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PRODUCTION TECHNOLOGY OF IRON AGE POTTERY FROM JNENEH AND TELL ABU AL-KHARAZ, JORDAN

Mayyas, A.[1(*)], Al-Naddaf, M.[2], Khrisat, B.[1], Douglas, Kh.[3,4], Bany-Yaseen, I.[5] & Al-Ajlouny, F.[3]

[1]*Conservation dept., Queen Rania Faculty of Tourism and Heritage, The Hashemite Univ., Zarqa, Jordan,* [2]*Conservation and Management of Cultural Resources dept., Faculty of Archaeology and Anthropology, Yarmouk Univ., Jordan,* [3]*Sustainable Tourism, dept., Queen Rania Faculty of Tourism and Heritage, The Hashemite Univ., Zarqa, Jordan,* [4]*Archaeology dept., College of Arts and Social Sciences, Sultan Qaboos Univ., Al-Khoud, Oman,* [5]*Institute of Earth and Environmental Science, Al al-Bayt Univ., Mafraq, Jordan*
E-mail address: a_s_mayyas@hotmail.com

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***Abstract**:*
The main purpose of this preliminary study is to establish the relationship between the mineralogical and chemical homogeneity of Iron Age pottery vessels from Jneneh in North-Central Jordan and Tell Abu Al-Kharaz in North-West Jordan, as well as to investigate the technological level of production of these vessels found at the two sites. Potsherds were subjected to examination using X-Ray diffraction (XRD), Polarized light microscopy (PLM) and X-Ray fluorescence (XRF), in order to determine the major and minor elements, as well as the mineral content of these potsherds. The results showed high homogeneity in chemical and mineralogical composition in Jneneh potsherds, and this indicates that the mother pottery vessels were manufactured using the same source of raw materials and the manufacturing techniques were not altered with time. Contrarily, high differences in chemical and mineralogical compositions were observed in Tell Abu Al-Kharaz potsherds, leading to the expectation that Tell Abu Al-Kharaz samples were manufactured using different sources of raw materials. The presence of primary Calcite crystals may indicate that the initial firing temperature of all the samples from the two sites did not exceed 800 ^{o}C. In addition, in all the samples, Quartz and Chert were crushed before being intentionally added to the clay used for the pottery production. For the purpose of increasing the clay plasticity and decreasing the shrinkage upon drying, bone fragments (Fluorapatite) were added. Some samples from Tell Abu Al-Kharaz indicated that the source of raw materials used for making pottery vessels came from the Upper Cretaceous deposits based on the presence of Foraminifer microfossils, Planulina Nacatochensis. Furthermore, the occasional presence of basalt-forming minerals such as Augite and Plagioclase in some samples from Tell Abu Al-Kharaz indicates that basaltic grinding tools were possibly utilised for preparing the raw materials of pottery vessels.

1. Introduction

1.1. *Archaeological background*

The northern part of Jordan is rich in archaeological sites, particularly those located along Wadis, such as Wadi Al-Zarqa in North-Central Jordan and along Jordan Valley, which extends from the Sea of

Galilee in the north to the Dead Sea, fig. (1) [1]. Therefore, this part had an effective and prominent role in the creation of human cultures and civilizations that produced many and different types of materials, such as pottery vessels, using different technologies. The Iron Age (IA) is one of these cultures that had flourished and continued for a long period of time. It is worth mentioning that the Iron Age territorial kingdoms started to establish, first, in the northern part of Jordan [2]. Jneneh and Tell Abu Al-Kharaz are examples on the settlements distributed in this part during the Iron Age.

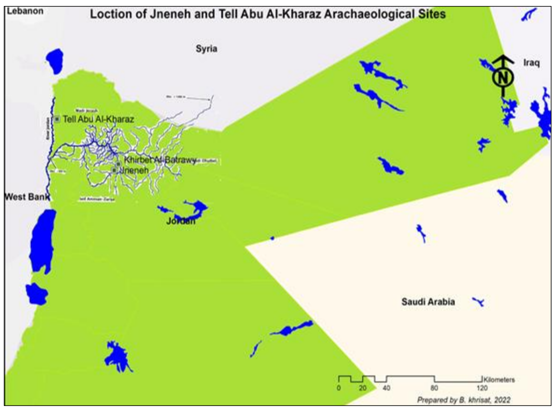


Figure (1) Shows locations of Jneneh and Tell Abu Al-Kharaz

Despite the significance of the Iron Age in Jordan, there is still very little information regarding this period. Only a few pertinent excavations have been conducted thus far, and there are no trustworthy textual materials accessible [3]. What most distinguishes the period of the Iron Age II (1000-539 BC) in Jordan is the emergence of a new political system completely different from the systems that preceded it during the Bronze Age (3600-1200 BC). A number of kingdoms emerged that divided Transjordan into three kingdoms known historically as the Kingdom of Ammon, whose borders extend from Wadi Al-Zarqa in the north to Wadi Mujib in the south, followed by the Kingdom of Moab, which extends from Wadi Mujib in the north to Wadi Al-Hasa in the south, then the Kingdom of Edom, which extends over a wide area in southern Jordan and Palestine. Its northern borders started from Wadi Al-Hasa to Al-Naqab Desert and the Gulf of Aqaba in the south. At the same time, the kingdoms of Israel and Judah appeared in the inner region of Palestine. As for the north of Jordan, Syria and Lebanon the situation was more complicated, as the Aramaic and Phoenician kingdoms existed. Despite the agreement of most archaeologists on the general borders of those kingdoms, the debate still exists about the changes that were taking place on those borders through different periods of time from the Iron Age II period [4-6]. The reason behind that was the conflicts that were occurring between those kingdoms on the one hand. On the other hand, the intervention of some external powers such as the Assyrian and Babylonian empires in the region, which dominated at different parts of the region during different stages and sometimes reconstituted its political system, affected its geopolitical borders. One of the most controversial kingdoms among archaeologists about its borders, extension, and external relationship was the Ammonite Kingdom [5,7,8]. A number of Ammonite cities and settlements were excavated in order to gain more information about the cultural aspects of this kingdom. The excavations at the site of Jneneh served the same goal, especially since it is located on the western bank of Wadi Al-Zarqa, which represents the northern border of Ammon [9,10]. At the same time, the question was about the region to the north of Wadi Al-Zarqa and its geopolitical nature. Unfortunately, the number of archaeological sites that have been excavated from the Iron Age II period in this region is considered small compared to other regions of Jordan. In fact, the area south of Wadi Al-Zarqa in which Jneneh is located, has been relatively better investigated than the area north Wadi Al-Zarqa. The literary resources like the Bible also give us more information about the land known as Ammonite [11]. Jneneh as shown by its material remains is certainly a part of the Ammonite Kingdom [9], whereas our information about Tell Abu Al-Kharaz is not very clear. According to the excavators of Tell Abu Al-Kharaz, the site witnessed a break in settlement sequence after phase VIII of Late Bronze Age. Therefore, they came to the conclusion that the site had new settlers in the next phase. New architectural styles appeared that were even strange to those of other sites in the Jordan valley. In addition to the differences in architecture, there were objects of foreign designs many of which had Philistine, Aegean, Cypriote, Phoenician and Egyptian influences. The scarcity of written evidences concerning the site led the excavators to rely on interpretation of cultural materials although they did not exclude written narratives from the Old Testament [12]. Therefore, the site of Tell Abu Al-Kharaz is considered one of the most important excavated sites in which evidence of a thriving city during the Iron Age II was revealed. Studying the cultural material in both sites, Jneneh and Tell Abu Al-Kharaz, is of particular importance in identifying the extent of similarity or difference in the cultural aspects between the two sites.

1.1.1. Jneneh site

Jneneh lies in North-Central Jordan. It is situated in the North-Western periphery of Al-Zarqa city on the western bank of Wadi Al-Zarqa, fig. (1). The site was discovered in 1993 by G. Palumbo during the Upper Wadi Al-Zarqa/Duleil Archaeological Survey. It was recognized as being a sizable open village [13]. The Hashemite University under the supervision of Khaled Douglas with cooperation of the Department of Antiquities of Jordan carried out an intensive survey and two seasons of excavations in 2011 and 2012. The investigations revealed two main phases of occupation. These are Early Bronze Age I/II (EBA-I/II) and Iron Age II (IA-II). The site was also used as a seasonal camp during the EBA-IV as attested by some few potsherds found on the surface. The intensive survey and the two seasons of excavation produced different types of potsherds and vessels including bowls, jars, cooking pots, kraters, cups, plates, incense burners, lamps and pilgrim flasks. Based on the pottery types and C14 analysis, most of the pottery potsherds and vessels were dated to the IA-II and they constituted a very important collection of Ammonite pottery [9,10,14].

1.1.2. Jneneh geological set up

The site of Jneneh is located on top of deposits that belong primarily to the Upper Cretaceous period, which spans from the Turonian to the Campanian ages. The lithology of the site is represented by the upper Ajlun and Belqa groups, composed primarily of the Wadi as-Sir limestone formation, which predominately consists of limestone with alternating layers of marls, fossiliferous and dolomitic limestone, marls with chert nodules, and oyster beds [15], through the Amman silicified limestone formations, which are made up of massive chert beds (lower strata) with varying layers of fossiliferous, coquinal, phosphatic, and micritic limestone, marl, and chert [15]. At the bottoms of the wadis, close to the sites, recent sedimentary formations accumulated during the Pleistocene. Generally, these formations are made of colluvium rounded gravels and pebbles with a small amount of alternative alluvium layers of clayish fine and coarse sands. The summit of the limestone formation, where the site is located, is generally covered with the red Mediterranean soils (Terra Rosa soils), which incorporate a higher carbonate nodules and fragments at its upper most part [15].

1.1.3. Tell Abu Al-Kharaz site

Tell Abu Al-Kharaz lies in the central Jordan valley in North-West Jordan. It is located north of Wadi Al-Yabis (*Wadi Al-Rayyan*) and ca. 4 km east of the Jordan

River [16]. The site enjoys a very strategic location along an old trade route that links the Dead Sea with the Sea of Galilee. It was first investigated in the 1940s by N. Glueck during his survey in Jordan. Glueck suggested that the site was inhabited during the Iron Age I and II [17]. Later, the site had been revisited by different archaeologists, who confirmed the date of the Iron Age I-II settlement [18-20]. The Swedish-Jordan expedition, under the direction of Peter Fischer and with the cooperation of the Department of Antiquities of Jordan, started investigations with an intensive survey in 1989, followed by sixteen seasons of excavations at Tell Abu Al-Kharaz site. Fisher confirmed that the Iron Age I settlement at the site witnessed a kind of decline compared to the earlier occupation of the Bronze Age. This had been changed completely during the Iron Age II, in which architectural remains, including towers and well-built houses, reflected a progress in economic status, in addition to exquisite finds and imported pottery that belong to this period [21]. In general, excavations produced a large number of stratified potsherds and different complete types of vessels, including rounded, carinated, and straight-sided bowls, incense burners, cooking pots, kraters, goblets, chalices, pilgrim flasks, jugs, juglets, lamps, jars, storage jars, and pyxides. The identification of the different types of vessels was based on their shape and function. Most of the vessels were made on fast wheels; few were made on slow wheels. Very few pieces were hand-made. Cooking pots are the most prevalent group of vessels, accounting for 21.8% of the pottery assemblage. They are also considered the best chronological markers. They were used for cooking foodstuffs and liquids on open fires, mainly grain. It was easy to recognize them because they were characterized by coarse to very coarse fabric, large inclusions, principally, Calcite or sand, and traces of secondary firing on their surfaces. The second common group is the rounded and carinated bowls. They were used as platters or bowls for preparing, eating, and serving. The third most common group of vessels (206/18.6 %) includes jugs, decanter-jugs, strainer-jugs, pilgrim flasks, and juglets. These were used for storing and serving liquids. Jars, which were used for storing liquids and foodstuffs like grain, were the fifth most common group. In general, most of the vessels were produced at the site, and they represent normal Canaanite shapes. However, there are some vessels that look like Egyptian types, but they were produced from local clays. In addition, there are some types like pyxides that show Aegean influences [22].

1.1.4. Tell Abu Al-Kharaz geological set up

The site is located on the Jordan Valley floor, which consists mainly of nonconsolidated alluvial sediments of clays, marls, shales, sands, and gravels. Additionally, extensive deposits and lenses of lake sediments and evaporites, which were precipitated from the antecedents of the current Dead Sea, may be observed, particularly in the southern and western regions of the valley [15,23]. In the northern portion of the Jordan Valley, basalts can be found. Rocks ranging in age from the Triassic to recent are found beneath and laterally enclosing the unconsolidated valley deposits. Different rock types from the Triassic period forward crop out in various locations in the foothills, with their western extensions buried by the more recent valley deposits [15,24].

1.2. *The Iron age II, pottery of the two sites and the study approach*

The period of the Iron Age II differs from the earlier periods in term of the emergence of political entities in the Jordan and Palestine, which were mentioned in various written sources. Despite the scarcity of these written sources, they are considered important in determining the nature of the peoples that inhabited the region. Among those sources are the Bible, the Assyrian and Babylonian writings, in addition to a number of inscriptions that were found in different locations in Jordan, such as the Siran Flask, Mesha Obelisk, and others. Many archaeologists, especially the biblical ones, have tried to link the different archaeological sites that were excavated in Jordan and Palestine to specific races [25-29]. This approach was rejected by other archaeologists, justifying that the archaeological material cannot be conclusive evidence of the ethnicity of the group that produced or used it [30, 31]. However, material culture considered a very important indicator of the different cultural aspects of a society including its social, political, religious, economic aspects as well as the relations with other societies. Pottery is considered one of the most important archaeological evidence that archaeologist rely on in identifying the cultural characteristics of a society, as it is an indicator that has high credibility in revealing the identity of a society and not the ethnicity of that society. In general, studying pottery can reveal the extent of the spread of a particular culture. This can be observed by determining the similarity in the pottery making technique that was used in a geographical area and the similarity in the shape of pottery vessels and the way they are decorated. Pottery is also considered an important indicator in revealing the nature of the commercial relations that linked the ancient societies, by identifying the different types of pottery that are found in the same site, and then determining whether these types were made from local clay or if they came from external sources. Jneneh and Tell Abu Al-Kharaz have yielded abundant Iron Age pottery vessels, which are different from those of other periods in terms of the form, fabric, size, thicknesses, slips, and technical characteristics. It is known that vessel types change frequently with time, and as a result, they can be used for observing the technological development from one time to another [32]. Information concerning different cultural aspects of the past, including selecting the clay raw material and manufacturing technology for pottery vessels, can be explored from this cultural material [33]. This can be achieved based on detailed archaeological and archaeometric investigations. For example, pottery from different regional and temporal sequences can be accurately differentiated from each other and then used to compare other pottery, and this can be accomplished by compositional analyses, including mineralogical and chemical analyses [34]. These two types of analyses are the most applicable methods used to determine the chemistry of ancient artefacts, such as pottery [35]. Therefore, the relationship between the mineralogical and chemical homogeneity of pottery artefacts, and also the technological level of production (for instance, the initial firing temperature) of these artefacts found at the site can be explored using suitable analytical techniques, such as X-Ray fluorescence (XRF), X-Ray diffraction (XRD), and Polarized light microscopy (PLM). These techniques are able to reveal the major and minor elements, as well as the mineral content of the pottery samples. Studying the mineral content and comparing the major and minor elements of pottery samples can provide data on whether these samples were made from the same source or from different sources of raw materials [36-41]. In addition, the initial firing temperature can be evaluated. Therefore, this study was carried out as a preliminary step toward a more comprehensive compositional analytical research that will target larger number of pottery samples from various Iron Age sites located in North-Central and North-West Jordan. The primary goal of this research is to determine the relationship between the mineralogical and chemical homogeneity of Iron Age pottery vessels excavated from Jneneh and Tell Abu Al-Kharaz, as well as to investigate the technological level of production of these vessels found at the two sites, which are located in North-Central and North-West Jordan, respectively. This, in turn, can aid understanding the cultural activities of Iron Age communities, such as the production of pottery vessels. For this study, only twenty pottery sherds from the two sites were available, tab. (1) and were subjected to various types of analyses.

Table (1) Pottery sherds from Jneneh and Tell Abu Al-Kharaz sites

No	Potsherd Code	Square and locus Codes	Sherds description
		Pottery sherds from Jneneh	
1	Jn05	Jn 2011-Sq IA-L015 Loc. type: Ash layer (*fire place*)	Body sherd of large storage jar, thick brown coarse ware, low fired. Inclusions: Limestone. Self-slip.
2	Jn07	Jn 2011-L015-IA Loc. type: Ash layer (*fire place*)	Body sherd of large storage jar, thick brown coarse ware, low fire. Inclusions: Limestone. Self-slip.
3	Jn13	Jn 2011-Sq IB-L008	Body sherd of large storage jar, coarse ware, thin brown, low fire. Inclusions: Limestone. Self-slip. Sherd of medium thickness.
4	Jn15	Jn 2011-Sq IB-L008 Loc. Type: Ash Layer	Base sherd of small jar, coarse ware, outside slip, thin, brown.
5	Jn17	Jn 2011-Sq IB-L012	Body sherd of large storage jar, coarse ware, out-side slip, thick, light brownish gray.
6	Jn20	Jn 2011-Sq IB-L013, A	Body sherd of large storage jar, coarse ware, slip outside, thick, gray.
7	Jn21	Jn 2011-Sq IB-L013, B	Base sherd of large storage jar, coarse ware, out-side slip, thick, light brownish gray.
8	Jn23	Jn 2011-L013, B	Base sherd of large storage jar, coarse ware, out-side slip, thick, brownish gray.
9	Jn24	Jn 2011-Sq IB-L013	Upper part sherd of medium jar with oval horizontal knob handle, coarse ware, outside slip, thin, gray.
		Pottery sherds from Tell Abu Al-Kharaz	
1	TK1	K10-TLVA-L263	Base sherd of possibly large to medium bowl or jar, reddish yellow coarse ware
2	TK2	K10-TLIIIB-L240	Body sherd of medium jar, pink coarse ware
3	TK3	K10-TLIIIA-L226	Base sherd, full with holes on the interior side, thin, yellowish gray coarse ware
4	TK4	K10- TLIVA-L222	Handle sherd of medium jar, thin reddish yellow and gray from inside coarse ware
5	TK5	K10-TLIIIB-L233	Body sherd of large storage jar, thick yellow coarse ware
6	TK6	K10-TLVA-273	Body sherd of krater, coarse, hard-fired, light grey core, light brown fabric, light yellow slip, multi-coloured inclusions,
7	TK7	K10-TLIIA- L213	Body sherd possibly of medium bowl, thin, pink coarse ware with medium to large inclusions
8	TK10	K10-TLIIIB-L206	Body sherd of storage jar, hard-fired, light greyish-brown fabric, light yellow patches of paint, large white inclusions.
9	TK11	K10-TLIIIB-L237	Body sherd of krater, coarse, medium, hard-fired, yellowish-grey fabric, thick, self-slip, mainly grey inclusions.
10	TK12	K10-TLIIIB-L237	Body sherd possibly from medium jar, yellowish gray medium coarse ware
11	TK15	K12-TLIXD-L377-6	Coarse fragile sherd like a mass of dried hard coarse clay, brown to black.

2. Materials and Methods

Twenty Iron Age potsherd samples (nine from Jneneh and eleven from Tell Abu Al-Kharaz) were examined. X-Ray Diffraction (XRD) Polarized Light Microscopy (PLM) and X-ray Fluorescence (XRF) were utilized to characterize the mineralogical and chemical composition of the studied samples. For XRD analysis, thirteen potsherds were selected from the two sites. These were eight from Jneneh (Jn05, Jn07, Jn13, Jn17, Jn20, Jn21, Jn23, and Jn24) and five from Tell Abu Al-Kharaz (TK1, TK2, TK3, TK4, TK5). The samples were selected depending on the diversity among them as revealed by visual examination. From each sample, a sub-sample was taken and ground to less than 80 microns. The mineralogical composition was determined using Phillips XRD diffractometer with Cu Ka radiation available at the laboratories of Al al-Bayt Univ. For PLM examination, 25 petrographic thin sections (4 cm×1.5 cm) were prepared (14 thin sections from Jneneh and 21 from Tell Abu Al-Kharaz) for the twenty potsherds. The preparation procedure was applied according to international standards. The samples were prepared by impregnating each sample with an epoxy resin/hardener under vacuum, and then each sample was cut in the presence of water-free oil to avoid dissolution of water-soluble minerals. Each sample was polished to 30 microns (the standard thickness), covered with a glass slip, and examined with the PLM available at the University of Jordan. Photomicrographs of the samples were taken using the Leitz Labrlux IZ Pols Polarized light microscope and Olympus OM-4Ti camera available in the petrography unit at the Natural Resources Authority (NRA) of Jordan. For XRF analysis, all the twenty potsherd samples were subjected to the analysis. A powder sample was taken from each potsherd and subjected to the analysis. The analysis was performed using Phillips XRF Majex PW-2424, available in the Water, Environment and Arid Regions Research Center at Al al-Bayt University.

3. Results

3.1. *Mineralogical and petrological results*

Visual examination of the potsherd samples taken for this study revealed that these samples lack to geometric patterns, lines, bands, motifs, or any decoration on their surfaces, but most of them have buff or light grey slip. All the samples are related to coarse mother wares. In general, XRD results showed that all the samples from the two sites contain quartz (SiO_2) and calcite ($CaCO_3$). However, Fluorapatite ($Ca_{10}(PO_4)_5CO_3F_{1.5}(OH)_{0.5}$) could be detected in the samples from Jneneh, but only in one sample from Tell Abu Al-Kharaz (TK5), whilst Augite ($(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$) could be only seen in one sample (TK5) from Tell Abu Al-Kharaz, fig. (2-a & b).

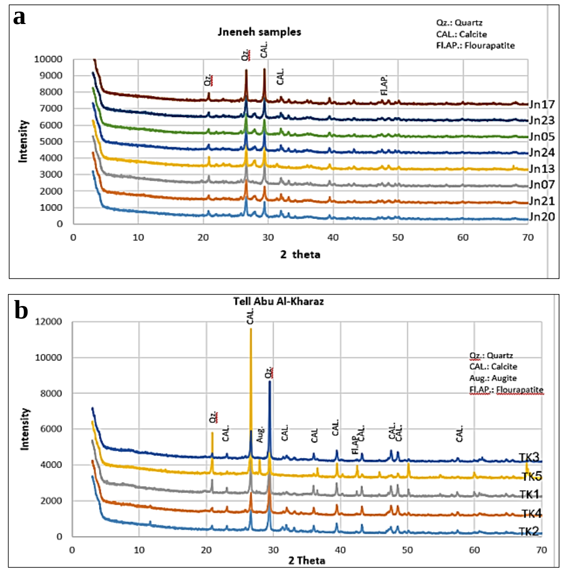
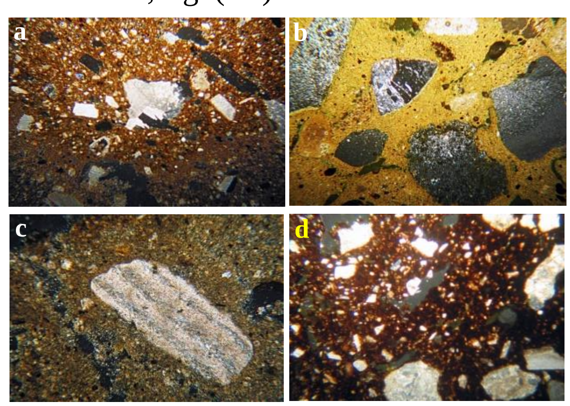


Figure (2) Shows XRD patterns of the potsherds from **a.** Jneneh, **b.** Tell Abu Al-Kharaz

Petrographic investigation showed that in addition to the minerals identified above by XRD, other constituents could be detected under PLM. Pots-herds from Jneneh contain angular calcite, fig. (3-a), angular chert grains, fig. (3-b), bone fragments, fig. (3-c) and fine-grained quartz, fig. (3-d). Potsherds from Tell Abu Al-Kharaz contain many foraminifera fossils, fig. (3-e), angular calcite, angular chert, grog and bone fragments. However, basalt grain (*Plagio-clase and Augite*) was only detected in one sample from Tell Abu Al-Kharaz, fig. (3-f).



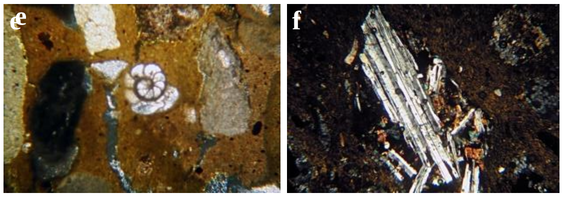


Figure (3) Shows photomicrographs under *XPL* for potsherds from Jneneh and Tell Abu Al-Kharaz; **a.** calcite (X 100), **b.** chert grains (X 100), **c.** bone fragment (X 100), **d.** quartz (X 40), **e.** foraminifera microfossils (X 100), **f.** basalt grain (*Plagioclase and Augite*) (X 100).

3.2. *X-ray fluorescence results*

The chemical composition of the studied samples is shown in tab. (2), as revealed by XRF. In order to determine the degree of homogeneity for the samples from each site, the standard deviation for each constituent in the samples from the same site was calculated tab. (2). In addition, a ternary diagram was drawn, taking into consideration the three major constituents; SiO_2, CaO, and Al_2O_3. The result is shown in fig. (4).

Table 2. Chemical composition (%) of the studied samples as revealed by XRF

Site		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I	total
Jneneh	**Jn05**	42.92	0.61	17.53	4.42	0.04	1.17	17.27	0.71	2.99	4.55	7.82	**100.03**
	Jn07	41.98	0.60	17.12	4.49	0.08	1.24	17.75	0.51	3.05	4.42	8.83	**100.07**
	Jn13	43.21	0.62	16.54	4.27	0.04	1.27	15.58	0.39	3.20	3.97	10.89	**99.99**
	Jn15	37.74	0.48	11.66	3.84	0.03	0.97	14.84	0.58	2.53	4.02	21.37	**98.00**
	Jn17	43.91	0.73	18.76	4.93	0.05	1.77	15.21	0.62	3.62	0.46	9.92	**99.98**
	Jn20	43.89	0.62	17.48	4.90	0.04	1.65	15.69	0.41	2.78	4.14	8.42	**100.03**
	Jn21	41.28	0.59	16.36	4.22	0.04	1.95	16.61	1.02	3.20	3.94	10.75	**99.95**
	Jn23	43.37	0.61	17.41	4.23	0.04	1.17	16.48	0.38	2.82	4.21	9.21	**99.93**
	Jn24	42.71	0.55	15.06	3.94	0.04	1.19	19.35	0.28	2.21	4.38	9.95	**99.65**
	average	42.33	0.60	16.44	4.36	0.04	1.38	16.53	0.54	2.93	3.79	10.80	**99.74**
	StD	1.92	0.07	2.06	0.38	0.01	0.33	1.42	0.22	0.41	1.27	4.10	**12.18**
Tell Abu Al-Kharaz	**TK1**	31.76	0.27	9.40	2.42	0.06	2.51	25.73	0.54	2.89	4.10	20.31	**100.00**
	TK2	30.25	0.29	11.10	2.48	0.05	0.88	28.31	0.85	2.53	4.16	19.02	**99.91**
	TK3	39.48	0.75	9.28	3.59	0.08	0.98	23.30	0.32	2.28	2.02	17.94	**100.03**
	TK4	65.78	0.70	11.01	3.78	0.06	1.22	9.03	0.95	2.09	0.27	5.13	**100.02**
	TK5	33.05	0.31	11.39	2.64	0.05	0.89	25.91	0.57	2.72	3.30	19.09	**99.92**
	TK6	34.45	0.24	10.76	8.63	0.33	0.90	23.27	0.84	1.75	3.97	13.65	**98.80**
	TK7	28.80	0.20	10.13	2.46	0.01	0.77	26.42	0.36	1.71	4.26	22.82	**97.90**
	TK10	54.58	0.92	16.45	6.30	0.02	2.70	7.03	0.53	4.38	0.36	5.63	**98.90**
	TK11	38.60	0.63	12.46	4.89	0.01	1.07	19.70	0.59	2.23	0.23	18.51	**98.90**
	TK12	32.70	0.29	12.12	3.35	0.03	2.45	25.38	1.48	2.28	1.14	18.67	**99.90**
	TK15	27.79	0.27	6.75	9.70	0.29	1.66	26.64	3.06	1.31	0.85	21.48	**99.80**
	average	37.93	0.44	10.99	4.57	0.09	1.46	21.88	0.92	2.38	2.24	16.57	**99.46**
	StD	11.84	0.25	2.40	2.57	0.11	0.75	7.23	0.78	0.81	1.73	5.99	**34.46**

4. Discussion

4.1. *Mineralogy and petrology*

XRD results indicate that the potsherds taken from Jneneh have a homogeneous mineralogical composition in terms of the type of the mineral content and the relative abundance of these minerals, fig. (2-a). They are all made of quartz as a major constituent. Calcite comes in the second place, with a much lower abundance compared to Quartz, and Fluorapatite comes in the third place. Comparatively, Tell Abu Al-Kharaz potsherds labelled TK1, TK2, TK3, and TK4 are all made of quartz as the major constituent, while calcite comes in the second place, and no fluorapatite could be detected in these samples, fig. (2-b). However, sample TK5 showed different relative abundance compared to the other samples from the site. It is mainly made of calcite as a major constituent and contains a considerable amount of quartz and fluorapatite and traces of augite as shown in fig. (2-b). The presence of primary calcite, existed before firing, in all the studied samples indicates that the initial firing temperature of the pottery did not exceed 800 ^{o}C. This is because at a temperature above 800 ^{o}C calcium carbonate decomposes into calcium oxide according to the following equation:

$$CaCO_3 \rightarrow CaO + CO_2$$

Carbon dioxide released from this reaction may cause the destruction of the pottery due to the pressure of the entrapped CO_2 gas, which does not take place if the calcium carbonate content is low. In this case, the produced CaO reacts with water from the atmosphere or from the burial environment to form slaked Lime $Ca(OH)_2$ according to the following equation:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Slaked lime reacts with atmospheric CO_2 to produce $CaCO_3$ according to the following equation:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3$$

However, the optical properties of calcium carbonate produced in this process are different from those of the primary calcium carbonate. The quartz grains detected by PLM in all the studied samples range in size between fine and medium. Many of them show wavy extinction and have angular edges. These observations indicate that quartz was subjected to crushing before being intentionally added to the clay to produce pottery. The Chert fragments revealed by PLM range in size between medium and coarse and have sharp edges, indicating that they were crushed and intentionally added. The presence of bone fragments (*Fluorapatite*) may indicate that they were added to clay to increase its plasticity without the need to add more water; therefore, to decrease the shrinkage upon drying. Foraminifer microfossils, ***Planulina Nacatochensis*** of Upper Cretaceous could be detected in some samples from Tell Abu Al-Kharaz (TK1). The presence of this type of fossil indicates that the source of materials used for producing this pottery came from the Upper Cretaceous deposits [21]. The occasional presence of basalt-forming minerals, such as augite and plagioclase in some samples (TK5), fig. (3-f) may indicate the use of basaltic grinding tools for preparing the raw materials to produce pottery [42,43]. Though, this conclusion needs further samples and more investigation in order to be confirmed.

4.2. *X-ray fluorescence*

It can be seen from tab. (2) that there are significant differences between the concentrations of some constituents present in the samples from each site. The main differences are related to the concentrations of SiO_2, CaO, Al_2O_3, P_2O_5, Al_2O_3 and loss on ignition (LOI). It is well known that the higher the standard deviation, the less homogeneity there is. The calculated standard deviation for each constituent in the potsherds from Jneneh is relatively low. For example, it is 1.73 for SiO_2, 2.6 for Al_2O_3 and 1.38 for CaO. The sum of the standard deviations of all the constituents in the potsherds from Jneneh is only 12.19. On the other hand, the standard deviation for each constituent in the potsherds from Tell Abu Al-Kharaz is much higher. It is equal to 11.8 for SiO_2 and 7.2 for CaO, tab. (2), with a sum of 34.40 for all the constituents of the potsherds. The ternary diagram, fig. (4) shows clear clustering for Jneneh samples and high scattering for Tell Abu Al-Kharaz samples. The high homogeneity in chemical and mineralogical composition of all Jneneh samples may indicate that the source of raw materials used for manufacturing the pottery was the same and the manufacturing techniques were well established and had not changed over time. While Tell Abu Al-Kharaz samples showed significant differences in their chemical and mineralogical composition, either in terms of type or relative abundance. As a result, it is assumed that Tell Abu Al-Kharaz samples were created using a variety of raw materials.

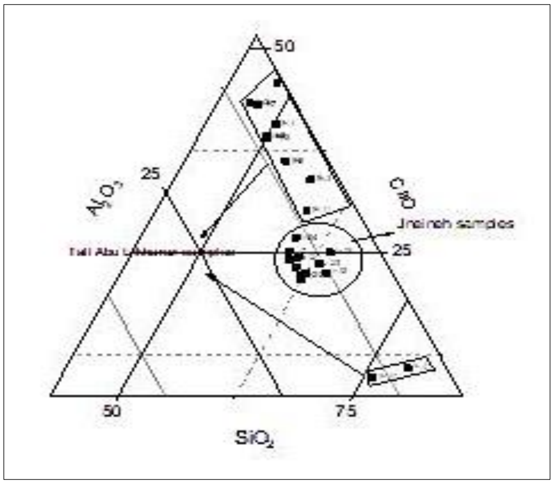


Figure (4) Shows Ternary diagram (SiO_2-Al_2O_3-CaO) with a clear clustering for Jneneh samples and high scattering for Tell Abu Al-Kharaz samples.

5. Conclusion

The relationship between the mineralogical and chemical homogeneity of twenty Iron Age pottery sherds excavated from Jneneh and Tell Abu Al-Kharaz, as well as the technological level of pottery production of vessels found at these sites, were investigated in this study based on the results obtained by PLM, XRD, and XRF. The investigations revealed that all Jneneh pottery samples have high homogeneity in their chemical and mineralogical composition, and this may indicate that the pottery vessels were produced using the same source of raw materials, and the productiobn techniques were not changed over time. Contrarily, Tell Abu Al-Kharaz pottery samples exhibit high differences in their chemical and mineralogical composition, either in terms of type or relative abundance; supposing that Tell Abu Al-Kharaz samples were manufactured using different sources of raw materials. According to Prof. Ali, N. (personal communication, 1. June, 2022), the heterogeneity of the Iron Age potsherds excavated at Tell Abu Al-Kharaz site may be attributed to its location; the site is in a commercially active area, where goods from different locations were traded, in contrast to the site of Jneneh. The strategic location of Tell Abu Al-Kharaz only four kilometres to the east of the Jordan River and at a crossing point between the Sea of Galilee and the Dead Sea and about 80 km. from the Mediterranean, makes it an ideal place as a trade route. The highest point of the site is sixty m. above the places around it. The site has the advantage of overlooking the hills of Nazareth, Beisan, Marj Ibn Amir Valley, and major parts of the Jordan Valley. As a result, its inhabitants can monitor the movements of people in the surrounding area and thus protect their land. It might be said that the heterogeneity of pottery wares from Tell Abu Al-Kharaz site reflects diversities of pottery production centers. The location of the site in the Jordan Valley at a connection of different trade roads reflected such diversities of pottery consumption. Meanwhile, the analysis of pottery corpus at Jneneh shows homogeneity and reflects local production. Such a result might be in accordance with site location and economic practices of the inhabitants of the site. It might be assumed that the site might be economically self-contained and did not benefit from regional and interregional trade network. The study also showed that the initial firing temperature of all the studied pottery samples did not exceed 800 ^oC based on the primary calcite crystals existed before firing. In addition, the study revealed that in all the studied samples, quartz and chert were subjected to crushing before being intentionally added to the clay to produce pottery. The occurrence of bone fragments (fluorapatite) suggests that they were added to clay to increase its plasticity instead of adding more water; and this can decrease the shrinkage upon drying. The presence of Foraminifer microfossils, ***Planulina Nacatochensis*** *of Upper Cretaceous, in some samples (TK1) from Tell Abu Al-Kharaz indicates that the source of materials used for producing this pottery came from the Upper Cretaceous deposits. In addition, the occasional presence of basalt-forming minerals such as augite and plagioclase in some samples (TK5) from Tell Abu Al-Kharaz may indicate the use of basaltic grinding tools for preparing the raw materials to produce pottery. These results, however, need to be confirmed using a larger number of pottery sherds for further investigations, which will be accomplished within the next works of our comprehensive analytical research.*

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