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LIMESTONE QUARRY OF SINOPE IN THE LIGHT OF ARCHAEOMETRIC ANALYSES*

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Abstract: Sinope, an important trade city in the Black Sea region, owed its prosperity to its strategic geopolitical location in Ancient Periods. Many monumental structures with different functions were built in the city. Spolia and various ancient architectural fragments discovered through scientific excavations and surveys suggest the presence of significant quarries in the region. Macro-analyses of these fragments indicate that a limestone type with a granular-texture was predominantly used. However, until now, no detailed analysis or archaeometric studies have been conducted to examine the chemical properties of this limestone. This study aimed to determine the chemical properties of this limestone and where it may have been obtained through archaeometric methods. Samples were collected from architectural fragments, such as column shafts and geison blocks, exhibited in the garden of the Sinop Archaeology Museum, as well as from the natural rock formation known as ‘Sayarkası’, located 65 km west of Sinop, which was likely used as a quarry in antiquity. ED-XRF and PSA analysis were conducted to determine the chemical compositions of these samples. The results revealed that the chemical compositions of the column shaft and geison block samples closely matched those of the Sayarkası samples. These findings suggest that the stone used in Sinope’s construction activities was sourced from the Sayarkası Quarry (Stephane), highlighting the strong trade relations between Sinope and Stephane.

ARKEOMETRİK ANALİZLER IŞIĞINDA SİNOPE’NİN KİREÇTAŞI OCAĞI

Öz: Antik Dönem’de Sinope stratejik ve jeopolitik konumu sayesinde Karadeniz’de önemli bir ticaret kentidir. Kentte Antik Dönem boyunca farklı işlevlere sahip birçok anıtsal yapı inşa edilmiştir. Bilimsel kazılar ve yüzey araştırmalarıyla keşfedilen devşirme malzeme ve çeşitli antik mimari parçalar, bölgede önemli taş ocaklarının varlığına işaret etmektedir. Bu parçaların makro analizleri, ağırlıklı olarak taneli dokuya sahip bir kireçtaşı türünün kullanıldığını göstermektedir. Ancak şimdiye kadar bu kireçtaşının kimyasal özelliklerini incelemek için detaylı analizler veya arkeometrik çalışmalar yapılmamıştır. Bu çalışma, bu kireçtaşının kimyasal özelliklerini ve nereden elde edilmiş olabileceğini arkeometrik yöntemlerle belirlemeyi amaçlamaktadır. Örnekler, Sinop Arkeoloji Müzesi bahçesinde sergilenen sütun gövdesi ve geison bloğu gibi mimari parçaların yanı sıra Sinop’un 65 km batısında yer alan, olasılıkla Antik Dönem’de

taş ocağı olarak kullanılan ve ‘Sayarkası’ olarak bilinen doğal kaya oluşumundan toplanmıştır. Bu örneklerin kimyasal bileşimlerini belirlemek amacıyla ED-XRF ve PSA analizleri gerçekleştirilmiştir. Sonuçlar, sütun gövdesi ve geison bloğu örneklerinin kimyasal bileşimlerinin Sa-

yarkası örnekleriyle yakından ilişkilidir. Bu bulgular, Sinope’nin inşaat faaliyetlerinde kullanılan taşın Sayarkası Taş Ocağı’ndan (Stephane) temin edildiğini göstermekte ve Sinope ile Step-hane arasındaki güçlü ticari ilişkileri vurgulamaktadır.

Introduction

Sinop is a coastal city on the Black Sea coast of Türkiye, located at the junction of the peninsula called ‘Boztepe’ with the mainland. Based on archaeological research conducted to date, it is generally understood that Sinop has been continuously inhabited from the Chalcolithic period to the present day. The city is of significant historical importance, having attracted the attention of nearly every civilization due to its strategic location, natural beauty, and sheltered harbors. In antiquity, Sinop was located within the Paphlagonia region and exhibited a notable urban profile characterized by the coexistence of local and foreign cultural elements, political influences, and economic activities, largely due to extensive commercial interactions with various cultures over time. In the Ancient period, the city was referred to as Sinope, and it is believed to have been founded as a colonial city by settlers from Miletus,¹ a prominent city-state in Western Anatolia, around the 8th century BCE. It played a central role in Black Sea trade due to its natural harbors and geopolitical significance, and it was distinguished by its well-planned urban layout and architecture. However, the ancient urban fabric of the city has suffered significant damage since Late Antiquity, particularly during the Seljuk Empire, when many ancient structures were repurposed as spolia. This destruction has hindered a full understanding of the city’s buildings and architecture. Nevertheless, ancient writers’ accounts suggest that Sinope featured an advanced urban design. For example, Ancient geographer Strabo provides the following important description of the city:² *“Higher up, however, and above the city, the ground is fertile and adorned with diversified market-gardens; and especially the suburbs of the city. The city itself is beautifully walled, and is also splendidly adorned with gymnasium and market-place and colonnades.”* In 1826, French geographers visiting the city also offered valuable insights into the use of spolia:³ *“During the construction of the city walls, the Turks used more than two thousand marble and granite columns from the agora and gymnasium as spolia.”* These researchers also mapped the locations of significant ancient public buildings, such as the agora, nymphaion, and temples, situated on ‘Boztepe’ in Sinope.⁴

Based on the information provided by ancient writers and geographers, it is evident that the city hosted numerous monumental public buildings. Although many of these structures have not survived, various architectural fragments uncovered through excavations and surveys, as well as spolia incorporated into the city walls, offer crucial insights into the city’s ancient architecture. Architectural fragments used as spolia are found not only in the city walls but also in the form of bases, columns, capitals, architraves, friezes, geison blocks, and sarcophagi with their lids, all of which are displayed in the garden of the Sinop Archaeology Museum. When observing the primary building materials such as stone or marble used in the ancient structures of the city, it is apparent that different stone types were employed. Macro-analysis of these architectural fragments has revealed that a limestone with a granular texture was predominantly used⁵ (Fig. 1: a-b).

¹ Strabo: XII. 3. 11; Greaves, 2002: 104-109.

² Strabo: XII. 3.11.

³ Journal des Voyages, 1826: 261-262.

⁴ Journal des Voyages, 1826: 257-263.

⁵ Yıldırım, 2020a: 178-186; Yıldırım, 2020b: cat. nos. 1-11.



Fig. 1: a-b. Granular textured limestone examples from Sinop Archaeology Museum

The widespread use of this limestone in Sinope's ancient architecture suggests the proximity of a quarry, which likely served as the primary source of this stone, used not only in construction but also in burial practices. The substantial presence of this material in both public and ritualistic spaces indicates its integral role in the city's development. However, until now, no detailed analyses or archaeometric studies have been conducted to examine the chemical properties of this limestone. Given this gap in research, the purpose of the current study is to analyze the chemical composition of the limestone and identify its likely source. To achieve this, samples were collected from two archaeological fragments exhibited in the garden of the Sinop Archaeology Museum. These two samples were chosen due to their distinctive forms and decorative features, which are representative of the stone types and styles used in Sinope's ancient buildings.

1. Samples for Analyses

The first sample was collected from an unfinished column shaft,⁶ which stands 2.18 meters tall and features spiral flutes (Fig. 2: a). This shaft, although still in its incomplete state, serves as an important representation of the architectural style and stoneworking techniques employed during the period. The second sample was taken from a geison block,⁷ a type of architectural element that forms part of the cornice in Ancient architecture. The block measures 71 cm in length, 50 cm in width, and 68 cm in height, and is adorned with intricate decorative elements. These include an anthemion, bead-and-reel moulding, consoles decorated with acanthus leaves, and cassettes featuring Medusa heads and poppy capsules⁸ (Fig. 2: b). This sample is significant because of its detailed sculptural decoration, which helps identify it as part of a high-quality architectural ensemble.

⁶ Museum inventory no.: 4.4.09.

⁷ Museum inventory no.: 13.26.70.

⁸ Yıldırım, 2020c: cat. no. 11.



Fig. 2: a-b. Column shaft and geison block from Sinop Archaeology Museum

Where could this limestone have been quarried? The limestone used in the construction of the ancient buildings in Sinope may have been quarried at Sayarkası, a site located along the coastline within Çaylıoğlu Village, in the Ayancık District, approximately 65 km west of Sinop. This area is the nearest natural rocky formation to Sinope that likely served as a quarry in antiquity. The Sayarkası Quarry is particularly notable due to the discovery of numerous semi-finished architectural fragments, including bases, columns, capitals, and sarcophagus fragments, which strongly suggest that the site was actively used for quarrying and stoneworking during Ancient periods.

To gain a clearer understanding of the quarry's role in the architectural development of Sinope, and to compare its material to the limestone samples from the Sinop Archaeology Museum, three representative samples were collected from Sayarkası. These samples, referred to as the 'Sayarkası samples', were chosen because they show clear evidence of stonemasonry traces on their surfaces, indicating they were semi-finished blocks prepared for further carving or construction (Fig. 3: a-c). The Sayarkası samples will provide valuable data that can be compared with the samples from the museum, contributing to a better understanding of the geological properties, chemical composition, and workmanship associated with the limestone used in the ancient architecture of Sinope.



Fig. 3: a-c. Sayarkası samples

Energy Dispersive X-ray Fluorescence (ED-XRF) analysis was employed to determine the elemental composition and concentration of all the samples. This non-destructive technique allowed for the precise identification of the elements present in the samples and their respective concentrations. Each sample was analyzed in its natural form without any dilution, ensuring that the data accurately represented the original material's composition. In addition to the ED-XRF analysis, Particle Size Analysis (PSA) was conducted on the column shaft and Sayarkası samples. The PSA provided insights into the particle size distribution of the samples, including the median, mean, and mode particle sizes.⁹

2. Results of Analyses

a. Column Shaft Sample

- **ED-XRF Analysis:** Calcium is the predominant element in this sample, constituting 67.39% of the composition. Other elements detected in lower concentrations include silicon (0.6057%), sodium (0.589%), magnesium (0.4547%), iron (0.3212%), aluminum (0.2498%), strontium (0.07895%), and nickel (0.0463%) (Tab. 1).
- **Particle Size Analysis (PSA):** The median particle size is 9.08 μm , the mean particle size is 12.69 μm , and the mode particle size is 10.78 μm . The transmittance rate, which measures the amount of light passing through the sample, is 81.2% (Tab. 2)

b. Geison Block Sample

- **ED-XRF Analysis:** Like the column shaft sample, calcium is the most abundant element at 67.86%. Other notable elements include sodium (0.567%), silicon (0.4907%), magnesium (0.4518%), iron (0.2606%), aluminum (0.2220%), strontium (0.07895%), and nickel (0.0427%) (Tab. 1).

c. Sayarkası Samples

- **ED-XRF Analysis:** Calcium concentrations are also dominant in these samples, ranging from 66.44% to 67.10%. Silicon is the second most abundant element, with concentrations ranging from 0.634% to 1.039%, while sodium, magnesium, iron, aluminum, strontium, and nickel are present in much lower concentrations (Tab. 1).
- **Particle Size Analysis (PSA):** The median particle size is 12.06 μm , and the mean particle size is 34.58 μm , which is larger compared to the column shaft sample. The mode particle size is 10.77 μm , and the transmittance rate is 82.5%, which is quite similar to the column shaft sample (Tab. 2).

Table 1. ED-XRF Analysis Results

Symbol	Elements	Column shaft	Geison block	Sayarkası	Sayarkası	Sayarkası
Ca	Calcium	67.39%	67.86%	67.04%	66.44%	67.10%
Si	Silicon	0.6057%	0.4907%	0.6342%	1.039%	0.7045%
Na	Sodium	0.589%	0.567%	0.658%	0.534%	0.610%
Mg	Magnesium	0.4547%	0.4518%	0.5937%	0.3953%	0.3900%
Fe	Iron	0.3212%	0.2606%	0.3385%	0.4840%	0.3778%
Al	Aluminum	0.2498%	0.2220%	0.2837%	0.3759%	0.2829%
Sr	Strontium	0.06857%	0.07895%	0.07892%	0.09963%	0.09186%
Ni	Nickel	0.0463%	0.0427%	0.0462%	0.0483%	0.0528%

⁹ All of the analyses in question were carried out at the Izmir Institute of Technology Integrated Research Centers Analysis Laboratory, with samples bearing tracking numbers RÜZMER-T6388401 and MAM-T6368801.

Table 2. PSA Analysis Results

	Median size (μm)	Mean size (μm)	Mode size (μm)	Transmittance
Column shaft (NY-4)	9.08876	12.69028	10.789	81.2%
Sayarkası (NY-1)	12.06355	34.58606	10.7778	82.5%

3. Conclusion from the Analyses

- The calcium concentration across all samples (column shaft, geison block, and Sayarkası) remains remarkably consistent, around 67%, suggesting that these samples likely originate from the same geological source.
- The elemental composition, including the trace amounts of silicon, sodium, and other metals, shows minimal variation between the different sample types.
- The Particle Size Analysis (PSA) indicates that while there are slight variations in particle size, particularly between the Sayarkası samples and the column shaft sample, these differences are not substantial enough to contradict the idea that these materials are from the same region or quarry.

4. Comment

The identification of the stones and quarries used in ancient Sinope is crucial for understanding the construction techniques and material sources of the city's architectural heritage. The Sayarkası quarry, located in the Çaylıoğlu Village within the Ayancık District, approximately 65 km west of Sinope, is likely the primary source of the stone used in the region's ancient structures¹⁰ (Figs. 4-5). Surveys and geological studies indicate that the quarry, covering an area of about 2.5 km², has been continuously active, with stone extraction still occurring today.

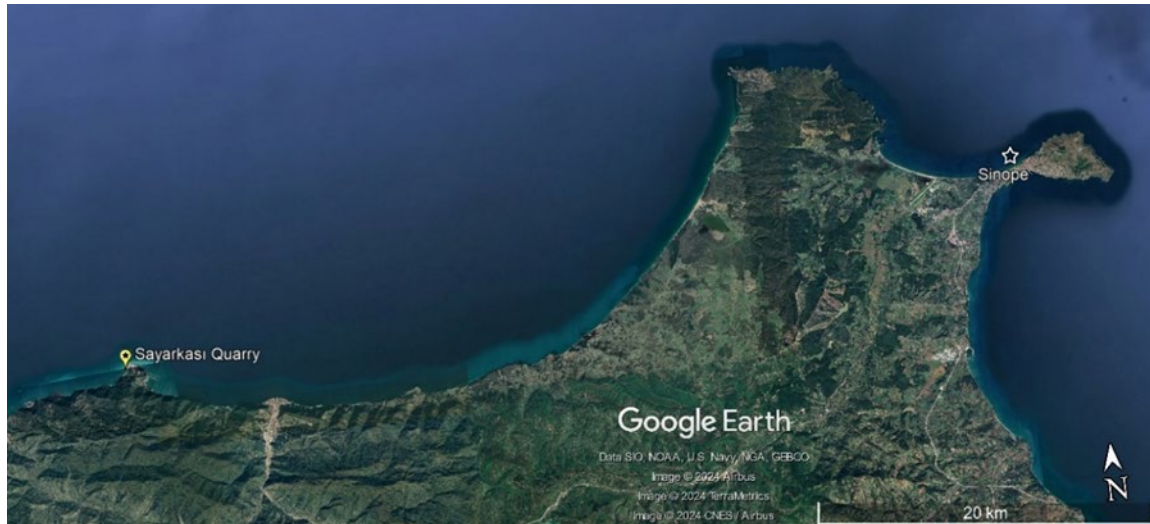


Fig. 4. Map showing the distance between Sayarkası Quarry and Sinope

The Sayarkası quarry is part of the 'İstefan (Usta Burnu) Limestone Member of the Kusuri Formation', which dates back to the Middle Eocene, approximately 56 to 33.9 million years

¹⁰ Gür and Köroğlu, 2023: 36-37.

ago.¹¹ The upper levels of the formation are represented by ‘shallow marine limestones’, and these rocks are geologically defined as follows:¹²

“The limestones observed in the northwest, near the seaside, generally have a granular-texture. The grains, typically ranging in size from 1 to 3 mm, are set in a sparitic matrix and are in direct contact with one another. A significant portion of the limestone grains in this section (90%) consists of intraclasts, 5% fossils, and 5% terrigenous material. The terrigenous material is dark gray, occasionally black, and is likely of clay or volcanic origin. However, the terrigenous component increases to nearly 50% as the formation approaches the clayey units toward the southeast. Since the grains are arranged in such a way that they are in contact, the units in this area exhibit ‘granular-texture stone’ characteristics.”



Fig. 5. Sayarkası Quarry

The limestone’s granular texture and high calcium content are significant because they make the rock suitable for use in construction. The characteristics of this stone, especially its mechanical properties and ease of extraction, likely contributed to its widespread use in architectural applications during antiquity. This quarry’s proximity to Sinope and the favorable geological properties of its stone would have made it an essential source for the stone used in the construction of monumental structures in Sinope. These findings help clarify not only the local sourcing of materials but also shed light on the quarrying practices and construction methods of the time.

The presence of cutting stone blocks, steps, and channels in the region (Figs. 6-8), along with rock surfaces marked by stonemason tools, offers compelling evidence that the area was actively used as a quarry¹³ (Figs. 9-10). These marks and traces suggest that the quarrying process was carried out in this location, likely for several centuries, with the tools and techniques

¹¹ Janbu et al. 2007.

¹² Çelik, 2013: 17-19.

¹³ Gür, 2023: 56-64.

of ancient stonemasons clearly reflected in the evidence left behind. Such traces are instrumental in confirming that the site not only served as a quarry but also as a workshop for crafting architectural components. Furthermore, the discovery of semi-finished blocks—including sarcophagi, bases, columns, and capitals—with visible signs of stonemasonry on their surfaces further emphasizes the dual role of the site as both a quarry and a place where stone products were shaped and prepared for use in construction (e.g., bases and columns being partially carved but not yet finished).



Fig. 6. Traces of cutting stone blocks from Sayarkası Quarry



Figs. 7-8. Traces of cutting stone blocks from Sayarkası Quarry



Figs. 9-10. Rock surfaces marked by stonemason tools from Sayarkası Quarry

These findings are crucial because they suggest that this quarry was not only a source of raw material but also a workshop where skilled laborers crafted stone pieces for Sinope and potentially other ancient cities. The connection between this quarry and Sinope is significant for understanding the architectural development of the city, as well as the quarrying operations that supported its growth and prosperity. The ED-XRF and PSA analysis results from samples taken from both the quarry and architectural fragments found in Sinope reinforce the hypothesis that this quarry was likely the primary source of the stone used in the construction of many important buildings in the city.

The ED-XRF analysis results indicate that calcium is the dominant element in all Sayarkası samples, with a concentration of approximately 67%. The levels of silicon, sodium, magnesium, iron, and aluminum in these samples are consistently low, generally below 1% (see Tab. 1). This mineralogical profile identifies the rocks from Sayarkası as granular-textured limestone, which is characterized by its high calcium content. These rocks are typically hard to medium hard, with a beige or off-white color and a crystalline luster.¹⁴

Similarly, the column shaft and geison block samples exhibit very similar results. In the column shaft sample, calcium makes up 67% of the composition, with the other elements, including silicon, sodium, magnesium, iron, and aluminum, all present in concentrations below 1%. These proportions are almost identical to those found in the Sayarkası samples. The same trend is observed in the geison block sample, where calcium again constitutes 67%, and the levels of other elements are similarly low, with no significant variation from the Sayarkası samples. Given the similarity in elemental composition and the high concentration of calcium, it is clear that both the column shaft and geison block are composed of high-calcium limestone, very much akin to the material sourced from the Sayarkası quarry. This suggests that the stone used in these architectural components, like that found in Sayarkası, was a granular-textured limestone, reinforcing the idea that Sayarkası could have been the primary source of the material used for constructing important buildings in Sinope.

The Particle Size Analysis (PSA) conducted on the Sayarkası and column shaft samples also yielded highly similar results. Specifically, the mode particle size values for the Sayarkası and column shaft samples were nearly identical, measuring 10.77 μm and 10.78 μm , respectively. These values suggest that both samples exhibit comparable granular characteristics. Additionally, the light transmittance rates for both sets of samples were very close, ranging from 82.5% for the Sayarkası sample to 81.2% for the column shaft sample (see Tab. 2). The small variation

¹⁴ Çelik, 2013: 17.

in transmittance rates further reinforces the similarity in the structure and properties of the two materials, particularly in terms of optical properties.

Given the similar elemental ratios obtained from the ED-XRF analysis and the comparable particle size distributions and light transmittance rates from the PSA analysis, it is reasonable to conclude that the Sayarkası quarry was likely the source of the ancient architectural fragments. The proximity of Sayarkası to Sinope further supports this hypothesis, indicating that this quarry may have been the primary supplier of stone materials for construction activities in Sinope.

The traces of stonemasonry and the numerous semi-finished architectural fragments found at the Sayarkası quarry suggest that the site functioned as both a quarry and a workshop for producing various architectural elements. Craftsmen working at the quarry likely used wooden wedges¹⁵ to extract the stone blocks from the bedrock. Once extracted, the stone blocks were roughly shaped to reduce weight, minimize damage during transport, and lower overall costs. This would have been crucial, as transporting large stone blocks over long distances in antiquity was a labor-intensive and expensive process. To ease the transportation of these materials, the blocks were likely semi-finished products, such as bases, column shafts, Corinthian capitals, and sarcophagus lids. These rough forms would have been further carved and decorated at the construction sites, where artisans could add detailed carvings and ornamental elements to the stone pieces.

Given the proximity of the quarry to the coast, sea transport would have been the most practical and cost-effective option for moving the materials to Sinope (Fig. 4). Compared to overland transport, which posed greater logistical challenges, sea routes offered distinct advantages in terms of safety, ease, and efficiency. The use of coastal shipping would have allowed for swift and secure delivery of the stone materials, facilitating their timely arrival at construction sites and contributing to the architectural development of Sinope. This efficient transportation system, combined with the quarry's output of semi-finished architectural pieces, highlights the central role of the Sayarkası quarry in supplying materials for Sinope's ancient construction projects.

The quarry and workshop likely remained active from the Ancient period until the end of the Ottoman period. This is supported by the historical fact that, following the 1923 population exchange, the Greek stonemasons from the Saraylar settlement (known as 'Palatia' on Marmara Island), who had worked in the quarries, were replaced by masons from Ayancık—likely sourced from this quarry.¹⁶ This continuity suggests that the quarry was a prominent source of stone throughout antiquity and that a long-standing tradition of stoneworking existed in the region. This long history of quarrying and craftsmanship not only highlights the significant role of the Sayarkası quarry in architectural production but also reflects the enduring cultural and economic ties between different periods, showing the importance of this quarry in both local and broader historical contexts.

The settlement where the quarry is located, known in antiquity as 'Mariandyn, Stephanos, Stephane, or Istefan',¹⁷ was a coastal town with a harbor and abundant forested lands, making it a key hub for maritime activities and timber production for shipbuilding.¹⁸ Archaeological surveys in the region have uncovered ceramics dating from the Early Bronze Age to the Hellenistic, Roman, and Byzantine periods.¹⁹ At the highest points of Usta Burnu, particularly in

¹⁵ Gür and Köroğlu, 2023: 42.

¹⁶ Asgari, 1978: 469; Beykan, 2004: 15; Albustanlıoğlu, 2006: 8.

¹⁷ Gür and Köroğlu, 2023: 37-41; Gür, 2023: 47-49.

¹⁸ Timor, 1999: 128-130.

¹⁹ French, 1986: 488-490, fig. 1.

areas known as ‘Doğu Giranüstü and Dikkaya,’ evidence of a fortress, necropolis, and residential buildings has been found. These are likely the homes of craftsmen who worked at the quarry.²⁰

Given that both Sinope and Stephane were important harbor cities, it is plausible that they maintained strong social and cultural connections throughout antiquity. These connections were likely reinforced by intensive commercial and architectural interactions, facilitated by the shared use of resources such as the quarry at Sayarkası. The proximity of these cities and the mutual reliance on trade and building materials would have contributed to the development of a robust relationship, particularly in the realms of construction and artistic endeavors.

Conclusion

Sinope, an important trading city on the Black Sea, flourished due to its strategic location and access to extensive maritime trade routes. Its rich architectural heritage, marked by monumental structures, suggests that quarrying played a crucial role in the city’s development. Despite archaeological evidence of the use of limestone in Sinope’s buildings, limited research has been conducted to identify the specific quarries that supplied the stone. This study provides compelling evidence that the limestone used in the monumental architecture of Sinope was sourced from the Sayarkası Quarry (Stephane). Through the application of ED-XRF and PSA, the chemical properties and particle size characteristics of limestone samples from both the quarry and architectural fragments were shown to be closely aligned. These findings suggest that Sayarkası was a vital quarry for Sinope, and the transport of materials likely relied on maritime routes due to the quarry’s coastal location. The continuity of quarrying and stoneworking practices, supported by historical and archaeological records, highlights the significant role of Sayarkası in Sinope’s architectural development.

The results of this study contribute to our understanding of the quarrying practices in the ancient city of Sinope, shedding light on the trade and cultural relationships that underpinned its architectural heritage. The long-standing tradition of stoneworking in the region and the continued use of Sayarkası as a quarry until the end of the Ottoman period underscore its enduring importance to the city and its surrounding settlements.

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²⁰ French, 1986: 488; Gür and Köroğlu, 2023: 41-43; Gür, 2023: 49-54.

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Araştırmacıların Katkı Oranı Beyanı: Araştırmacılar makaleye eşit oranda katkı sağlamışlardır.

Çıkar Çatışması Beyanı: Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.