W., & Yavuz, A. B. (2015). A Multi-Method Database of the Black and White Marbles of G öktepe (Aphrodisias), Including Isotopic, EPR, Trace and Petrographic Data. Archaeometry, 57(2), 217-245.

12. Antonelli, F., & Lazzarini, L. (2015). An updated petrographic and isotopic reference database for white marbles used in antiquity. Rendiconti Lincei, 26, 399-413.

13. Wahab, G. M., Gouda, M., & Ibrahim, G. (2019). Study of physical and mechanical properties for some of Eastern Desert dimension marble and granite utilized in building decoration. Ain Shams Engineering Journal, 10(4), 907-915.

14. Siegesmund, S., Weiss, T., Vollbrecht, A., & Ullemeyer, K. (1999). Marble as a natural building stone: rock fabrics, physical and mechanical properties. Zeitschrift der deutschen geologischen Gesellschaft, 237-257.
15. ASTM C503 / C503 M-10 ; Standard Specification for Marble Dimension Stone.
16. ASTM C97 / C97 M Test Methods for Absorption and bulk Specific Gravity of Dimension Stone.
17. ASTM C170 / C170 M Test Methods for Compressive Strength of Dimension Stone.
18. ASTM D3148 / D1348 M. Test Methods for Elastic Moduli of Intact Rocks.
19. ASTM D4644 / C4644 M. Test Methods for Slake – Durability Index.

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