

## INSIGHTS INTO SELJUK-PERIOD STONEPASTE CERAMICS FROM AZERBAIJAN: EVIDENCE FROM SEM ANALYSIS

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### Abstract

This study presents the results of Scanning Electron Microscopy (SEM) analyses conducted on stonepaste samples excavated from the medieval urban sites of Beylagan and Ganja in Azerbaijan. Until now, the provenance of stonepaste materials discovered in Azerbaijani medieval settlements has remained uncertain. In some earlier studies, researchers attempted to determine the origin of these ceramics merely by the colour of their bodies. The present research, however, provides a scientific basis for understanding their technological and compositional characteristics. SEM analyses revealed that the stonepaste samples from Beylagan and Ganja differ significantly in their microstructural composition. This suggests that the raw materials employed in Ganja's stonepaste production were distinct from those used in Beylagan, indicating that the two sites represent separate production centres. These findings contribute to a clearer understanding of medieval Azerbaijani ceramic technology and regional production traditions within the broader context of Islamic art and industry.

**Keywords:** Azerbaijan, Stonepaste, SEM analysis, Seljuk, Glaze, Lusterware, Minai

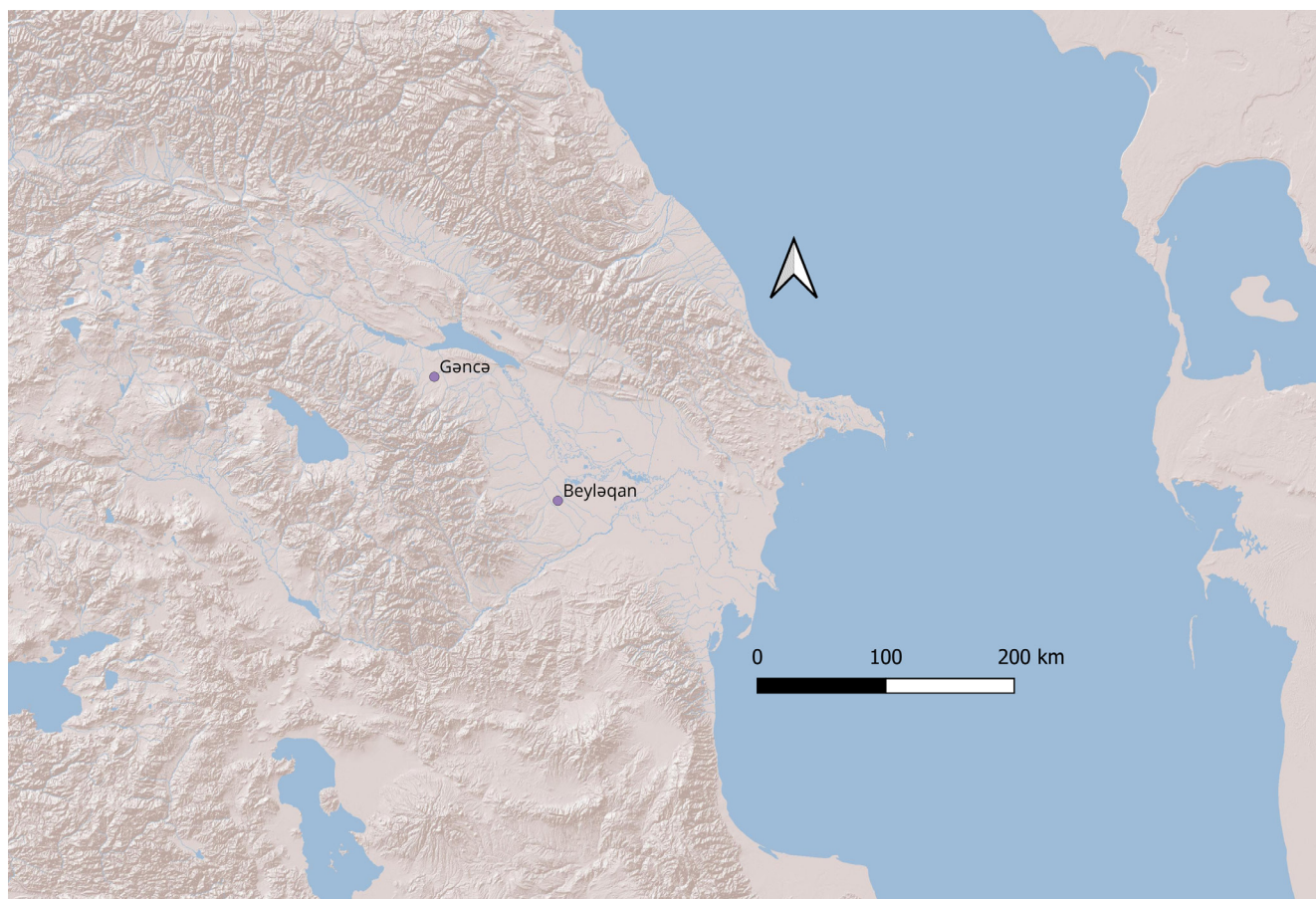
### INTRODUCTION

The Seljuk period spans approximately 200 years, from the mid-11th century to the early 13th century. This era began with the Seljuk Turks' campaigns in the South Caucasus and ended with the Mongol invasion. The Seljuk period is characterised by cultural and economic growth in Azerbaijan. During this time, urbanisation accelerated, urban planning expanded, cities grew both in size and population, artistic production flourished, specialisation within the arts deepened, domestic and international trade developed, and the circulation of money increased (Dostiyev, 2005).

The introduction of stonepaste products into the daily life of Azerbaijan's urban population coincided with the Seljuk period. Stonepaste refers to glazed ceramic items made from silicate-based white clay (Mason & Tite, 1994, p.78). The ratio

of crushed quartz, glass, and clay in stonepastes is 10:1:1 (Mason, 1997, p. 107). These ceramics are distinguished not only by their diverse range of uses but also by their high artistic and aesthetic value. During the Seljuk period, technological innovations such as *minai*, silhouette, and grain de rice were introduced. The ornamented ceramics, known in the Muslim East since the early Islamic period, were redefined in the main pottery centres of the Seljuk Empire. Their highly artistic design became a key marker of applied and decorative art. At the same time, the *minai*-style stonepaste ceramics represented the pinnacle of applied and decorative arts of the period.

Despite extensive archaeological excavations, the origin of stonepaste products discovered at medieval sites in Azerbaijan remains a topic of debate among experts. Statistical indicators and stylistic features suggest that some of the



**Fig. 1.** A map depicting the medieval cities of Ganja and Beyləqan. The map was produced by the author using QGIS.

stonepaste samples were imported rather than locally produced (Aghalarov, 2025, pp. 324-325). B. Shelkovnikov suggests that the lustre-painted stonepaste wares found in Beyləqan were imported from the Iranian city of Rey (Shelkovnikov, 1959, p. 322), a view also supported by archaeologist G. Ahmadov (Ahmadov, 1997, p. 111). N. Najafova argues that stonepaste wares were not produced locally due to a lack of raw materials in Azerbaijan (Najafova, 1961, p. 321). Other experts contend that stonepaste wares could have been produced locally. Archaeologist T. Dostiyev, citing the discovery of wasters from the city of Shamkir (Dostiyev, 2017, p. 115) and Farhad Ibrahimov, noting typological differences in bodies of stonepaste wares found in Beyləqan (Ibrahimov, 1965, p.122), along with Vladimir Leviatov's discovery of raw material — white clay reserves in a potter's workshop during excavations in Ancient Ganja, suggest that stonepaste products may have been locally produced (Leviatov, 1940, p. 33). Furthermore, Hasanagha Ramazanli emphasises the possibility of local stonepaste production, noting the availability of all necessary raw materials (Ramazanli, 2001, p. 240). In fact, the complete availability of raw materials might not

be a primary condition for stonepaste production.

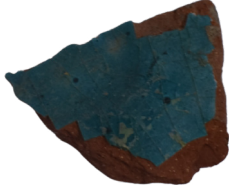
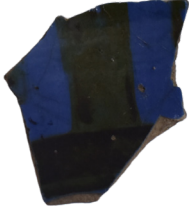
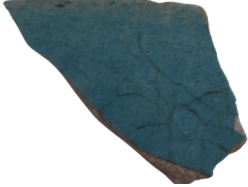


Abul Qasim Kashani, a medieval author, dedicated a chapter of his 1301 work to the technology of stonepaste production, shedding light on several interesting details. Kashani himself was from the Abu-Tahir family, renowned for producing stonepaste in the city of Kashan, which adds further value to the technological processes described in his work, confirming that this production method was characteristic of Kashan. In his account, Kashani categorises the stonepaste raw materials into 12 main groups, some of which were sourced from Khorasan, Bulgars, Rum, Firangistan, and Azerbaijan (Allan, 1973, pp. 111–113). This suggests that Kashan potters obtained raw materials for stonepaste production from distant regions, indicating that the absence of local raw materials was not the primary obstacle to stonepaste production in the Middle Ages. Finally, although the discovery of raw material residues in a potter's workshop is often considered evidence of production, such a finding is only mentioned in I. Jafarzadeh's monograph lacks photographic documentation (Jafarzadeh, 1949, p. 74).

Some researchers argue that artefacts with production defects or outliers discovered during



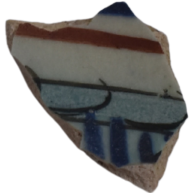

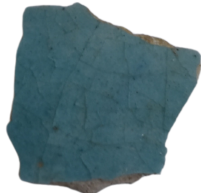
archaeological excavations do not necessarily indicate local production. Researcher Oliver Watson observes that stonepaste vessels with minor manufacturing defects that do not affect the material's appearance were typically suitable for sale. In contrast, production defects were used to export materials to distant cities (Watson, 1985, p. 43). Thus, while production defects may point to local production, they are not definitive evidence of it.

## MATERIALS AND METHODS

Considering the above, the use of archaeometric methods is crucial for addressing the origin of stonepaste products. The main goal of this study is to conduct chemical analyses of stonepaste products and compare the results with those from analyses of stonepaste samples from other regions. Atomic analyses were performed at the Physical and Chemical Research Laboratory of the Institute of Petroleum and Chemical

№	Photo	Artefact description
1		<p>This fragment is the body of a glazed ceramic vessel. The vessel is made of red clay and coated with a turquoise-colored glaze.</p>
2		<p>This is a body fragment of a lustre-decorated stonepaste vessel. Both surfaces are coated with a blue glaze and decorated with a lustre layer. The lustre is dark brown.</p>
3		<p>This is a rim fragment of a stonepaste vessel. Both surfaces are coated with a turquoise-colored glaze.</p>
4		<p>This is a body fragment of a lustre-painted stonepaste vessel. The exterior surface is coated with an opaque white glaze and decorated with a lustre layer, while the interior surface is coated with a blue glaze. During the production process, slight variations in firing temperature resulted in changes in the colour of both the glaze and the body.</p>
5		<p>This is a rim fragment of a stonepaste vessel. Both surfaces are coated with a turquoise-colored glaze. Due to deviations from the proper production process, the glaze layer has cracked, and its colour has altered in some areas.</p>

**Fig. 2.** Photographs and descriptions of stonepaste samples from Ganja analyzed using SEM.

№	Photo	Artefact description
6		The specimen represents a body fragment of a lustre-painted stonepaste vessel. The exterior surface is coated with an opaque white glaze and decorated with a dark brown lustre. The interior surface is plain. The stonepaste has a dense texture and a pinkish hue.
7		A body sherd of a lustre-painted stonepaste vessel, bearing an opaque white glaze on both surfaces and a golden-hued lustre overglaze. The stonepaste has a whitish tone and a brittle texture.
8		A body fragment of a <i>Minai</i> (overglaze-painted) stone-paste vessel, with both surfaces coated in a white glaze and the interior further decorated with pigments and overglaze painting.
9		A body fragment of a lustre-painted stonepaste vessel, with both surfaces coated in a blue glaze and decorated with a dark-brown lustre layer.
10		A body fragment of a stone-paste vessel, with both surfaces coated in a turquoise glaze.

**Fig. 3.** Photographs and descriptions of stonepaste samples from Beylagan were analysed using SEM.

Processes of Azerbaijan, using an “OXFORD Instruments” atomic analyser combined with a “Hitachi S-3400N” Scanning Electron Microscope, employing the probe method. The probe method differs from complete chemical analysis in that it provides elemental composition values at discrete analytical points. Increasing the number of analysed points on a specimen enhances the objectivity of the results. Consequently, to obtain the most reliable and representative dataset, analyses are typically performed across numerous points in the sample.

Both Ganja and Beylagan are located on the Great Silk Road and were important commercial and cultural centres of their time (Fig. 1). From the

small fragments obtained during archaeological excavations in these cities, preserved in the Archaeological Department of the National Museum of History of Azerbaijan (non-museum specimens and unregistered), a total of 10 fragments were selected for chemical analysis—5 from each site. Archaeologist Ishaq Jafarzadeh discovered the Ganja samples (Fig. 2) between 1938 and 1940 (Jafarzadeh, 1949). The Beylagan samples (Fig. 3) were discovered during archaeological excavations conducted by archaeologists Alexander Iessen and Gara Ahmadov between 1953 and 1968 (Ahmadov, 1979).

Of the 5 samples selected from the Ganja collection, one is a red clay fragment with a

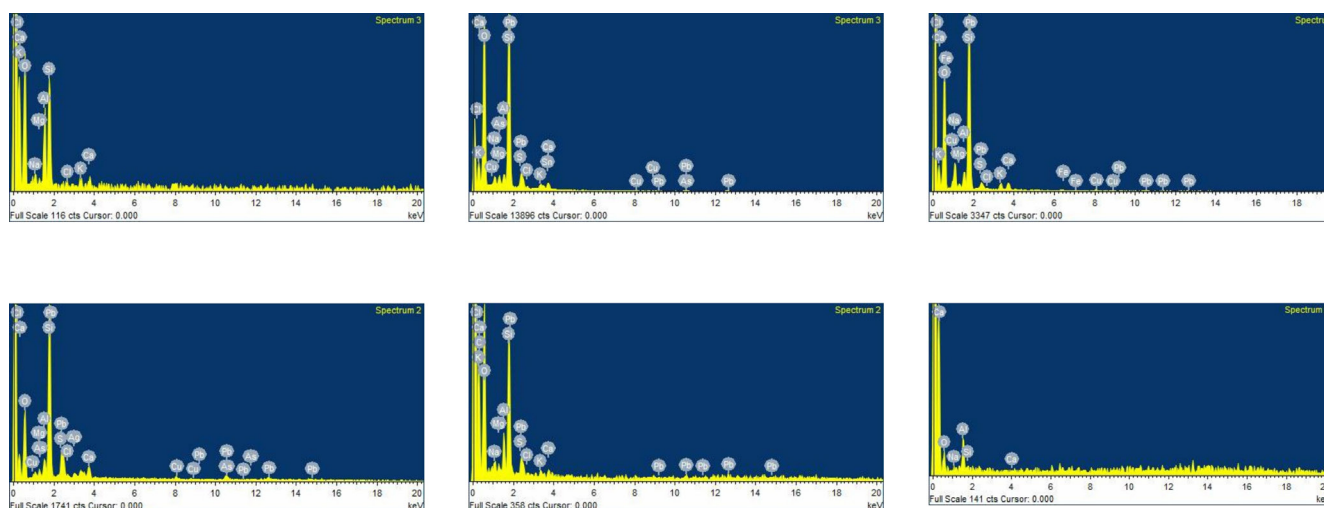
turquoise glaze, another is a white, glazed, lustre-painted piece, another is a blue, glazed, lustre-painted fragment, one is a finely made, turquoise-glazed stonepaste, and the final one is a turquoise-glazed stonepaste bowl with manufacturing defects. Of the 5 samples selected from the Beylagan (Orangala) collection, two are white, milky-glazed stonepaste; one is blue-glazed stonepaste; one is turquoise-glazed stonepaste; and the last is a stonepaste with a minai pattern.

## ANALYSIS RESULTS

Chemical composition analysis was conducted on two turquoise-glazed stonepaste samples, one from the Ganja collection and one from the Beylagan collection (Fig. 4, Fig. 6). Among the two turquoise-glazed stonepaste samples from Ganja, one (No. 5) exhibited a production defect. In contrast, the other (No. 3) was finely crafted. Additionally, the glaze layer of a red clay turquoise-glazed ceramic sample (No. 1) from Ganja was analysed.

The chemical compositions of the glaze layers in samples No. 1 and No. 5 were similar, except for magnesium (Mg) and iron (Fe) content. Sample No. 1 contained only 0.91% Mg and 0.46% Fe. At the same time, both elements were present in higher concentrations in sample No. 5. Other elements were present in both samples, and the silicon (Si) ratios were very close: 48.3% in No. 1 and 45.02% in No. 5 (Fig. 7).

The finely crafted sample (No. 3) had a different composition, with elements such as copper (Cu), lead (Pb), and sulfur (S) present in the glaze layer, which were absent in samples No. 1 and No. 5. Notably, Cu and Pb were also found in the glaze layer of a turquoise-glazed stonepaste sample from Beylagan (No. 10), suggesting a similarity in the glaze composition between samples No. 3 and No. 10. Furthermore, sample No. 10 contained 0.66% manganese (Mn), which was not found in other turquoise-glazed samples. Comparing the chemical compositions of the turquoise-glazed samples from both cities, it can be said that while



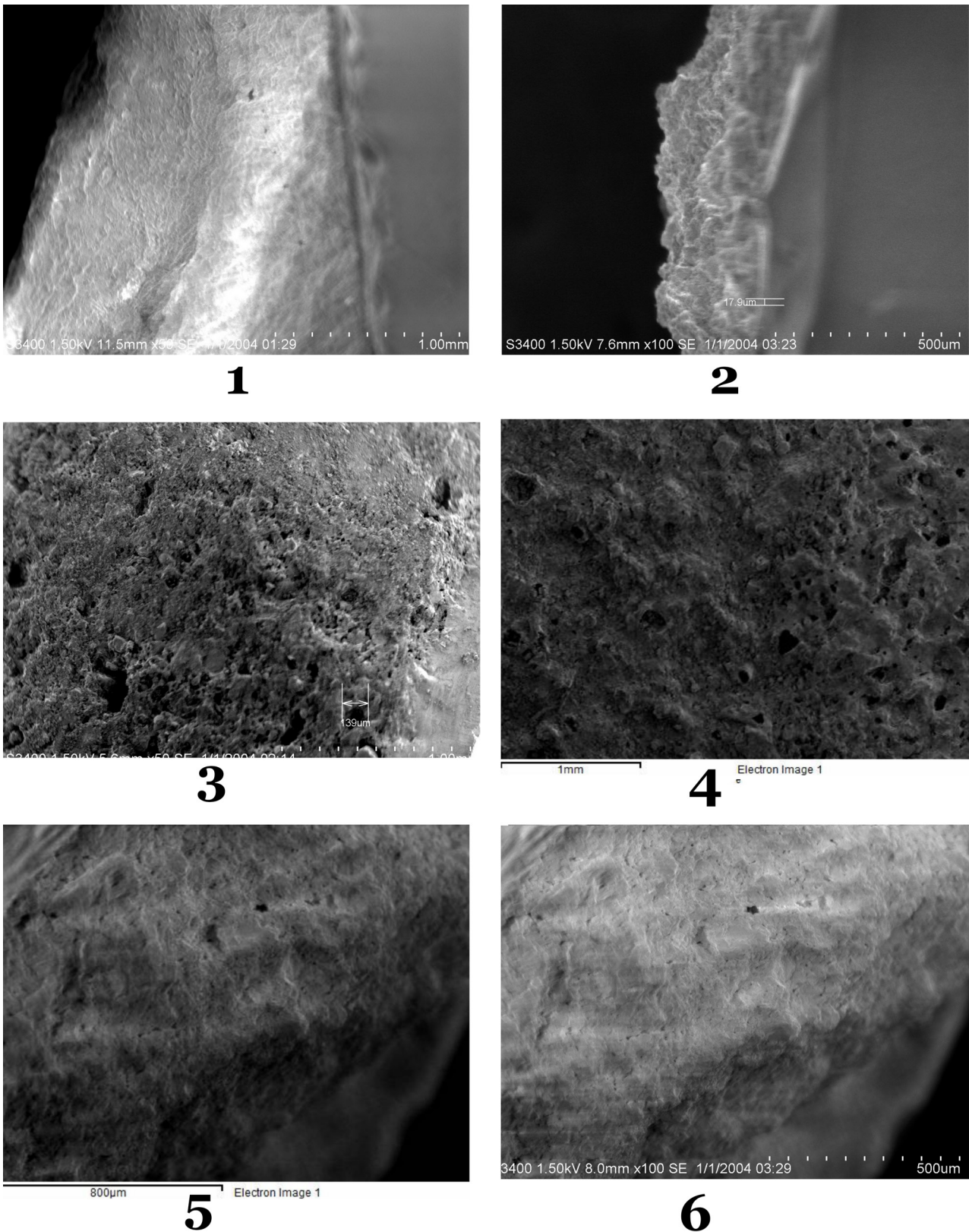
**Fig. 4.** SEM-EDS spectrum showing the elemental composition of some samples.

there are differences, samples No. 3 and No. 10 share a closer chemical composition than sample No. 5.

Regarding the lustre-painted stonepaste samples from Ganja and Beylagan, their chemical compositions differ significantly. One of the two samples analysed from Ganja was a blue-glazed stonepaste fragment (No. 2), and the other was a white-glazed stonepaste fragment (No. 4). Both samples have thin, delicate stonepaste, and their compositions are relatively close, though some differences are evident. The Si content in samples No. 2 and No. 4 was 50.98% and 51.99%, respectively, which are pretty similar. Additionally, elements such as aluminium (Al), potassium (K),

calcium (Ca), iron (Fe), and tin (Sn) were found in comparable amounts in both samples. However, lead (Pb) was present at 9.81% in sample No. 4, whereas it was absent in sample No. 2 (Fig. 5).

The stonepaste of the lustre-painted samples from Beylagan varied in texture and colour. Samples No. 6, No. 7, and No. 9 all exhibited thin, whitish, and delicate stonepaste, while sample No. 6 was pinkish and dense. Samples No. 6 and No. 7 had white glaze, while sample No. 9 had blue glaze. Overall, the chemical analysis results showed no significant differences. The Si content in all three samples ranged from 63.62% to 71.04%, with the lowest in sample No. 7 and the highest in sample



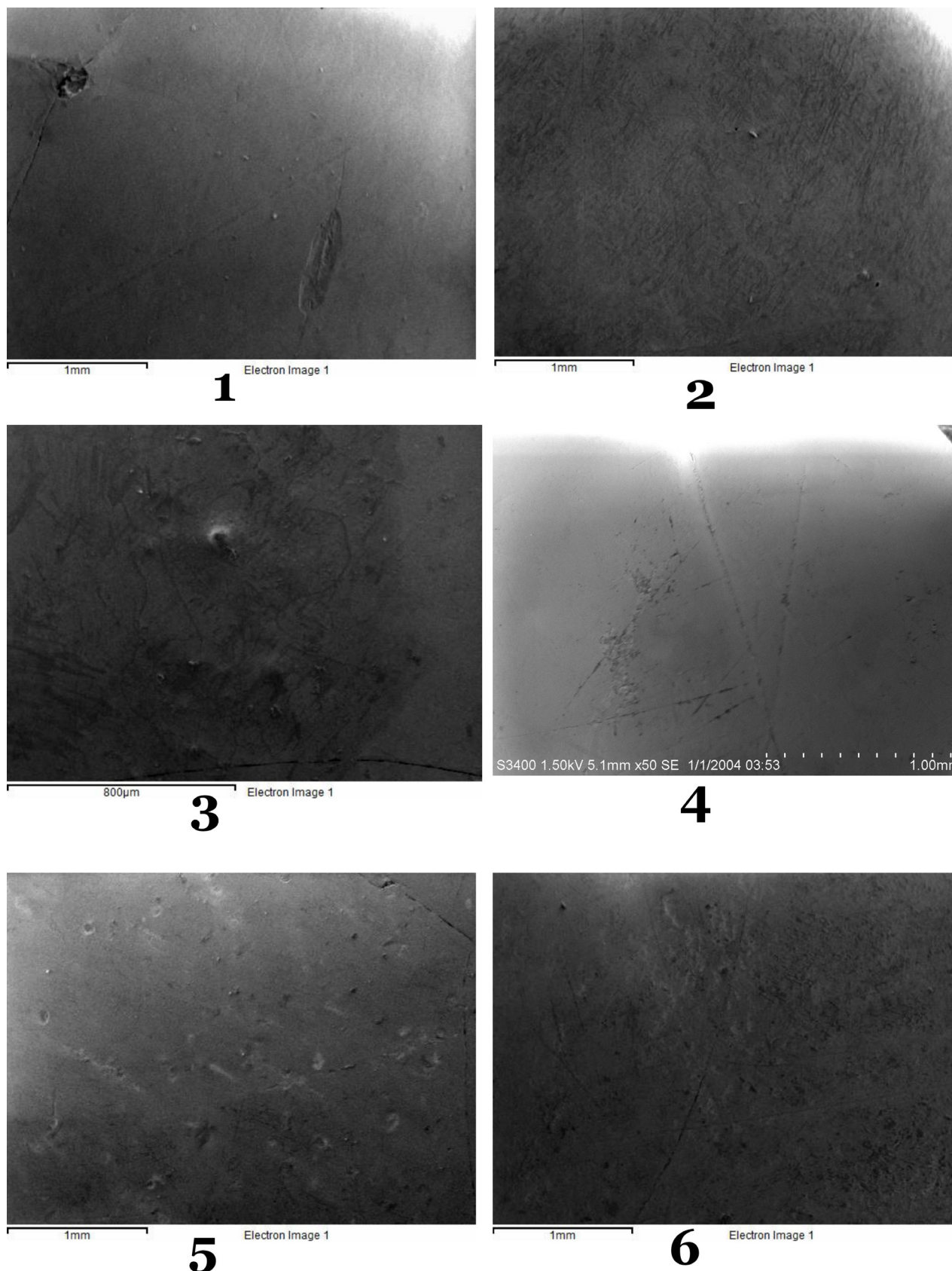
**Fig. 5.** SEM micrograph showing the body of the stonepaste samples.

No. 6. Titanium (Ti) was present at 0.62-0.65% in all three samples. Sample No. 6 contained 0.28% phosphorus (P), which was not found in any of the other samples. Notably, titanium (Ti) was absent in the Ganja samples but present in all the Beylagan samples. The Si content of the Ganja samples

ranged from 51% to 52%, whereas the Beylagan samples had a content of more than 63%.

The chemical analysis of the glaze layers of the stonepaste samples also yielded interesting results. For instance, sample No. 9 from Beylagan, which was covered with a blue glaze, contained

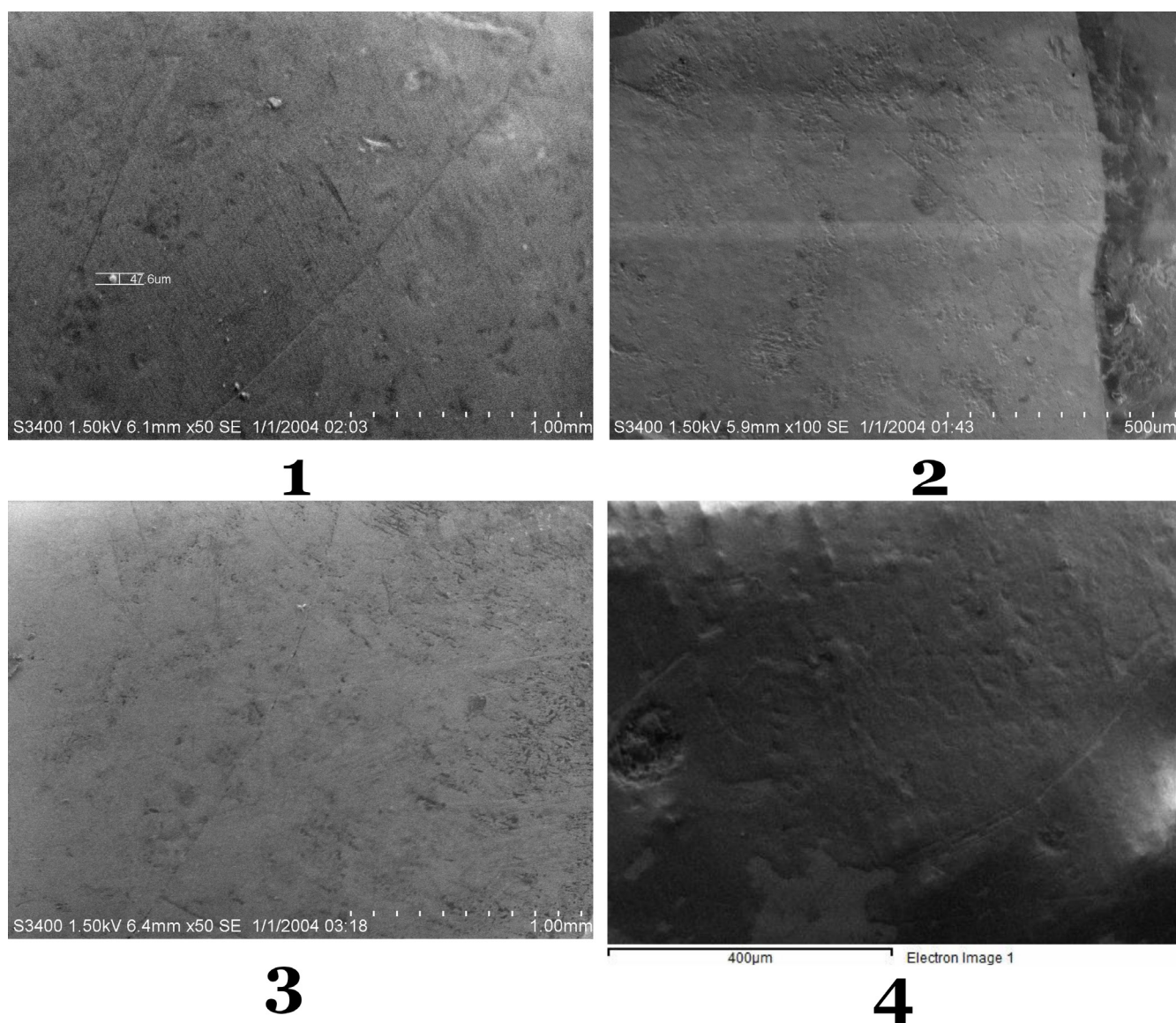




**Fig. 7.** SEM micrograph showing the glaze of the stonepaste samples.

5.59% cobalt (Co), whereas this element was not present in the glaze layer of sample No. 2 from Ganja. Lead (Pb), which was absent in the stonepaste compositions from Ganja, was found

in the glaze of all the Beylagan samples. Tin (Sn) was not present in the stonepaste compositions of any sample, but it was found in the glaze layers of sample No. 2 from Ganja at 4.15%, and in samples



**Figure 8.** SEM micrograph showing the lustre of the stonepaste samples.

No. 7 and No. 9 from Beylagan at 6.46% and 5.05%, respectively.

The lustre layers (Fig. 8) of the samples also revealed unique features. Sample No. 4 from Ganja had 6.2% bismuth (Bi) in its lustre layer, which was not found in any other sample's lustre, stonepaste, or glaze layers. Sample No. 7 from Beylagan contained 3.73% silver (Ag) in its lustre layer, which was not observed in other samples. Copper (Cu) was found only in the lustre layers of stonepaste samples from Beylagan, at 2.6% in sample No. 7 and 0.21% in sample No. 9.

Sulfur (S) was also present in the stonepaste compositions. In the gilding layer of sample No. 4 from Ganja, the sulfur content was 0.26%; in sample No. 6 from Beylagan, 2.37%; and in sample No. 7, 0.25%. The colour of the lustre layer depends directly on the ratio of copper and silver in the

composition: a higher copper content results in a brownish or reddish hue. In contrast, a higher silver content yields a greyish or yellowish hue.

Sample No. 8 was the only analysed sample with an enamel-minai pattern. This sample was discovered during excavations in Beylagan.

Noteworthy elements in the composition of the blue enamel paints include cobalt (Co), nickel (Ni), and zinc (Zn), which were not found in any other stonepaste samples. The silicon (Si) content of the enamel paints ranged from 37.09% to 59.09%.

#### **Comparative Analysis with Other Regions**

Chemical analyses of Seljuk-period stonepaste products discovered in various regions have been conducted over different periods. These analyses mainly focus on regions such as Syria, Egypt, and Iran. Comparing the chemical composition of

stonepaste samples from Azerbaijan with that of samples from other regions is of great practical importance. Through this comparative analysis, it is possible to identify both similar and distinct chemical composition markers of stonepaste from Azerbaijan.

While the Pb element is rarely found in the glaze layer of stonepaste products from Syria, it is relatively more prevalent in those from Egypt and Iran (Pradell et al., 2008, p. 2653). PbO oxide is present in the glaze layer of stonepaste products from Iran at 18-23%, which is a significant indicator. Among the samples from Ganja and Beylagan, only four contain the Pb element. One of these is the turquoise-glazed stonepaste from Ganja (No. 3), which contains only 2.6% Pb. The other three are samples from Beylagan (Nos. 6 and 7), with Pb contents of 3.25% and 16.67%, respectively. The last one is a turquoise-glazed sample from Beylagan (No. 10), with a Pb content of 6.65%.

Another important element is titanium (Ti). While this element is present in all three lustre-painted samples from Beylagan, it is absent from any sample from Ganja. Ti is detected in the composition of samples from Syria, Egypt, and Iran as the chemical compound TiO<sub>2</sub> (Pradell et al., 2008, p. 2654). However, this element is rare in Syria; although absent from samples from Damascus and Tel Minis, it is observed in only 0.10-0.14% of Raqqa stonepastes (Pradell et al., 2013, p. 3).

The proportion of the Si element is also noteworthy. In the analysis of Seljuk-period stonepaste bodies from Iran, the SiO content is very high, ranging from 84% to 88% (Tite et al., 2011, p. 572). In contrast, the Si content in Beylagan samples ranges from 63% to 71%, while in Ganja samples it ranges from 51% to 52%.

## CONCLUSION

The primary goal of this study was to clarify the origin of stonepaste products discovered in the urban areas of Beylagan and Ganja. The chemical analyses have revealed interesting results. The fact that the samples from Ganja and Beylagan have different chemical compositions is a key finding. Generally, the Ti element is present in

the composition of many stonepaste samples from regions such as Iran, Egypt, and Iraq. This element is present in all three stonepaste samples from Beylagan but absent from the two analysed samples from Ganja. This suggests that the raw materials used in Ganja's stonepaste production differ from those used in Beylagan, implying that the two cities' stonepaste products belong to different production centres.

The absence of Ti in the Ganja sample makes it stand out from lustre-painted stonepaste products from other regions, suggesting that these lustre-painted items may have been produced in Ganja's pottery workshops.

Continuing with the Ti element, while it is present in the lustre-painted stonepaste samples from Beylagan, its absence in the turquoise-glazed stonepaste of the same region suggests that the turquoise-glazed and lustre-painted stonepaste samples from Beylagan originate from different production centres. The turquoise-glazed stonepaste was likely produced locally in Beylagan, while the lustre-painted items were imported from elsewhere. Farhad Ibrahimov has noted that stonepaste with a rough and pinkish structure differs from fine, white stonepaste, suggesting that the pinkish samples may belong to a different production centre, possibly local. However, the results of this study contradict this, as both white-grained and coarse, pinkish stonepaste samples share similar chemical compositions, indicating a common production origin. The difference in texture is more likely due to firing temperature than to chemical composition.

Although many scientific texts refer to blue-glazed stonepaste as cobalt-glazed, chemical analyses indicate that cobalt (Co) is absent from the blue-glazed stonepaste from Ganja. In contrast, the blue-glazed sample from Beylagan contains Co in its glaze.

Thus, part of the study's objectives has been addressed. Future archaeological research in pottery workshops will be essential for resolving other issues related to stonepaste production. Furthermore, analysing stonepaste from other cities in Azerbaijan would provide a more precise understanding of the subject.

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