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INVESTIGATION OF THE POSSIBILITY OF USING GRANITE RAW MATERIAL FROM THE BİLECİK-BOZUYUK REGION IN TWO- COMPONENT SYSTEMS AT 1050°C, 1100°C AND 1200°C TEMPERATURES IN GLAZING RECIPES

BİLECİK-BOZÜYÜK BÖLGESİ GRANİT HAMMADDESİNİN 1050°C, 1100°C VE 1200°C SICAKLIKLARDA İKİLİ SİSTEMDE SIR REÇETELERİNDE KULLANIM OLANAKLARININ ARAŞTIRILMASI

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Abstract
Natural stones and ceramic materials have played various roles throughout human history in architecture, art, and daily life practices, serving as significant components of cultural heritage and technological advancement. In parallel with modern technological developments, ceramic production has increased, and this led to the rapid depletion of natural raw material resources. Within this context, the exploration and reassessment of alternative raw material sources in line with sustainability principles have become increasingly important. Granite rocks are considered promising alternative raw materials for the ceramic industry due to their appropriate chemical composition and the presence of minerals such as feldspar, quartz, mica, and amphibole. This study examines the potential application of naturally occurring granite from the Bozüyük district of Bilecik Province in ceramic glaze compositions. Although this granite is currently used as a filling material in the construction sector, it remains underutilized in the ceramic industry. However, the Bilecik District possesses rich and diverse mineral deposits, offering significant potential for the use of local resources in ceramic technologies. During the research, the chemical and mineralogical properties of the granite were analyzed, and the material was combined with fluxing agents such as boric acid, borax decahydrate, colemanite, ulexite, and sulyen (Red Lead Pb_3O_4) to create binary systems. Standard glaze formulations containing kaolin, quartz, boric acid, and borax decahydrate were applied to red and white ceramic bodies, and firing tests were conducted at 1050 °C, 1100 °C, and 1200 °C. The findings reveal that Bozüyük granite is technically viable for use in ceramic glazes and presents an environmentally sustainable, locally sourced alternative raw material for the industry.

Keywords: Granit, Ceramic, Glaze, Raw Material, Bilecik, Bozüyük, Turkey.

Öz
Doğal taşlar ve seramik malzemeler, insanlık tarihi boyunca mimari, sanat ve gündelik yaşam pratiklerinde çeşitli işlevler üstlenmiş; kültürel birikimin ve teknolojik ilerlemelerin önemli bir bileşeni olmuştur. Günümüzde teknolojik gelişmelere paralel olarak seramik üretimi artmakta; bu üretim artışı, doğal hammadde kaynaklarının hızla tükenmesine yol açmaktadır. Bu bağlamda, sürdürülebilirlik ilkeleri doğrultusunda alternatif hammadde kaynaklarının araştırılması ve yeniden değerlendirilmesi giderek daha büyük önem kazanmaktadır. Granit kayaçları, içerdikleri feldspat, kuvars, mika mineralleri ile uygun kimyasal bileşimleri sayesinde seramik endüstrisinde potansiyel bir alternatif hammadde olarak değerlendirilmeye elverişlidir. Araştırma kapsamında Bozüyük ilçesinde doğal olarak bulunan granit hammaddesinin seramik sır bünyelerinde kullanım potansiyeli incelenmiştir. Granit hammaddesi inşaat sektöründe dolgu malzemesi olarak kullanılmakta olup, seramik endüstrisinde yeterince değerlendirilmemiştir. Ancak Bilecik yöresi, sahip olduğu zengin ve çeşitli mineral yatakları sayesinde, seramik teknolojilerinde yerel kaynak kullanımına yönelik önemli bir potansiyel barındırmaktadır. Araştırma sürecinde, granit hammaddesinin kimyasal ve mineralojik özellikleri belirlenmiş; bu hammadde, ikili sistem oluşturacak şekilde borik asit, boraks dekahidrat, kolemanit, üleksit ve sülyen gibi ergiticilerle birlikte kullanılmıştır. Kırmızı ve beyaz seramik bünyeler üzerinde 1050 °C, 1100 °C ve 1200 °C sıcaklıklarında pişirme denemeleri gerçekleştirilmiştir. Elde edilen bulgular, Bozüyük granitinin seramik sırlarında teknik açıdan kullanılabilirliğini ortaya koymakta ve bu hammaddenin sektöre çevresel açıdan sürdürülebilir, yerli bir kaynak alternatifi sunabileceğini göstermektedir.

Anahtar Kelimeler: Granit, Seramik, Sır, Hammadde, Bilecik- Bozüyük, Türkiye.

* *This article is derived from the master's thesis entitled "Investigation of the Utilization Potential of Granite and Feldspar Raw Materials from the Bilecik–Bozüyük Region and Boric Acid and Borax Decahydrate Wastes from Eti Maden in Glaze Bodies"*

INTRODUCTION

More than 2.000 types of minerals are known to exist in the Earth's crust, with different crystal structures and compositions (Yüzer et al., 2008, p. 37). Among the magmatic rock minerals that first undergo alteration under weathering conditions are granites, gneisses, feldspars, and pegmatites. The transformation of these primary rocks occurs through the influence of water, wind, glaciers, carbon dioxide, humic acids, and, at times, sulfuric and hydrofluoric acid gases at high temperatures (Sümer, 1990, p. 10). Granite is a type of igneous rock with a granular structure composed of hard, crystalline minerals and occurs naturally in the environment (Kazanbaş, 2022, p. 6). Granite, one of the second most important natural stones after marble in the natural stone group, is of plutonic igneous origin and has an acidic composition (MTA, 2018, p. 18). It generally forms deep within the Earth's crust, slowly crystallizing under high temperature and pressure. Granite is composed of feldspar, quartz, and mica minerals, and this gives it a durable and hard structure. Structurally, granite has a coarse-grained texture and is widely used as a building material in the construction industry.

The mythological significance of granite is exemplified by the narratives found in the Karaçay-Malkar Nart epics. These epics recount that Sosurka was born from a granite stone; granite is treated as a symbol of strength and resilience (Nartla, 1995, p. 290; Tavkul, 2001, p. 187).

In addition to mythological narratives, archaeological findings have revealed that granite has been one of the oldest raw materials used for decorative purposes throughout history. It was widely preferred in architectural and artistic structures in ancient civilizations, and it has also maintained its significance as a building material throughout history with its aesthetic appearance, durability, and workability. However, granite was not used in architectural structures by the Mesopotamians or the Greeks in ancient times. This was due to the lack of technological equipment during those periods that would have failed to process granite.

A true transition to quarrying began with the start of operations in the granite quarries in the Aswan region of Egypt (Waelkens et al., 1988, p. 12; Ay, 2017, s. 4). Throughout history, granite has been an important building material, especially favoured in artistic and monumental architecture. Since ancient times, the Egyptians and Romans used granite in architectural structures due to its durability and aesthetic qualities. Granite was used in the construction of the city of Perge in 1550 BCE, in the Theodosius Obelisk around 1200 BCE. Granite was also a significant building stone in the construction of the Great Wall of China (Kum, 2025, p. 8).

These examples demonstrate that granite has historically been used as an important building material both functionally and symbolically. Granite has a significant place not only as a construction stone but also as a symbol of humanity's engineering and artistic development. Its durability, aesthetic appeal, and longevity have made it a preferred material throughout history. Granite has provided solid foundations for structures and served as a medium of aesthetic value in the creation of artistic works. Granites come in a variety of color tones depending on differences in their chemical composition. They have a wide range of colors, from gray-white to gray, gray-green, brown, and red. In addition, due to their formation characteristics and chemical composition, granites are among the rocks that show high resistance to acids (Gündüz, 1995, p. 106). Turkey possesses approximately 40% of the world's natural stone reserves with 5.1 billion m^3 of mineable marble, 2.8 billion m^3 of mineable travertine, and 1 billion m^3 of granite reserves (Erol & Pekdemir, 2022, p. 28).

Granite formations and potential reserves can be found in the provinces of Ordu, Rize, Trabzon, Balıkesir, Çanakkale, Kırklareli, Kırşehir, Bolu, İzmit, Aksaray, Gümüşhane, İzmir, Yalova, Kütahya, Bursa, and Niğde (Türkiye Cumhuriyeti Ticaret Bakanlığı, 2021, p. 2).

Characteristics of the Bilecik-Bozüyük District Granite Raw Material

Bilecik Province is located in the southeastern part of the Marmara Region and, due to its strategic position, it shares borders with the Marmara, Black Sea, Central Anatolia, and Aegean regions. Geographically, it borders Kütahya to the south, Bursa to the west, Sakarya to the north, and Bolu and Eskişehir to the east.

The foundation of Bilecik province consists of Paleozoic (I. Era) metamorphic masses, such as gneiss, schist, and marble, there are intrusions of granite (Türkiye Cumhuriyeti Başbakanlık Köy Hizmetleri Genel Müdürlüğü, 1998, p. 12). In the Bozüyük (Eskişehir) area of the Bursa-Bilecik series, Jura-aged units have been studied. In this area, highly altered Middle Sakarya granite has been observed, intersected by pegmatitic and aplitic dikes (Altıner et al., 1991; Kayacı, 2007, p. 53).

The granite raw material extracted from the Bozüyük district of Bilecik province is currently primarily used in the construction sector in sand form to meet the demand for filling material. However, due to their mineralogical and chemical composition, these raw materials are also suitable to use in the ceramic industry. This makes it possible to utilize these resources in a way that offers higher added value beyond their current applications. In this context, the main objective is to examine the potential use of these raw materials in ceramic glaze compositions.

The mining site from which the granite samples were obtained in the study is located along the Bursa-Eskişehir highway, within the borders of the Bozüyük district. The licensed area of the mining site is 160 hectares, the permitted operating area is 24.5 hectares, and the area currently in active use is 4.5 hectares. However, at present, no detailed reserve measurement has been conducted for the site. The granite deposit from which the raw material extracted is shown in Figure 1, 2.

Figure 1. Image of aerial view of granite quarry and extracted raw material in Bozüyük/Turkey (Google Earth, 2024).

Figure 2. Granite quarry and extracted raw material in Bozüyük/Turkey (Kum, 2024).

The chemical analyses of the granite raw material have been determined based on the XRF results, and the weight percentages are shown in Table 1.

Table 1. XRF chemical analysis results of granite raw material from the Bozüyük District (weight %).

Raw materials	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	MnO	SO_3	P_2O_5	*A.Z
Bozüyük District Granite	59,33	17,01	7,57	0,85	4,14	3,88	1,43	2,61	0,03	0,15	0,12	2,88

**A.Z: Heat Loss*

These analysis results reveal that the granite raw material has a chemical composition suitable for ceramic glaze applications.

The granite raw material obtained from the quarry was first broken into smaller pieces using hammer to have sizes suitable for passing through a cone crusher (Figure 3). Following this process, the samples were reduced to approximately 10 mm in size by the cone crusher and then finely ground in ball mills (Figura 4 and Figure 5). The moisture present in the raw materials was removed in a kiln at 110°C and then passed through a 120 mesh sieve to achieve a homogeneous particle size, making it ready for use.

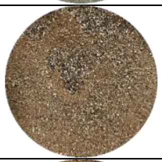
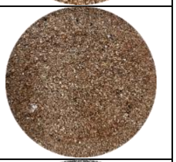
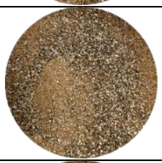
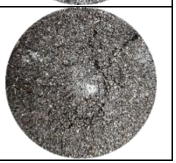
Figure 3. The granite raw material sourced from the Bozüyük District is initially size-reduced (Kum, 2024).

Figure 4. Using a hammer subsequently subjected to cone crushing (Kum, 2024).

Figure 5. It is ground in a ball mill (Kum, 2024).

The granite raw material was placed in crucibles in its natural state after being sieved, and its color changes and melting behavior were observed under nine different temperatures ranging from 850°C to 1250°C in 50°C intervals.

Table 2. The natural appearance of granite raw material from the Bozüyük Region and the results obtained at firing temperatures of 850–1250 °C.

Temperature (°C)	Granite Raw Material	Temperature (°C)	Granite Raw Material
Natural		**1050 °C**	
850 °C		**1100 °C**	
900 °C		**1150 °C**	
950 °C		**1200 °C**	
1000 °C		**1250 °C**	

Granite raw material appears gray in its natural state, and it has been observed that significant color changes occur with increasing firing temperatures. At 850 °C, it takes on a matte appearance close to earth tones; at 900 °C, it turns brown in warmer tones. At 950 °C, yellowish and warm brown tones become more pronounced; at 1000 °C, light brown tones are observed, and at 1050 °C, darker brown tones are seen. At 1100 °C, a color scale progressing towards brown, accompanied by different shades of orange, is formed. At 1150 °C, the granite raw material reached darker brown tones. At 1200 °C, with the start of the melting process, the colors shifted back towards gray tones; at 1250 °C, dark gray colors close to black were determined.

Evaluation of Granite Raw Material from the Bilecik–Bozüyük Region in Binary Glaze Systems

In the binary glaze systems developed using the granite raw material obtained from the Bozüyük District, the fluxing agents used were boric acid (Table 3), borax decahydrate (Table 5), colemanite (Table 7), ulexite (Table 9), and suleyen (Table 11). Various formulations were prepared with granite content ranging from 40% to 90%, and flux additive ratios ranging from 10% to 60%. In these formulations, the granite content was reduced by 10% in each step, while the fluxing material was increased by 10% correspondingly. These glaze systems were applied at temperatures of 1050 °C and 1100 °C on red and white ceramic bodies, and at 1200 °C only on white ceramic bodies. The glaze properties obtained at different firing temperatures have been examined in detail. In the study, the granite raw material was represented with the letter "G," boric acid as "B," borax decahydrate as "D," colemanite as "K," ulexite as "U," and suleyen as "S." Accordingly, the prepared glaze formulations were coded as GB1–GB6 for the granite–boric acid system, GD1–GD6 for granite–borax decahydrate, GK1–GK6 for granite–colemanite, GU1–GU6 for granite–ulexite, and GS1–GS6 for granite–suleyen binary glaze systems.

Bilecik-Bozüyük District Granite Raw Material and Boric Acid Binary Glaze System

Table 3. Recipe composition of the binary glaze system containing granite from the Bozüyük District and boric acid raw materials.

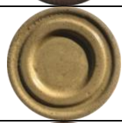
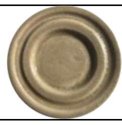
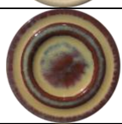
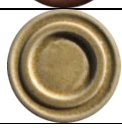
Raw material	Recipe No and Composition (%)					
	GB1	GB2	GB3	GB4	GB5	GB6
Bozüyük District Granite	90	80	70	60	50	40
Boric Acid	10	20	30	40	50	60

The results shown in Table 4 indicate that for recipe GB1**,** after firing at 1050 °C, 1100 °C, and 1200 °C, matt and semi-matt surface characteristics with brown and cream color tones were observed on both types of ceramic bodies depending on the temperature. Notably, distinct crusting formations were detected on the white ceramic body at higher temperatures, especially at 1200°C.

In the results of recipe GB2, matt surfaces and crusting were observed at 1050°C. As the temperature increased, melting occurred, leading to spotted, glossy surfaces with bubbling in the glaze, and dark brown to reddish-brown color tones were noted. Melting and clustering were observed at 1050 °C for recipe GB3. At 1100–1200 °C, melting and speckling occurred, resulting in transparent surfaces with beige tones. The increase in the proportion of boric acid led to melting, **s**peckled transparent surfaces, and beige color tones for recipe GB4, at all three temperatures—1050 °C, 1100 °C, and 1200 °C.

As shown in Table 4; for recipe GB5, at 1050 °C, 1100 °C, and 1200 °C, melting was observed, with beige tones and speckling on the White ceramic body and red ceramic body have created transparent glazes. The results of recipe GB6 at temperatures of 1050 °C, 1100 °C, and 1200 °C indicate that melting occurred. On the red ceramic body, boron glaze (borate veil) in olive green and blue tones was observed, while on the white ceramic body, speckled surfaces with yellow-beige tones were noted. The appearance of GB-coded glazes in three-dimensional form is shown in Figure 8 and Figure 10.

Table 4. Results of Recipes Coded GB1–GB6 at 1050 °C, 1100 °C, and 1200 °C.

Recipe No (Granite-Boric Acit)	Ceramic Body	Temperature		
		1050°C	1100°C	1200°C
GB1	Red			
	White			
GB2	Red			
	White			
GB3	Red			
	White			
GB4	Red			
	White			
GB5	Red			
	White			
GB6	Red			
	White			

Bilecik-Bozüyük District Granite Raw Material and Borax Decahydrate Binary Glaze System

Table 5. Binary glaze system recipe composition (%) of Bozüyük District granite and borax decahydrate raw materials.

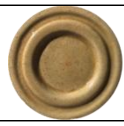
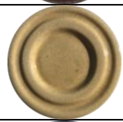
Raw Material	Recipe No and Composition (%)					
	GD 1	GD 2	GD 3	GD 4	GD 5	GD 6
Bozüyük District Granite	90	80	70	60	50	40
Borax Decahydrate	10	20	30	40	50	60

As shown in Table 6, the glaze recipe coded GD1 shows the formation of glazes with a matt surface and reddish-brown color tones. The results of the GD2 recipe indicate matt reddish-brown surfaces with matt yellow-brown mottled glazes. For the GD3 glaze recipe, mottled glazes with speckled glossy finishes and yellow-brown tones were observed. Due to the influence of the red ceramic body, brown tones are present. The results of the GD4 recipe, show glossy crackle glazes at 1050°C, while at 1100°C and 1200°C temperatures, glossy glaze bodies with speckles caused by the granite raw material and peach blossom color were observed.

In the tests of the glaze recipe coded GD5, the glaze surfaces exhibited a glossy and crackled structure. Additionally, a transparent body was obtained on the red ceramic body, while cream-toned glazes were observed on the white ceramic body. In the tests of the glaze recipe coded GD6, glossy and crackled glazes were seen on both substrates. Yellow color tones and speckled glazes were observed on the white ceramic body substrate, while slight blue borate glaze were detected on the red ceramic body.

Table 6. Results of Recipes Coded GD1-GD2-GD3-GD4-GD5-GD6 at 1050 °C, 1100 °C, and 1200 °C.

Recipe No (Granite - Borax Decahydrate)	Ceramic Body	Temperature		
		1050°C	1100°C	1200°C
GD1	**Red**			
	White			
GD2	**Red**			
	White			
GD3	**Red**			
	White			

GD4	**Red**			
	White			
GD5	**Red**			
	White			
GD6	**Red**			
	White			

Bozüyük District Granite Raw Material and Colemanite Binary Glaze System

Table 7. Binary glaze system recipe composition (%) of Bozüyük District granite and colemanite raw materials.

Raw Material	Recipe No and Composition (%)					
	GK1	GK2	GK3	GK4	GK5	GK6
Bozüyük District Granite	90	80	70	60	50	40
Colemanite	10	20	30	40	50	60

As shown in Table 8, melting was observed on the red ceramic body for the glaze recipe coded GK1 at the temperature of 1050 °C, while the white ceramic body showed a matt surface with reddish brown tones. Matt speckled glaze surfaces in dark brown and reddish-brown tones were obtained at temperatures of 1100 °C and 1200 °C. Melting was observed on the red ceramic body for the glaze recipe coded GK1 during the tests conducted at 1050 °C, while the white ceramic body appeared matt with the formation of reddish-brown tones. In the temperature range of 1100 °C to 1200 °C, matt speckled glaze surfaces in dark brown and reddish-brown tones were obtained.

Three different firings showed speckled, matt grey, and brown color tones for the recipe-coded GK2. Glossy and speckled glazes were observed for the glaze recipe coded GK3, while the glaze appeared transparent on the red ceramic body and in cream-brown tones on the white ceramic body. The results of the tests conducted with the glaze recipe coded GK4 showed glossy, speckled, and beige color tones. The firings performed with the glaze recipe coded GK5 revealed borate glaze formations in areas where the glaze was thick on the red ceramic body, while on the white ceramic body, glossy, speckled, and beige color tones were observed, and crystal glaze formations were obtained at 1200°C. The tests conducted with the glaze recipe coded GK6 showed borate glaze formations on the red ceramic body, while on the white ceramic body, glossy, speckled, and beige tones appeared. Crystal glaze formation was observed at 1200°C. The appearance of the GK coded glaze in three-dimensional form is shown in Figure 11.

Table 8. Results of the glaze recipes coded GK1–GK2–GK3–GK4–GK5–GK6 at 1050 °C, 1100 °C, and 1200 °C.

Recipe No (Granite-Colemanite)	Ceramic Body	Temperature		
		1050°C	1100°C	1200°C
GK1	Red			
	White			
GK2	Red			
	White			
GK3	Red			
	White			
GK4	Red			
	White			
GK5	Red			
	White			
GK6	Red			
	White			

Binary Glaze System of Bilecik-Bozüyük District Granite Raw Material and Ulexite

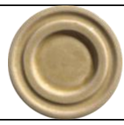
Table 9. Binary glaze system recipe composition (%) of granite and ulexite raw materials from the Bozüyük District.

Raw Material	Recipe No ve Composition (%)					
	GU1	GU2	GU3	GU4	GU5	GU6
Bozüyük District Granite	90	80	70	60	50	40
Ulexit	10	20	30	40	50	60

As shown in Table 10, matt reddish-brown and green-brown color tones were observed in the trials of the GU1 coded recipe. Glaze accumulations were seen on the white ceramic body at 1050°C. The GU2 coded glaze recipe yielded matt, speckled glazes with light-dark brown and green-brown color tones. The firing results of the GU3 coded glaze recipe showed glossy dark brown on the red ceramic body, while matt, speckled, and light brown tones were observed on the white ceramic body. The firing results of the GU4 coded glaze recipe revealed glossy and transparent glazes on the red ceramic body, while glossy, speckled, and dark beige tones were obtained on the white ceramic body. Colored, transparent, and speckled favorable glazes were achieved without the addition of pigments or coloring oxides. According to the results of the GU5 coded glaze recipe, glossy and transparent glazes were observed on the red ceramic body, while glossy, speckled, and dark beige color tones were observed on the white ceramic body. The red ceramic body exhibited glossy, dark beige, and slightly bluish borate glaze formations in the trial results of the GU6 coded glaze recipe, while the white ceramic body showed glossy, speckled, and beige color tones. The appearances of the glazes coded as GU in three-dimensional form are shown in Figure 6, Figure 7, Figure 9 and Figure 12.

Table 10. Results of GU1-GU2-GU3-GU4-GU5-GU6 Coded Recipes at 1050 °C, 1100 °C, and 1200 °C.

Recipe No (Granite-Ulexit)	Ceramic Body	Temperatures		
		1050°C	1100°C	1200°C
GU1	Red			
	White			
GU2	Red			
	White			
GU3	Red			
	White			
GU4	Red			

	White			
GU5	**Red**			
	White			
GU6	**Red**			
	White			

Binary Glaze System of Bozüyük District Granite Raw Material and Sulyen (Red Lead Pb_3O_4)

Table 11. Binary Glaze System Recipe Composition (%) of Bozüyük District Granite and Sulyen (Red Lead Pb_3O_4) Raw Materials.

Raw Material	Recipe No and Composition (%)					
	GS1	GS2	GS3	GS4	GS5	GS6
Bozüyük District Granite	90	80	70	60	50	40
Sulyen (Red Lead Pb_3O_4)	10	20	30	40	50	60

As shown in Table 12, the tests of glaze recipe coded GS1 showed matt surfaces with reddish-brown colors, while semi-matt surfaces with reddish-brown and dark brown tones were observed at increasing temperatures. The results of the glaze recipe coded GS2 showed matt glaze surfaces in reddish-brown tones. Semi-matt glaze surfaces in dark brown tones were obtained in the tests at higher temperatures. In the tests of glaze recipe coded GS3, semi-matt glazes with reddish-brown tones were observed. According to the test results of the glaze recipe coded GS4, semi-matt, speckled glaze surfaces in reddish-brown and beige tones were identified. The results for the glaze recipe coded GS5 show that matt glaze surfaces were replaced by glossy glaze surfaces with increasing temperature. Additionally, color tones ranging from light yellow to brown were obtained. It was determined that the matt appearance gave way to a glossy surface for the glaze recipe coded GS6 with the increase in temperature; furthermore, glaze surfaces exhibited oyster pink and brown tones.

Table 12. Results for the glaze recipes coded GS1, GS2, GS3, GS4, GS5, and GS6 at 1050 °C, 1100 °C, and 1200 °C.

Recipe No (Granite-Sulyen(Red Lead Pb_3O_4)	Ceramic Body	Temperature		
		1050°C	1100°C	1200°C
GS1	Red			
	White			
GS2	Red			
	White			
GS3	Red			
	White			
GS4	Red			
	White			
GS5	Red			
	White			
GS6	Red			
	White			

In this study, the selected three-dimensional forms were designed to observe the fluidity of the glaze on the inner and outer surfaces and the colors that may form in areas where it is applied densely. The angled and multi-surfaced geometric structure allows for the observation of the glaze's fluidity and the effect of surface tension. After the design of the three-dimensional form was completed, it was printed using filament from a 3D printer. After plaster molding of the printed model, it was replicated using the casting method. The forms, bisque fired at 950 °C, were glazed using the slip casting method and then fired at 1050 °C, 1100 °C, and 1200 °C. Figures 6, 7, 8, 9, 10, 11, and 12 show the three-dimensional views of the recipes selected based on the experimental results.

Figure 6. GU6, 8x11x11.5 cm, casting method, red ceramic body, 1050°C (Kum, 2025).

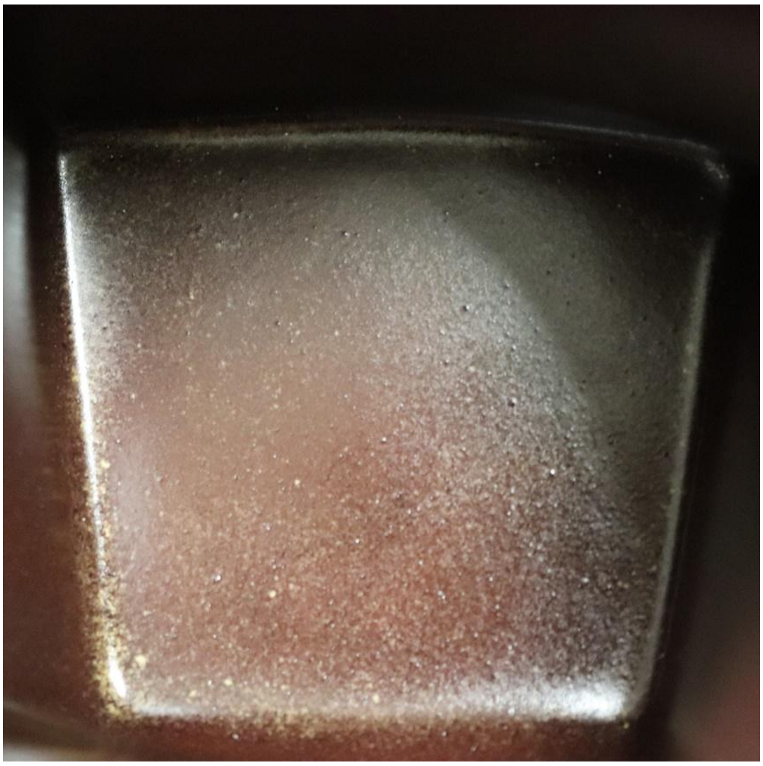


Figure 7. Detail of GU2, casting method, white ceramic body, 1050°C (Kum, 2025).

Figure 8. GB5, 8x11x11.5 cm, casting method, red ceramic body, 1100°C (Kum, 2025).

Figure 9. Detail of GU3-GU4, casting method, white ceramic body, 1100°C (Kum, 2025).

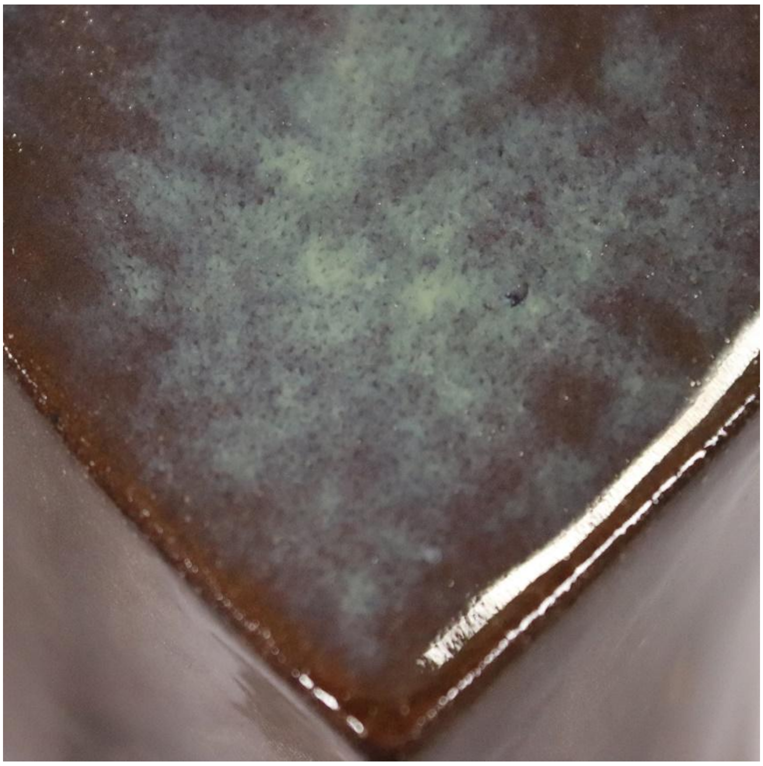


Figure 10. Detail of GB6, casting method, red ceramic body, 1100°C (Kum, 2025).

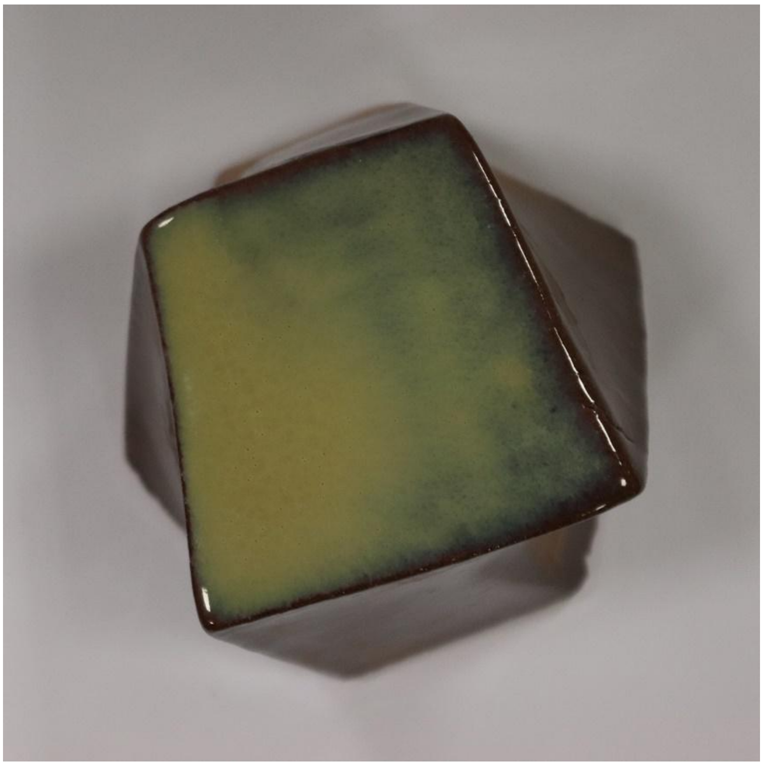


Figure 11. GK6, casting method, red ceramic body, 1100°C (Kum, 2025).

Figure 12. Detail of GU3-GS3, casting method, white ceramic body, 1200°C (Kum, 2025).

DISCUSSION

It was determined in the study that the granite from the Bozüyük District is used as a filler material in the construction sector, and it was considered to have contributed to the ceramic industry. For this purpose, glaze recipes prepared with granite and fluxing agents; boric acid, borax decahydrate, colemanite, ulexite, and red lead (Pb_3O_4), were applied and evaluated on red and white ceramic bodies at three different temperatures (1050°C, 1100°C, and 1200°C). It was observed that colored and positive glaze effects were obtained at three different temperatures without the addition of pigments or coloring oxides depending on the properties of the ceramic bodies using granite raw material. According to these positive results, various color tones such as beige brown, reddish brown, dark brown, ochre, light yellow, brown, and champagne, as well as surface effects including matt, semi-matt, glossy, speckled, and mottled were obtained. Borate glaze effects were detected in the red ceramic body, while speckled surface formations were identified in the white ceramic body.

The angled and multi-surface three-dimensional forms used in this study were designed to observe the effects of fluidity and surface tension on the inner and outer surfaces of the glaze. Observations made on these forms revealed that glaze formulations containing boron exhibited more fluid behavior.

Positive glaze results were achieved both aesthetically and technically in the binary glaze system. These findings indicate that the combined use of natural and industrial raw materials can contribute to the development of alternative glaze recipes in the ceramic industry. The sustainable and local sourcing of raw materials is also important from environmental and economic perspectives in ceramic production. Within the scope of the research, crystal glaze formations were identified in tests conducted at 1200°C using the binary system glaze recipes coded GK5 (50% granite, 50% colemanite) and GK6 (40% granite, 60% colemanite). The ability to achieve glaze effects in GK5 and GK6 recipes by utilizing locally sourced raw materials and lower material ratios is noteworthy both in terms of raw material savings and providing high-quality surfaces. The obtained findings demonstrate that the developed system can be considered an aesthetic, economical, and sustainable alternative in ceramic glaze production, and can also be evaluated as an upcycling material. Furthermore, it is shown to have the potential to contribute to future studies.

CONCLUSION

Natural stones and ceramic raw materials have been used throughout history in various fields ranging from architecture and art to everyday objects and industry. Increasing production and diversity are causing rapid depletion of natural resources today and this brings along the need for sustainable material use. Granite is an igneous rock formed by slow crystallization under high temperature and pressure deep within the Earth's crust. This coarse-grained rock, composed of feldspar, quartz, and mica minerals, has been used throughout history as a building and decorative material due to its durability and aesthetic appearance. Since ancient times, granite has been preferred especially in monumental structures of civilizations such as Egypt and Rome. Examples include the city of Perge, the Theodosius Obelisk, the Great Wall of China, and the Mount Rushmore Monument. These examples demonstrate that granite is not only a durable building stone but also a cultural and symbolic material. Additionally, the Sosurka legend found in the Karaçay-Malkar Nart epics reveals that granite has been perceived mythologically as a strong and resilient element.

Today, granite is widely used in the construction and decorative sectors with its diverse colors and textures. Turkey has a mineable granite reserve of 1 billion m^3 across the country. This study has examined it as one of the natural building stones, which is currently preferred in the ceramic sector for both interior and exterior spaces, as well as in public areas. This preference is due to granite's aesthetic qualities, durability, and functionality. Within the scope of the research, the usability of granite raw material from Bozüyük district in ceramic glazes was examined.

The feldspar, quartz, and mica minerals contained in granite are thought to have created a vitrification effect in ceramic glazes. In this context, chemical analysis was conducted on the granite raw material obtained from the district. The analysis results revealed the following composition: SiO_2 59,33%, Al_2O_3 17,01%, K_2O 2,61%, Na_2O 1,43%, Fe_2O_3 7,57%, CaO 4,14%, MgO 3,88%, and TiO_2 0,85%. These values indicate that the granite raw material is suitable for use in ceramic glazes.

Based on the chemical analysis results, glaze recipes were formulated by combining the granite raw material with fluxes. These glazes were prepared by mixing boric acid, borax decahydrate, colemanite, ulexite, and sulyen (Red Lead Pb_3O_4) with granite raw material in specific proportions. The resulting glazes were applied to red and white ceramic bodies and fired at 1050 °C, 1100 °C, and 1200 °C. Within the scope of the study, glaze recipes containing varying proportions of granite and boron-based fluxes were applied and evaluated on white and red ceramic bodies at three different temperatures. The results revealed that variables such as firing temperature, type of body, and glaze composition had significant effects on the glaze surface, color development, and melting behavior of the glaze. At lower temperatures (1050 °C), most recipes exhibited matt surfaces and effects such as glaze clustering, while melting increased with increasing temperature (especially at 1200 °C), resulting in higher gloss and more distinct speckled and transparent structures.

In experiments using white ceramic bodies, beige, cream, yellow-beige tones, and transparent effects are generally observed, while in red ceramic bodies, iron oxide effects produce reddish brown, dark brown, and green-brown tones. Additionally, in some recipes, blue and olivegreen borate glazes formations originating from boron compounds in red ceramic bodies have been noted.

However, richer and more natural color tones have been obtained in some glaze recipes without the addition of pigments or coloring oxides. Furthermore, it has been determined that speckled, transparent, borate glaze and crystal glaze types have been obtained in recipes prepared using a binary glaze system, and that the results of this study contribute to the field in terms of the developability of these types.

In conclusion, the analyses, experimental applications, and observations conducted have demonstrated the usability of Bozüyük granite in ceramic glazes. This research, aimed at evaluating local raw materials, also contributes to sustainability in ceramic production.

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