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Petrographic Composition, Physico-Chemical Characteristics, And Mechanical Properties of The Renzikhel Marbles In Central Afghanistan

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ABSTRACT

This article presents the geological and engineering geological characteristics of Ranzi Khel marbles. The Ranzi Khel mine is located in Maidan Wardak province. Geologically, it lies within the Helmand tectonic zone. To achieve the objectives, several samples were collected from different sites of the marble areas and transported to laboratories in Kabul city. Several slides were prepared from representative samples to characterize the petrographic composition under a polarizing microscope. The preliminary chemical composition of marbles was determined through X-ray Fluorescence (XRF) analysis. The physical and mechanical characteristics of marbles were assessed using various physico-mechanical tests. The petrographical study indicates that calcite is the main mineral in the slides. The physico-mechanical tests show that the specific gravity is 2.7, the bulk density is 2.7, the water absorption is 0.02%, the marble's resistance to impact and pressure is 13.67%, the marble's resistance to abrasion is 26.13%, and the marble durability index is 97.39%. The findings indicate that the marble samples exhibit excellent resistance to uniaxial compression and point load, with a durability of 97.49%. The results show that Ranzi Khel marbles are considered quite satisfactory for various applications from a physico-mechanical perspective. The results of the XRF analysis indicate that calcium has the highest proportion among the elements. Besides calcium, Ranzi Khel marbles also contain magnesium, iron, silicon, and aluminum. The findings of this study may contribute to sustainable mining development in Afghanistan in various ways.

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INTRODUCTION

Although marble is widely used in various construction applications, no research has been conducted in this field (Sahak, 2012). This research focused on determining the geological-petrographic and physical-mechanical characteristics of Ranzi Khel marbles.

In Afghanistan, large marble mines are located in various parts of the country, including the Chesht-e-Sharif marble in Herat province, the Afghan-White and Kama mines in Nangarhar province, the Khair-khana marble, the Tarakhel marble, the Kezag and Pul-e-Charkhi marble mines in Kabul province, the Salang marble in Parwan province, and some

other marble mines. Afghanistan is one of the largest marble-producing countries in the world, with many companies operating domestically and internationally in the production and processing of marble (Behzad, 2018).

It is worth mentioning that the petrographical and physico-mechanical characteristics of some marbles, such as Mullah Rum marble in Punjab district of Bamyan province (Behzad, 2018), marbles of Salang district of Parwan province of Kabul (Azimi et al., 2023), Kama district of Nangarhar province, black marbles of Gazak, Khak Jabbar district of Kabul province, and Anjirk marbles of Shakardara district of Kabul province have been studied in the past recent years (Behzad et al., 2022; Zia, 2019; Waizy et al., 2025). However, Ranzi Khel marbles have not yet been studied. Therefore, it is important to investigate the geological and engineering geological characteristics of the Renzi Khel marble mine.

Several researchers have applied various approaches, such as petrographic analysis, XRD-XRF analysis, and physico-chemical analysis (Hussain et al., Javid et al., 2022; Ali Shah et al., 2022). Javid et al. (2022) and Ali Shah et al. (2022) studied the physico-mechanical properties and mineralogical composition of Nikana Cave limestone, KPK. Mechanical properties of marbles are commonly determined in the laboratory (Mohammadi et al., 2022). Brilli et al. (2018) studied the lithography and mineralogical composition of white marble and black rock from Göktepe, Muğla, Turkey. Emami et al. (2014) investigated the marbles of the Jiroft and Shahr Sokhteh regions using XRD-XRF and petrographic analysis. Lvanovna (2020) determined the concentrations of fluoride, sulfur, and chloride in calcite-rich limestone and marble. Badouna et al. (2020) evaluated the petrological and geochemical characteristics of Greek carbonate rocks.

The Ranzi Khel marbles of Sayed Abad are located 30 km south of Maidan Wardak city. Their chemical, mineralogical, petrographic, physical-chemical, and geological characteristics have not yet been studied (Ministry of Mines and Petroleum, n.d.). The objectives of this research are:

- To investigate the geological, petrographic, and mineralogical characteristics of the Ranzi Khel marbles in the Sayed Abad district of Maidan Wardak province, Central Afghanistan.
- To determine the physical and mechanical characteristics of the Ranzi Khel marbles.

The study will answer to following research questions;

1. What are the key geological and mineralogical characteristics of marbles in the study area?
2. How do physical and mechanical properties vary by location/depth?

METHODS AND MATERIALS

To conduct this study, relevant articles and available sources were reviewed. A field visit was conducted to assess the site geologically, and sampling points were identified. In laboratory studies, particularly petrographic studies, the rock material composition is of interest. Several samples were taken according to geological profiles and transported to laboratories in Kabul. For the chemical composition of rocks, chemical methods are usually used. In this research, an XRF machine was used to determine the chemical composition of Renzi Khel marbles. XRF is a non-destructive, fast approach for determining the chemical composition of rocks. The marble samples were crushed and ground into fine powders. The prepared samples were placed in the XRF spectrometer, where they were irradiated with primary X-rays. Prior to analysis, the instrument was calibrated using certified reference material to ensure accuracy. The data were reported as parts per million.

To determine the mineral composition of the studied rocks, thin-section slides were prepared from the collected samples. First, the rock samples were cut into small blocks using a diamond saw. The samples were then ground flat on one side and glued to a glass slide using epoxy. After the adhesive cured, the samples were cut to approximately 30 micrometers thick using a grinding machine at the Afghan Geological Survey. Afterward, the section is further polished to smooth the surface for optical analysis under a polarized microscope in Kabul Polytechnic University. Crystal optics is one of the main methods for studying the petrographic characteristics of rocks, during which the mineral composition of the rocks (significant, minor, accessory, and secondary minerals) is determined, and their texture and structure are revealed (Sahak, 2012; Musazai, 2017).

Due to the absence of physical and mechanical testing equipment at Kabul Polytechnic University at that time, the samples were transported to Afghanite Company to determine their physical and mechanical characteristics. In the Afghanite Company, the following marble parameters were determined in accordance with ASTM standards: durability index, specific weight, volumetric weight, water absorption, point load resistance, and abrasion resistance. Finally, a comprehensive interpretation of laboratory data was conducted to determine the overall geological characteristics of Renzi Khel marbles.

Study area and geological setting

Ranzi khel mine is geologically located in the Helmand tectonic zone (Firoz, 1357), which is one of the structures of the old Alpine folding phase. From a geological perspective, it lies in the south of the Hindu Kush, within the upper and middle parts of the Helmand and Arghandab blocks. The phase of the young Alpine folding is also directly bordered by the Helmand Block (Musazai et al., 2019; Firoz, 1357). The location of the Ranzi Khel marble quarry is shown on the geological map of Maidan Wardak province (Figure 1).

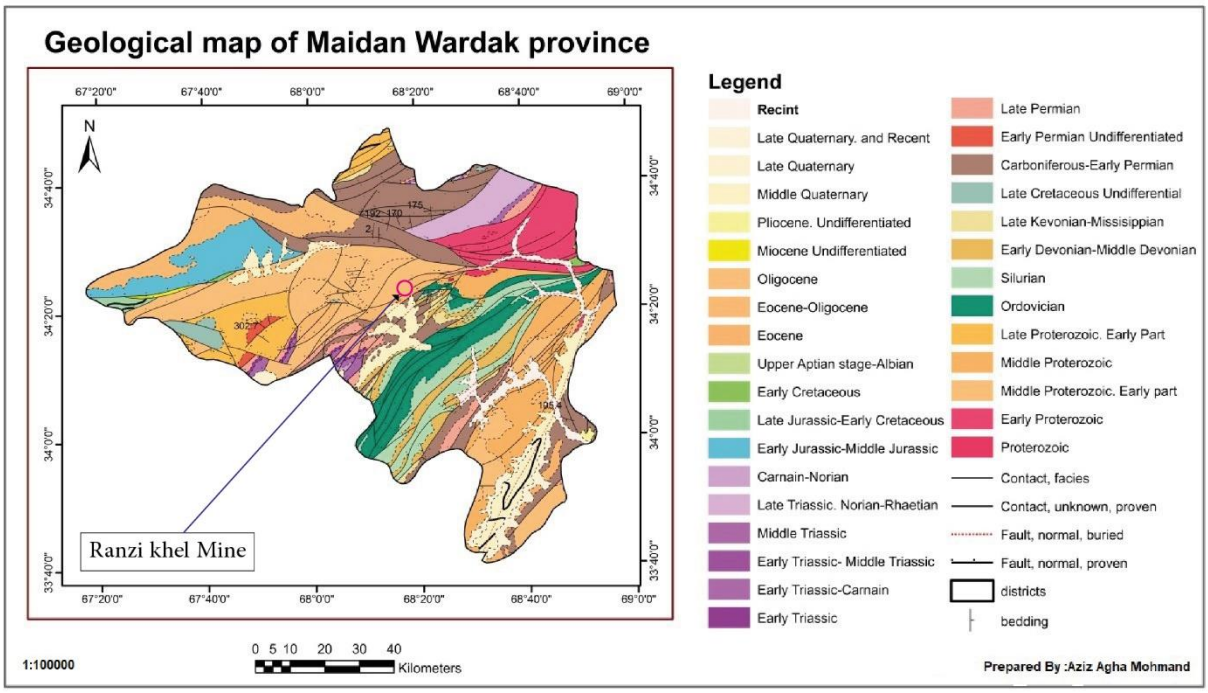


Figure 1. *Geological map of Ranzi Khel marble mine*

Ranzi Khel mine is located in Maidan Wardak province, in central Afghanistan at 68° 86' 83" longitudes and 34° 39' 45" latitude and an elevation of 2210 meters above sea level.Maidan Wardak is one of the country's central provinces. Maidan Shahr is the center of Maidan Wardak province, located about 35 kilometers southwest of Kabul city (Khpalwak, 2016). The distance from Ranzi Khel marble quarry to Maidan Shahr is about 30 km, and the quarry is located in the southwest of Maidan Shahr. The distance from the quarry to Sayed Abad district is approximately 7 km.The Ranzakhel. Baraki Barak district of Logar province is located on the east side of the quarry, and Hazira village is located on the west side. On the north side of the quarry, secondary roads and agricultural lands are located. An access gravel road has been constructed from the secondary road to the quarry site, and its length is about 1 kilometer. The quarry site landscape is shown in Figure 2.

Figure 1. *Showing the Ranzi Khel marble quarry (quarry No. 1)*

Data Collection

We conducted a comprehensive literature review and collected related data from the Ministry of Mines and Petroleum. Besides collecting secondary data, we collected many samples from various locations of the Ranzi Khel marble mine to investigate the geological and engineering geological characteristics of the marble.

Field Investigation

We visited the Ranzi Khel marble quarry site, studied its general geological structure, and measured the dip azimuths and dip angles. After visiting the study area and specifying the route, we selected the profiles for sample collection. Totally, we selected two profiles in the study area: profile A along the marble quarry and profile B adjacent to the rocks. From profile A, five marble samples. The sample was taken from sampling point 1 of profile A, which was numbered A-1, and the other samples were numbered accordingly. The color of almost all marble samples was grayish-white. Various parameters of the quarry, such as length, width, thickness, and joint characteristics, were measured in the field. Samples from adjacent rocks in profile B were also collected during the site investigation. Geological tools such as a geological hammer, compass, GPS, heavy hammer, and meter were used for measurements and sampling.

Laboratory Work

Numerous samples were collected to study the petrographic and physical-mechanical properties of the Ranzi Khel marbles. Later, the collected samples were transferred to the laboratories of the Afghan Geology Survey (AGS) of the Ministry of Mines and Petroleum for slide preparation and XRF analysis.

Petrographic Analysis

The samples were transported to the AGS for slide preparation and XRF analysis. The steps of slide preparation include cutting, initial polishing, mounting the specimen on a glass slide, grinding, and initial thinning. After slide preparation, microscopic studies were carried out at the petrographic laboratory of the Geological Engineering and Exploration of Mines department at Kabul Polytechnic University. The microscopic studies included the determination of major, minor, accessory, and secondary minerals; the size of these minerals; their mutual relationships; texture, structure, and conoscopic shape.

XRF Analysis

The samples were transported to the AGS for XRF analysis. In total, eight samples were analyzed using an XRF machine in the Afghan Geological Survey. At first, the stone samples were ground into powder, and the powders were prepared for XRF analysis. The testing time for each sample was 3 to 5 minutes, and the chemical composition of elements was presented in ppm units. After test completion, the analysis was downloaded from the XRF machine using a laptop.

Physical and Mechanical Testing of Marbles

A sufficient quantity of samples was collected from the quarry site and transported to the rock mechanics laboratory of Afghanite Geo & Mining Engineering Company in Kabul for determining the physical and mechanical characteristics of the Ranzi Khel marbles. Physical and mechanical properties of Ranzi Khel marbles, such as durability index, specific gravity, bulk density, compressive strength, water absorption, point load resistance, and abrasion resistance, were determined in the laboratory according to ASTM standards.

Petrographic Studies

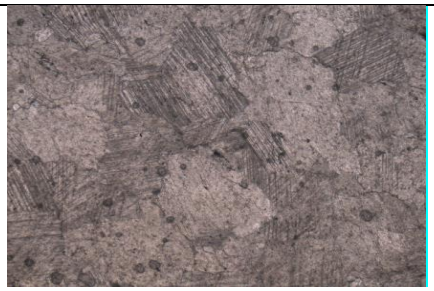
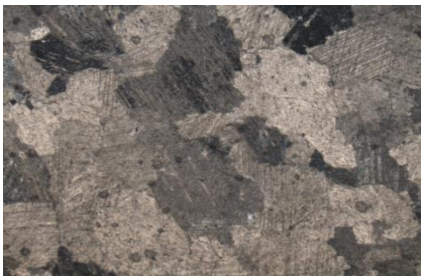
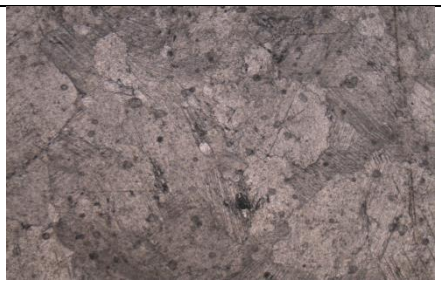
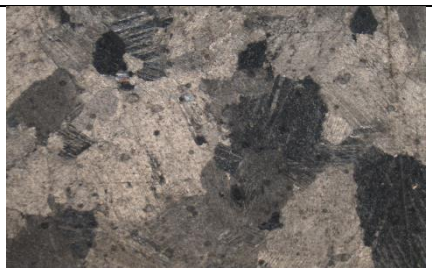
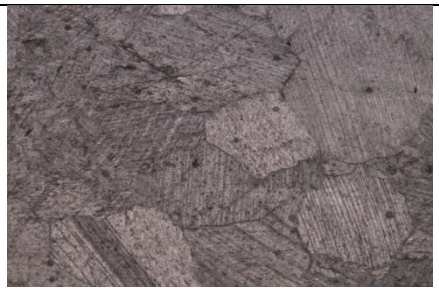
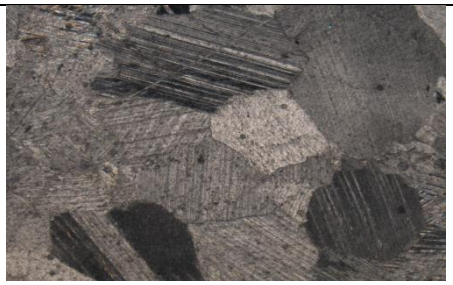
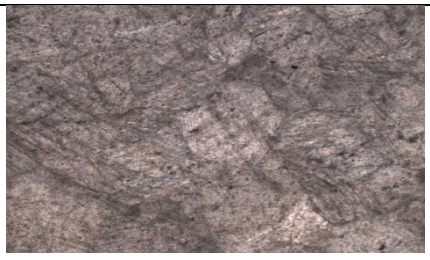
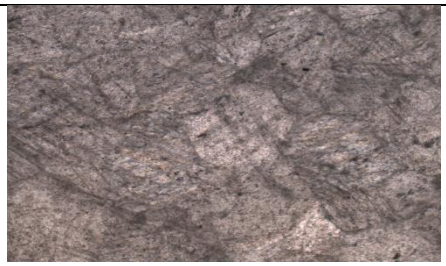
Slides were prepared from field samples collected at the Ranzi Khel quarry in the laboratory of the Afghan Geological Survey and studied under a polarizing microscope. The results of microscopic studies indicate that these marbles are monomineralic, with calcite widely distributed and visible throughout the entire slide area. In addition to calcite, phlogopite and magnetite are observed. The presence of minerals such as iron oxides in marble can significantly change its color.

FINDINGS

The results indicate that calcite is the dominant mineral in Ranzi Khel marbles. In addition to calcite, phlogopite, and magnetite, black particles are widely distributed throughout the slides. These particles are organic materials present in the composition of the carbonates and have caused the change from white to grayish color in the Ranzi Khel marbles. The components in these samples are almost equal and isometric. The marble rocks have a granuloblastic structure, and the texture of these samples is a mass texture, as shown in Figure 2.

Petrographic Composition and Microscopic Properties

In the petrographic studies of the rocks that I made from those slides, I first studied under a microscope more on the mineral composition, major minerals, minor, accessory minerals, and secondary minerals, mineral size, mutual relationships of these minerals with each other, texture, structure, secondary changes, conoscopic shapes, etc., and their microscopic characteristics. Microscopic images of the various slide preparations are shown below.

Under one-Nicol	Under two-Nicol
	
	
	
	

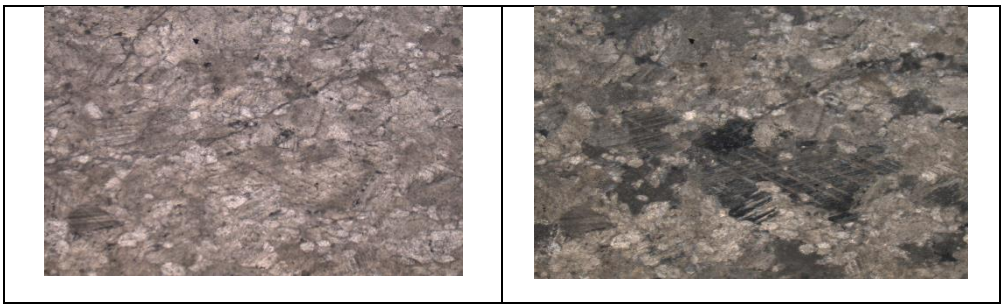


Figure 1. *Microscopic photograph of slide A-1*

The thin-section slides were prepared from collected samples of the Ranzi Khel mine at the laboratory of the Afghan Geological Survey. The thin-section slides were studied under a polarizing microscope at the Department of Geological Engineering and Exploration of Mines, Kabul Polytechnic University.

The analysis indicates that these marbles are monomineralic, with calcite widespread and observed throughout the slide area. Next to the calcite mineral, the minerals phlogopite and magnetite are observed. Iron oxides are present as minerals in the rock, and their presence has caused color changes in the marble.

The components in the samples are almost equal and isometric, so based on this, it can be said that the rock's structure is granoblastic and the sample's texture is a mass texture.

Table 1. *Microscopic characteristics of slide A-1*

Test	Description				
	Sample A-1	Sample A-2	Sample A-3	Sample A-4	Sample A-5
Specimen name	Calcite Marbles	Calcite Marbles	Calcite marbles	Calcite Marbles	Calcite marble
Petrographic class	Metamorphic Rock	Metamorphic Rocks	Metamorphic stones	Metamorphic Rocks	Metamorphic stones
Geological formation	Metamorphic	Metamorphic	Metamorphic	Metamorphic	Metamorphic
Color	Grayish White	Grayish White	White-grained	Grayish White	White with black veins
Structure	Granoblastic	Granoblastic	Granoblastic	Granoblastic	Granoblastic
Texture	Cateloy	Cateloy	Cateloy	Cateloy	Cateloy
Main mineral	Calcite	Calcite	Calcite	Calcite	Calcite
Associative mineral	Phlagopite	Magnetite and Phlogopite	Magnetite and Phlogopite	Magnetite	Phlogopite and organic matter
Synthesis	Organic Matter	Organic Materials	No	Organic Materials	Organic Materials
Acid reaction	Highly Effervescent	Highly Effluent	Strongly molten	Highly Effluent	Highly effervescent
Specific gravity	2.70	2.70	2.70	2.70	2.70

XRF analysis

Five rock samples from Ranzi khel marbles and three rock samples from adjacent rocks were collected, prepared, and analyzed in the Afghan Geological Survey laboratory using an XRF machine. The testing time for each sample was about 3 to 5 minutes, and the chemical

composition of the sample is presented in ppm. After the test was completed, the results were downloaded from the device to the computer. The results of XRF analysis are presented in Table 2.

Table 2. *The results of XRF analysis of rock samples*

Element	Sample No.1 (PPM)	Sample No.2 (PPM)	Sample No.3 (PPM)	Sample No.4 (PPM)	Sample No.5 (PPM)
Bal	496748.78	516372.69	502176.16	504033.44	499444.94
Ca	479313.06	461794.84	476666.84	467087.44	460640.75
Si	10537.51	11326.68	11484.16	14672.38	9178.04
Al	7040.35	4250.46	3312.85	6036.98	3628.74
Fe	1150.63	1077.39	1066.29	1864.75	953.01
K	853.39	712.10	636.62	1488.09	499.19
S	1660.19	1534.45	1879.39	1444.14	1524.41
Mn	208.14	182.56	189.87	239.91	174.63
Sr	107.54	232.01	113.83	114.523	227.87
Ti	197.70	132.16	162.72	336.74	140.15

Physico-mechanical characteristics

The physical and mechanical properties of marbles from the Ranzi Khel area are presented in Table 3. The color is one of the factors that can significantly impact the economic value and marketability of marbles, as the Ranzi Khel mine produces mostly white, grayish, and off-white marbles. We need to understand the reasons for this. One of the reasons that can make the color of these marbles appear grayish white and white with a hint of white is the presence of organic materials that are part of the composition of the original carbonate rocks of the marbles, because marbles are metamorphic rocks that are formed as a result of the recrystallization of carbonate sedimentary rocks under pressure and heat.

The results obtained from mechanical tests of the Ranzi Khel marbles in Maidan Wardak province are considered quite satisfactory. The marbles have excellent resistance to uniaxial compression and point load, and high durability.

Table 3. *Physical and mechanical characteristics of Ranzi Khel marbles*

No	Test	Method	Description	Minimum	Maximum	Average
1	Specific gravity, bulk density, and water absorption of Ranzi Khel marble aggregates	ASTM D-6473	Water absorption	0.02%	0.02%	0.02%
			Special gravity	2.70	2.70	2.70
			Bulk density	2.70gr/cm^3	2.70gr/cm^3	2.70gr/cm^3
2	Resistance of Ranzi Khel marble aggregates by impact in the Los Angeles apparatus	ASTM C – 131	The average Percentage of abrasion material	26.13	26.13	26.13%
3	Slake Durability	ASTM D-4644	Average durability	97.42	97.56	97.49%
4	Aggregate impact value of Ranzi Khel marble	BS-812	Aggregate resistance to impact	13.44	13.90	13.67%
5	Point load resistance of Ranzi Khel marbles	ASTM D–5731	Average	3.12	3.42	3.23 MPa
6	Uniaxial unconfined compressive strength (USC) of Ranzi Khel marble	ASTM C-170	Average	42.99	101.65	75.95 MPa

DISCUSSION

The samples were collected from the Ranzi Khel marble quarry to determine physical-mechanical characteristics and characterize the petrographic properties of Ranzi Khel marble. Sampling and laboratory analyses were conducted in accordance with international standards. Petrographic analysis of Ranzi Khel marble indicates that it mainly consists of calcium carbonate ($CaCO_3$), with nearly 99% of the calcite mineral present in the Ranzi Khel marble quarry. However, other minerals, such as phlogopite, magnetite, and iron, are also observed in the mineralogical composition of this rock. It indicates that the Ranzi Khel marbles are softer than dolomitic marble in terms of hardness. The marble is primarily white, making it remarkably suitable for various applications. The mineralogical and chemical compositions of the Ranzi Khel marble quarry are relatively similar to those of the Kunar marble deposits (Waizy et al., 2025).

The results of the XRF chemical analysis show that it has the highest proportion of calcium. In addition to calcium, marble contains magnesium, iron, silicon, and aluminum. It indicates that the marble quarry at Ranzi Khel can be included among Afghanistan's high-quality marbles.

As shown in the results table for the chemical composition test of Ranzi Khel marble, this rock contains more than 45 chemical elements. The quantities of chemical elements in the table differ. Only a few limited elements play an important role in the chemical composition of this rock. The elements with the highest percentages are calcium, iron, silicon, and

ammonium. The remaining forty or so elements included in the chemical composition of this stone have a negligible percentage. Therefore, the aforementioned elements, given their quantity, cannot have a significant effect on the properties and characteristics of Ranzi Khel marble.

A large percentage is allocated to elements located in the upper parts of Mendeleev's table. These elements may include gases, light metals, and other non-metallic elements. Heavy metal elements, which are in the transition element group, are included in a negligible percentage in the composition of the aforementioned rock. Only five out of the 45 elements in the table, only five elements such as calcium, magnesium, iron, silicon, and ammonium, have the highest percentage. Among these five elements, the only one with a higher percentage is calcium, whose average in the tested samples exceeds 40 percent. Therefore, we can say that calcium carbonate mineral plays a dominant role in this rock.

On the other hand, calcium is one of the important elements of the calcite mineral; therefore, it is known that, in the composition of this rock, along with the presence of other minerals, calcite is widespread. The Afghan marble industry has suffered from a lack of investment and limited access to international markets (Rafi et al., 2024). However, in the past few years, access to international markets has improved, and several national and international investors have invested in the country's marble mines.

Conducting physical and mechanical tests in private companies is expensive. In addition, there are no advanced laboratories in Afghanistan capable of conducting mineralogical and isotopic analysis.

CONCLUSION

A multi-parameter approach was applied to determine the geological characteristics of Ranzi Khel marbles. The petrographic analysis revealed that all marble samples from the Ranzi Khel mine are monomineralic (calcite) in composition, with other minerals such as phlogopite and magnetite present as small black particles on the slide surface. The chemical composition of Ranzi Khel marble showed results consistent with those of petrographic studies. The chemical composition of Ranzi Khel marble indicates that it contains calcium, iron, magnesium, silicon, and aluminum. Overall, calcium, as a fundamental element, averages about 40 percent, and the quantities of iron, magnesium, silicon, and aluminum are very low. The research findings indicated that the constituent particles are almost equal in size, circular, and isometric in shape. The structure of Ranzi khel marbles is granoblastic, with a primarily massive texture. In terms of physical-mechanical properties, the marbles of the Ranzi Khel area have a specific gravity of 2.7, a bulk density of 2.7 gr/cm^3, water absorption (0.02%), resistance of marbles to impact and pressure (13.67%), and resistance of marbles to abrasion (26.13%). The marble's durability index is 97.39%. The findings of this research indicate that the marble deposit at Ranzi Khel can be classified as among the country's high-quality marbles.

RECOMMENDATIONS

1. Environmental studies should be conducted before any work on the mine begins.
2. It is recommended that exploration reports and mining extraction plans prepared by private companies should be reviewed and approved by a team of experts.
3. It is recommended that the government, in collaboration with national and international investors, establish commercial factories in provinces with high-quality, valuable mineral resources.
4. After the mine is extracted, the mining site must be restored appropriately in accordance with national and international standards.

AUTHORS CONTRIBUTIONS

Aziz Agha Mohmand: conceptualization, methodology, data curation, software, formal analysis, visualization, writing – original draft, writing-reviewing & editing. Abdulhalim Zaryab: methodology, formal analysis, conceptualization, validation, supervision, writing, reviewing, and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

All study data are included in the paper.

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ASTM(D6473): Standard Test Method for Density ،Relative Density (Specific Gravity) and Absorption of Coarse Aggregate.

ASTM C-170): Standard Test Method for Compressive Strength of Dimension Stone.

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