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Journal of Ancient History and Archaeology No. 8.1/2021
COMPOSITIONAL ANALYSIS
ANALYSIS OF THE POTTERY
SHARDS FROM KUH-I KHAWJA
HISTORICAL SITE, SISTAN, EAST
OF IRAN

Abstract: The aim of this study was to determine whether pottery shards from Kuh-i Khawja were locally made or imported. Kuh-I Khawja is one of the most ancient settlements in Iran's Sistan during the Sassanid period. The study shows that the antiquity of the site goes back to the 3rd to 8th centuries CE and the earthenware found in Kuh-I Khawja can be categorized into four groups which are i) Plain unglazed pottery; ii) Unglazed painted pottery; iii) Plain glazed pottery; iv) Glazed and painted pottery. Archaeologists believe that most of the pottery shards are locally made; hence, to test this hypothesis, a scientific analysis was done to determine the chemical composition of the pottery shards. X-Rays Fluorescence (XRF) was applied to determine the major and trace elements of the pottery shards. The results demonstrate that most of the pottery shards are in the same group and this strongly suggests that they are local products. Additionally, based on the major and trace elements, it can be suggested that some of the samples were imported items.

Keywords: Kuh-I Khawja, Sistan, Sassanian, X-Rays Fluorescence (XRF).

INTRODUCTION

Sistan is located in a vast territory in the south east of Iran, and a large part of it today is in Afghanistan. The Sistan region, along with Baluchestan, constitutes the Sistan and Baluchestan Province of Iran1. Kuh-I Khawja is the one and only elevated condition in Sistan plains, located 30 kilometers away from the city of Zabol (Map 1). The complex consists of Islamic and pre-Islamic structures, which are considered to be Iran's most prominent adobe monuments2.

Like other ancient Iranian Lands, the foundation of Sistan is also rooted in myth and history. Kuh-I Khawja is only mountain on the extensive plain of Sistan that has had a special sanctity for at least three religions, Zoroastrianism, Christianity and Islam. On the other hand, the natural attractions of Hamun Lake, with its green grass, favorable weather and the possibility of hunting different kinds of birds and aquatic animals has attracted the attention of rulers and powerful people. The complex consists of Islamic and pre-Islamic structures, which are considered to be Iran's most prominent adobe monuments.

2 SARHADDI-DADIAN 2013.
ARCHEOLOGICAL BACKGROUND

The first studies conducted on Kuh-I Khawja were mostly geological surveys, which was conducted by a British military officer, Goldsmid in the second half of the 19th century. But the first serious step in identifying was taken by the Hungarin-English archaeologist Aurel Stein in 1915, he included the results of his studies and excavation in his well-known work, Innermost Asia. After that, Ernst Herzfeld, German archaeologist continued to explore the Kuh-I Khawja in 1925, he visited the site and, four years later, returned with a board to study and survey this place. His final work was published in 1941 in the book Iran in the Ancient East. The third scientific work, after Herzfeld’s work at Kuh-I Khawja, was conducted by Italian board supervised by Giorgio Gullini in 1961, whose results were published in a book Kuh-I Khawja.

The fourth scientific archaeological work was undertaken by an Iranian team, and since then, Iranians have been able to bring the exploration on Kuh-I Khawja under own control. Initially three short-term exploratory excavation 1982-1987 under the supervision of Seyed Mahmoud Mousavi were conducted with the aim of training students in archaeology. In 1997 the archaeological team of Shahri Sukhta, let by Syyed Mansour Seyyed Sajjadi worked on this complex but unfortunately, the related reports have not been published yet. Then Sorur Ghanimati studied and researched the ancient palace of this mountain, and the latest research has been done in August 2018 by authors.

According to architectural evidence, Herzfeld assumes that Kuh-I Khawja palace at least two construction phases. He argues that the first stage relates to in the 1th century CE, and the second stage relates to the 3th century CE, the early Sasanid Dynasty. After more than three decades, Gollini started to work in this complex and introduced six consecutive layers of settlement from the Achaemind period to the Islamic era. Of course, archaeologists did not accept Gollini's dating and he was faced with a wave of criticism.

Based on 14C tests, Sorur Ghanimati attempted to provide an absolute date for the entire sites. She collected the samples from two distinct areas; the first sample was obtained from mortar and other structural materials belonging to the ceiling of the gallery, and the second sample was taken from a wooden nail used in bas-relief in the southern façade of the ceiling of the gallery, and the second sample was taken from mortar and other structural materials belonging to the external part of the wall with a semicircular plan and in a conical shape. The structure of these towers is uniform; they have been built not based on a determinate order in the external part of the wall with a semicircular plan and in a conical shape. The structure of these towers is uniform, and they are located on the external part of the wall in not so orderly form. The thickness of the tower in the base was almost 2 half meter and as the height of the tower increases this thickness gets lower in so far as in the highest part. The general form of the tower was semicircular and like the structure of the fort a clay wall has been used on the foundation and in higher levels of the tower, adobes might have been used. Inside this clay wall has been filled with mud, dust and other stuffs. In other words, the tower itself was not built fully of the clay wall rather its external body as well as its lower part has been built from the pure clay wall and then the clay and adobe have been used as the thick crust of the tower and its inside has been filled. These towers had been used as supporting walls for the fort. There was an entrance with narrow width of 50 to 60 cm from the top of the wall into the small internal space of the tower and the remnants of this entrance can only be found in the tower number 1, i.e. the far eastern tower in the fort. Tower number 1 is enumerated as the most complete discovered tower from the point of view of the structure and from the other third towers only part of the remnants and structure exists that generally includes the lower parts. But

In the last season of the exploration on external wall of the site has been done by authors in this part 4 cone-shaped tower were identified throughout the fence. Although it seems that the total number of the watchtowers had been more that the identified ones, only the remnants of these fourth towers were discovered and the rest of towers were destroyed in the course of time. The structure of these towers is uniform; they have been built not based on a determinate order in the external part of the wall with a semicircular plan and in a conical shape. The structure of these towers is uniform, and they are located on the external part of the wall in not so orderly form. The thickness of the tower in the base was almost 2 half meter and as the height of the tower increases this thickness gets lower in so far as in the highest part. The general form of the tower was semicircular and like the structure of the fort a clay wall has been used on the foundation and in higher levels of the tower, adobes might have been used. Inside this clay wall has been filled with mud, dust and other stuffs. In other words, the tower itself was not built fully of the clay wall rather its external body as well as its lower part has been built from the pure clay wall and then the clay and adobe have been used as the thick crust of the tower and its inside has been filled. These towers had been used as supporting walls for the fort. There was an entrance with narrow width of 50 to 60 cm from the top of the wall into the small internal space of the tower and the remnants of this entrance can only be found in the tower number 1, i.e. the far eastern tower in the fort. Tower number 1 is enumerated as the most complete discovered tower from the point of view of the structure and from the other third towers only part of the remnants and structure exists that generally includes the lower parts. But

In the last season of the exploration on external

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3 STEIN 1937.
4 HERZFELD 1941.
5 GULLINI 1964.
we can reconstruct the plan and body of other towers based on the structure of the eastern tower number 1.

**KUH-I KHAWJA POTTERIES**

In Kuh-I Khawja Site; According to coats, being plain or painted, pottery can be categorized into four groups: 1-. Plain unglazed pottery. They are with no design and decoration. In the category, shreds clay is red, red brown, buff, brown, orange, and gray. The slip is buff-colored, red brown, brown, orange, or grey as well. 2-. Unglazed painted pottery. In the category, slip is clayey and the clay itself is red, orange, grey, dark brown, or buff. The pottery of this category can be subdivided into three groups: a. Burnished designed pottery b. Burnished designed pottery c. Polychrome decorated pottery. The decoration themes in this category are of geometrical type. 3-. Plain glazed pottery. In this category, clay is red brown and buff while potteries are glazed in green, blue, and transparent. The potteries are kilned enough while the clay is dense and solid. 4-. Glazed and painted pottery. The category is subdivided into two subcategories, according to decoration: a. Pottery with under glazed incised decoration b. Pottery with under glazed paintings meanwhile, according to color it is subdivided into green and turquoise groups. In this category, decoration themes are of geometrical and floral type.

**SAMPLE PREPARATION**

For the analysis (picture 1), in order to determine the chemical composition of the pottery, each sample of weight 0.7 g was pulverized, heated up at a temperature of 105°C for one hour and mixed until homogenous with the flux powder, a type of Spectroflux 110 (product of Johnson & Mathey).

These mixtures were baked for one hour in a furnace with a temperature of 1100°C. The homogenous molten material was molded in a container and cooled gradually into pieces of fused glass with a thickness of 2 mm and a diameter of 32 mm. The samples were of 1:10 dilution. Press pallet samples were prepared by mixing 1.0 g of samples together with 6.0 g of boric acid powder; then, a pressure of 20 psi (137.895 kPa) was applied using hydraulic pressure equipment. The samples of fused pallets and pressed pallets were analyzed by wavelength-dispersive X-Ray Fluorescence (WD-XRF). A Philips PW1480 sequential spectrometer fitted with a rhodium-anode X-Ray tube (3kW 60kV) was used for the analysis of major and trace elements. The spectrometers were controlled using Philips X40 application software package version 3.2 and 4.01 running under the DEC VMS operating system.

Scatter plot diagrams of CaO versus K\textsubscript{2}O and Rb versus Sr, were then performed to demonstrate the differences among the groups and was analyzed using Microsoft Excel software. The main purpose was to see the distribution of the samples in the group. Hierarchical Cluster Analysis (HCA) was applied to the chemical data from the three components, namely calcium oxide (CaO), potassium oxide (K\textsubscript{2}O), rubidium (Rb) and strontium (Sr). All the 17 pottery shards were sampled in order to verify the presence of compositional groups of pottery shards differentiated by their probable major element sources. The measurement of distance used in the assignment rule was based on Ward’s Linkage and the Squared Euclidean Distance algorithm. The results are presented in the form of a dendrogram (Figures 5 and 6), showing in graphical form the distance between the pottery samples on the basis of their CaO and K\textsubscript{2}O percentage and Rb and Sr concentration. The applicability of the analytical methods for the multi-elemental analysis of the pottery shards by XRF was evaluated using an analysis of certified reference material, 315 Fire Brick (Calibration: G_FBVac28mm) for major elements.

**RESULTS AND DISCUSSION**

XRF

The X-ray fluorescence analysis of the 17 pottery shards samples was conducted to determine the major elements content in the pottery shards from Kooh-e Khajeh (Figure 2). In the compositional analysis, each compositional

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9 RANILJAMALI et alii 2016, 46-47.
The pottery samples show quite homogeneous composition of trace elements except for three samples Kh.3, Kh.10 and Kh.12 which had lower content of calcium. The result clearly shows that the pottery samples have quite homogeneous composition except for three samples Kh.11 ans Kh.12 which had lower content of calcium. The percentage of P₂O₅, Al₂O₃, CaO, Fe₂O₃, MgO, and K₂O, respectively shows content of dry weight percentage from 4 to 67, 1 to 3 and 1 to 2.89%, respectively.

Table 1 shows the content of major element of the pottery shards taken from several potential archaeological sites in Kuh-I Khawja. The pottery samples show quite homogeneous composition except for three samples Kh.3, Kh.10 and Kh.12 which had higher content of calcium. The range of the silica dry weight percentage for shards from the same resources. One group is considering non-local pottery shards or came from different raw material. One group is considering a local production pottery or came from the same resources. One group is considering non-local pottery shards or came from different raw material.

The content of trace elements is shown in Table 2. The result clearly shows that the pottery samples have quite homogeneous composition of trace elements except for three samples Kh.11 ans Kh.12 which had lower content of calcium and iron are from 4 to 11% and 6 to 8%, respectively. Alkaline element such as magnesium, sodium and potassium shows content of dry weight percentage from 4 to 67, 1 to 3 and 1 to 2.89%, respectively. The percentage of P₂O₅, which is average in every shard indicates that none of the shards have been used as a container for some organic materials. The high percentage of CaO in the shards shows that potters in Kuh-I Khawja site used calcareous clays as their main resources.

### Table 1: Content of Major Element of Pottery Shards from Kuh-I Khawja

<table>
<thead>
<tr>
<th>Sample</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>Na₂O</th>
<th>MgO</th>
<th>K₂O</th>
<th>TiO₂</th>
<th>MnO</th>
<th>P₂O₅</th>
<th>LOI</th>
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<tr>
<td>Kh.1</td>
<td>59.35</td>
<td>14.47</td>
<td>7.56</td>
<td>5.41</td>
<td>2.04</td>
<td>4.06</td>
<td>2.82</td>
<td>0.69</td>
<td>0.10</td>
<td>0.33</td>
<td>3.17</td>
</tr>
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<td>Kh.2</td>
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<td>13.90</td>
<td>6.94</td>
<td>8.06</td>
<td>1.43</td>
<td>6.05</td>
<td>2.50</td>
<td>0.65</td>
<td>0.09</td>
<td>0.13</td>
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<td>13.34</td>
<td>6.71</td>
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<td>1.78</td>
<td>5.19</td>
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<td>0.10</td>
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<td>Kh.4</td>
<td>60.12</td>
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<td>6.08</td>
<td>6.94</td>
<td>2.47</td>
<td>5.92</td>
<td>2.11</td>
<td>0.59</td>
<td>0.10</td>
<td>0.13</td>
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<td>4.85</td>
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<td>4.70</td>
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<td>5.57</td>
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<td>0.12</td>
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<td>4.81</td>
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### SCATTER PLOT AND CLUSTER ANALYSIS

Figure 1 show a scatter plot of CaO and K₂O percentage of pottery shards from Kuh-I Khawja.
One group is considering a local production pottery or came from the same resources. One group is considering non-local pottery shards or came from different raw material. Figure 2 show a scatter plot of Rb and Sr which shows that there were also two major group of pottery shards. One group is considering a local production pottery or came from the same resources. One group is considering non-local pottery shards or came from different raw material.

Hierarchinal agglomerative clustering of CaO and K₂O percentage shows that there are three component of groups which are group A that is considered a local production of pottery shards and has significance value below 5; group B is also considered as a local production pottery shard which has significance value below 10 and group C is considered as non-local pottery shards (see figure 3).

Hierarchinal agglomerative clustering of Rb and Sr concentration (ppm) shows that there are three component of groups which are group A that is considered a local production of pottery shards and has significance value below 5; group B is also considered as a local production pottery shard which has significance value below 10 and group C is considered as non-local pottery shards (see figure 3).

CONCLUSION
It can be suggested based on recent studies the site of Kuh-i Khawja goes back to the 3rd to 8th centuries CE and the earthenware found in Kuh-i Khawja can be categorized into four groups which are i) Plain unglazed pottery; ii) Unglazed painted pottery; iii) Plain glazed pottery; iv) Glazed and painted pottery. Based on compositional analysis most of the pottery shards are locally made. A scientific analysis was done to determine the chemical composition of the pottery shards was done X-Rays Fluorescence (XRF) technique and applied to determine the major and trace elements of the pottery shards. The results demonstrate that most of the pottery shards are in the same group and this strongly suggests that they are local products. Additionally, based on the Hierarchical Agglomerative Clustering shows that there was three group of pottery signature, it can be suggested that one of the group was imported pottery items.

<table>
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<th>Sample</th>
<th>Cl</th>
<th>S</th>
<th>As</th>
<th>Ba</th>
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Fig. 5. Scatter plot graph of Sr and Rb (ppm) in pottery shards from Kuh-i Khawja.
Fig. 6. Hierarchical agglomerative clustering of the CaO and K2O percentage of the pottery shards from site Kuh-i Khawja.

Fig. 7. Major elements of pottery shards from Kuh-i Khawja. Hierarchical agglomerative clustering of the Rb and Sr concentration (ppm) of the pottery shards from site Kuh-i Khawja.
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