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A DISTINGUISHED GLASS VESSEL EXCAVATED FROM JERASH /GERASA, NORTHERN JORDAN: DAMAGE ASSESSMENT AND ARCHAEOMETRIC STUDY

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ABSTRACT

During the 2019 excavation works carried out by the University of Jordan in cooperation with the Department of Antiquities, at the archaeological site of Jerash, ancient Gerasa, Northern Jordan, a considerable collection of different objects of different materials, typologies and colours were uncovered in a Late Roman – Late Early Byzantine area. A distinguished intact and huge glass vessel was uncovered from this site, obviously subjected to intensive deterioration. X-ray fluorescence spectroscopy (XRF) and optical digital microscopy (ODM) analysis of glass, and surrounding sediment tests were made to characterize and assess the damage and apply proper conservation actions. The results of the present case study indicated that this glass vessel is of soda-lime–silica type corresponding to the previously defined Levantine I glass group, archaeologically dated back to the Early Byzantine period (4th-5th Century AD).

KEYWORDS: Jerash, Gerasa, Excavation, glass, lifting, diagnosis, chemical characterization, deterioration, corrosion

1. INTRODUCTION

The City of Gerasa/ Jerash, north of the capital city of Jordan, was rediscovered in 1806 by the German explorer Ulrich Jasper Seetzen, who was the first to identify the site with the former Decapolis city of Gerasa (Seetzen 1854). The ancient city was called Gerasa, while Jerash is the name used later in history. The Semitic name and dispersed finds indicates a pre-Hellenistic settlement, including the Bronze and Iron Ages. In the Hellenistic period (second century B.C.), Gerasa was founded by Antiochus 111 or 1V the Seleucids and therefore named Antiochia at the Chrysorrhoas (The golden River). Gerasa developed into a large city during the Roman period and continued to prosper throughout the Byzantine.The importance of Gerasa ended after an earthquake hit the Levant and devastated the city in 749 A.D. (Tsafrir and Foerster 1992). Resettlement took Place on small place in the Ayyubid-Mamluk periods. The northern part of the city, where it was believed that this area of the city does not contain any monuments especially near the northern gate, was partially investigated previously. For this reason, archaeological excavations were conducted in this area, starting in 2017 (Clark et al. 1986).

The main discovery in this area was parts of a huge wall begins from the east and extending to the west, its width exceeds a meter, consisting mostly of three courses of dressed stones, each course contains two rows of internal and external stones linked by pieces of small stones and mortar. The length of the wall from east to west amounts to or exceeds 25 m. What draws attention in this wall is that its construction was not completely vertical, but that there is an incline towards the south whenever it comes higher. Until now, it was not possible to ascertain whether this inclination was intended structurally, or if an earthquake struck the wall, leading to this inclination in the upper edges. It is noted that this huge wall extending from east to west ends in square (J9) where it perpendicular to another main wall to the north-east. A portion of it has been uncovered in square (J8 and J7), where it remains of a course and sometimes two, built of regular limestone and largely were dressed and with two internal and external rows joint by small stones as well as mud. This wall contains in its southern part an entrance with a width of about (1, 2) m. Then, it completes to the north-east. In square J7 the glass vessel was found (Fig.1). The main objective of this study is firstly to characterize the chemical composition of this Byzantine glass vessel excavated from the archaeological site of Jerash, secondly to assess the deterioration state in relation to burial environment and diagnosis the various aspects of decay by using visual observation and microscopic examination.

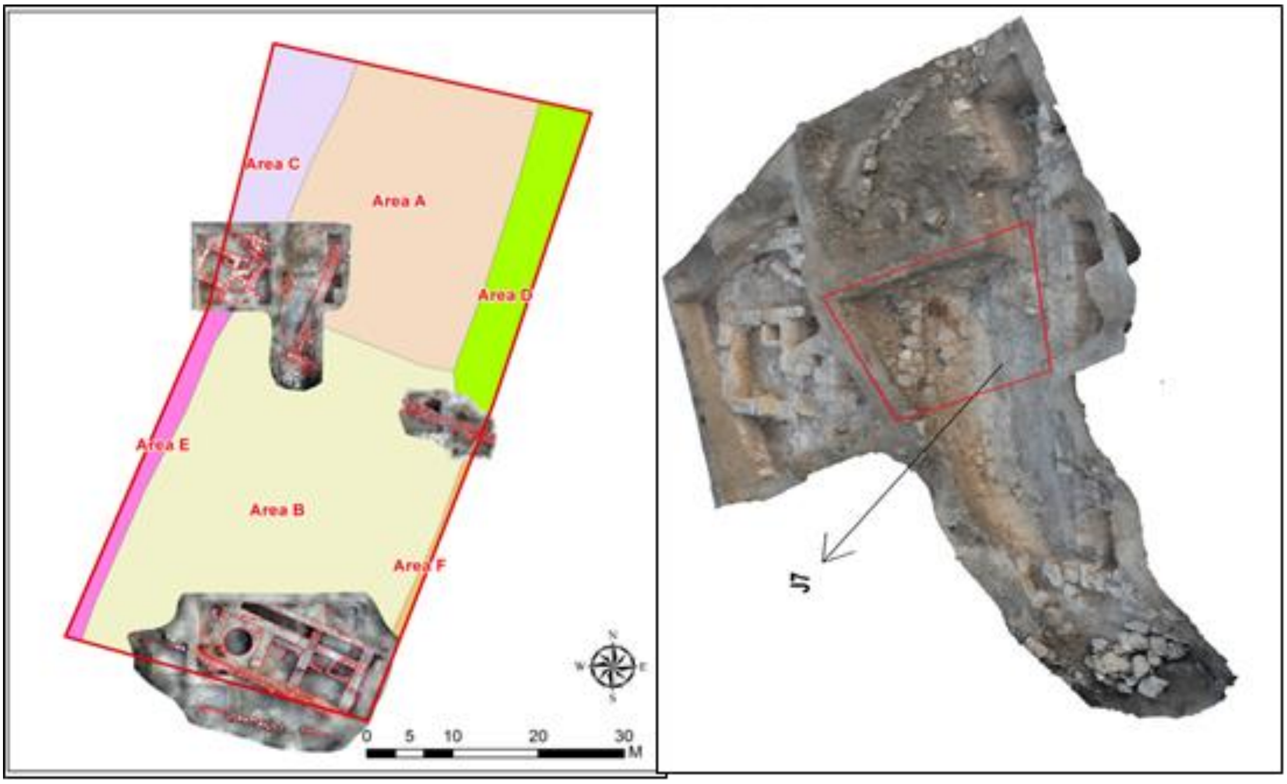

Fig. 1. The site where the square J7 in which the glass vessel was found and the site of Gerasa as part of the Decapolis.

2. STRATIGRAPHY AND THE CONTEXT OF THE GLASS VESSEL

In the area of this structure (Area A, square J7), where the glass vessel have been discovered, 5 layers have been found (Fig.2). The upper strata 0, 1, 2, 3 represent layers of backfill made up of stones of different sizes and soil. Most of these loci refer to the modern agricultural use of the site and as an area of dump. The last 2 layers (Loci 4 and 5) are typical Late Roman-Early Byzantine. This depends on the discovery of some pottery Lamps, objects and shards, in addition to some coins that found exactly near the Vessel. All these architectural details as well as important archaeological finds are a clear indication of the importance of this building and the need to continue scientific work in it in the coming seasons in order to determine its nature and the functional roles it played.

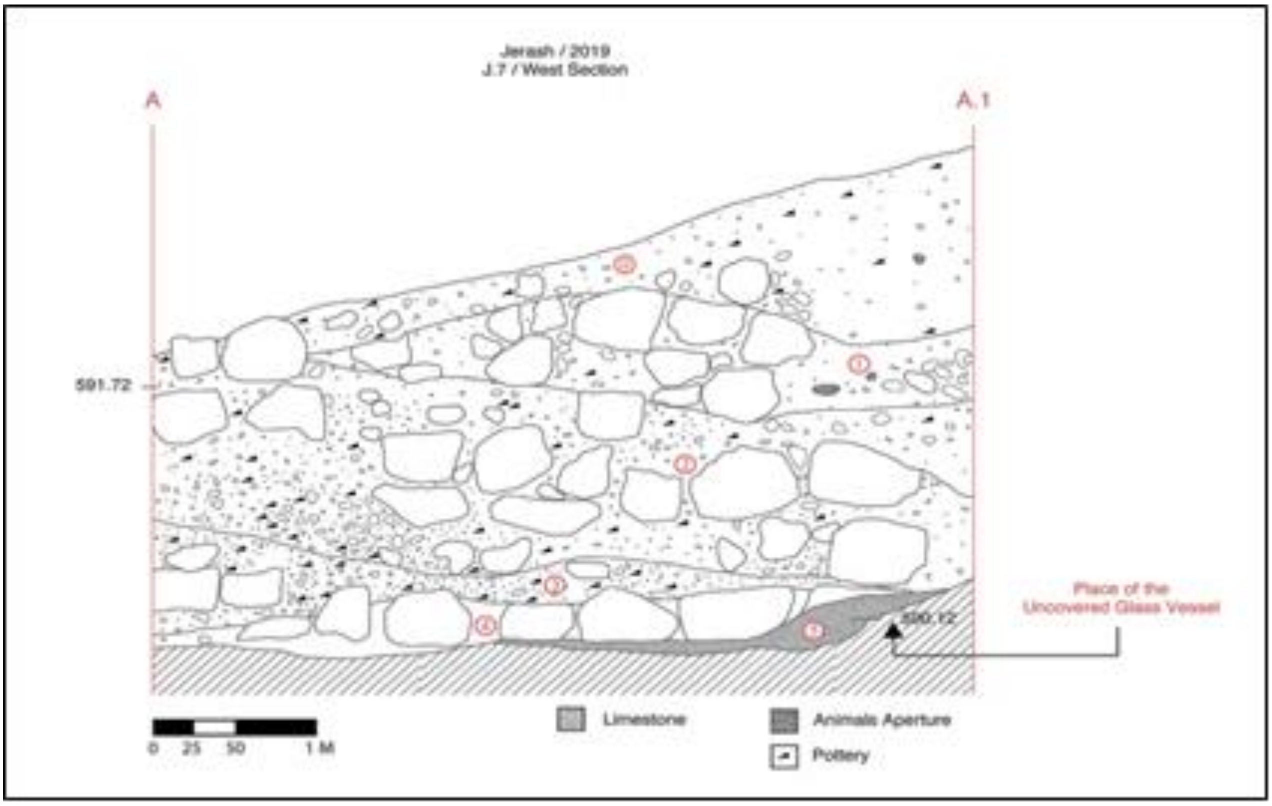

Fig. 2. Stratification of the loci in Sq. J7.

3. LIFTING AND DESCRIPTION OF THE DISTINGUISHED GLASS VESSEL

As shown in Figure 3 during the excavation work, a huge glass vessel was found upside down; firstly its glass base was appeared. For a safe lifting method, a mix of free and block lifting methods were applied where a lead frame was wrapped around it. The digging was gently carried out with fine tools and brushes to reduce the soil layers accumulated around it and relieve pressure on its sides in an attempt to reach the borders of the side vessel. After revealing its side borders, it was also excavated with precise tools in depth in order to know its height while leaving part of the soil below it. After determining the dimensions of the vessel, a solid wooden board was placed under the vessel, a small layer of soil between the board and the vessel was remained. The sides are backed with sponge and cardboard. Unfortunately, the round base of the vessel was found broken beside it. However, the intact vessel was lifted in one piece with the supporting materials. The glass vessel and broken base fragment were gently packaged in a rigid plastic container which is well padded with acid-free tissue and a layer of moisture-absorbing silica gel and sent to the conservation laboratory to be investigated and restored scientifically.

Fig. 3(a,b). The excavated glass vessel during the excavation and lifting process.

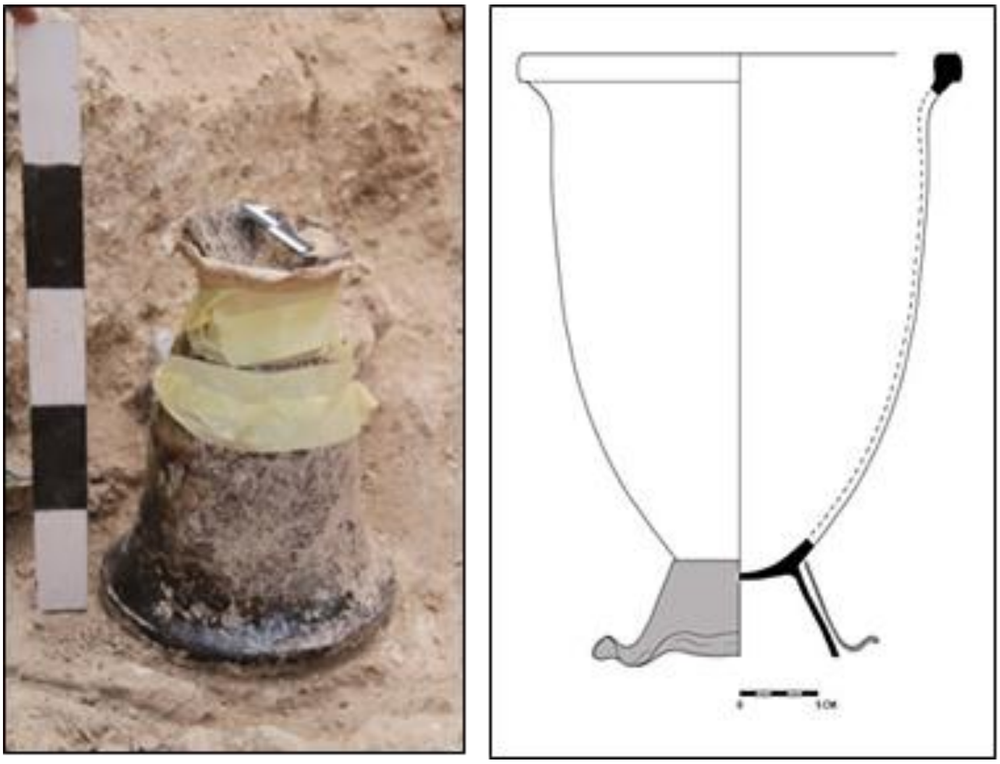

Fig. 4(a,b). The intact form and drawing of the Glass vessel.

4. MATERIALS AND METHODS

4.1 Glass samples

Two separated glass fragments of the glass vessel (No.1 and 2), and additional ten glass fragments from another glass vessels (No.3-12) of different colors and typologies were collected. They were fully cleaned from the soiled deposits and weathering crusts and prepared for the chemical analysis and microscopic examination (Table 1).

4.2 Analytical techniques

The fragments of glass samples were analyzed by the means of a Philips Magix pw 2424 X-ray fluorescence spectrometer (XRF), which uses the high-purity silica BCS-CRM 313/1 standard certified reference material from the Bureau of Analyzed Samples LTD, UK and works under vacuum, voltage 20-60 KV, current 5-150 mA and a Power limit of 4050 watt. Furthermore, microscopic and optical assessment was carried out. A BPM-220 USB digital optical microscope provides powers from 10× to 200× with 2.0MP Image sensor was used to examine the surface morphology and investigate the structure of encrustations and the underlying glass surface. Furthermore, the soil tests were carried out in situ using simplest materials and tools.

Table 1. Chemical composition of the glass vessel and ten selected glass samples obtained by XRF

Sn.	Form style	Color	Oxides (wt.%)													Total %
			SiO_2	Na_2O	K_2O	CaO	Al_2O_3	MgO	MnO	Fe_2O_3	PbO	TiO_2	P_2O_5	SO_3	Cl_2O	
1	The glass ves-	Yellowish green	68.45	15.32	0.73	8.65	2.93	0.55	0.04	0.43	0.04	0.10	0.28	0.13	0.84	98.48
2	The glass ves-	Yellowish green	67.43	14.91	0.74	8.68	3.18	0.47	0.03	0.48	0.08	0.11	0.16	0.11	0.65	97.03
3	Base fragment	Yellowish green	67.65	15.12	0.95	8.90	2.55	0.80	0.54	0.64	0.07	0.08	0.21	0.09	0.91	98.51
4	Base fragment	Yellowish green	67.09	14.80	0.87	8.78	3.46	0.49	0.32	0.48	0.09	0.11	0.16	0.13	0.77	97.55
5	Neck fragment	Colorless	67.42	14.97	0.76	8.82	3.47	0.47	0.06	0.53	0.06	0.13	0.13	0.12	0.82	97.76
6	Body fragment	Greenish blue	67.36	14.69	0.71	8.93	3.02	0.51	0.03	0.52	0.06	0.07	0.11	0.13	0.96	97.10
7	Body fragment	Greenish blue	67.71	15.11	0.61	8.46	2.81	0.45	0.05	0.55	0.10	0.11	0.17	0.09	0.82	97.04
8	Body fragment	Light blue	68.77	15.00	0.69	8.57	2.74	0.50	0.03	0.46	0.07	0.12	0.13	0.10	0.94	98.12
9	Body fragment	Light blue	67.48	14.49	0.76	8.89	3.10	0.48	0.04	0.53	0.05	0.09	0.11	0.08	0.92	97.02
10	Body fragment	Yellowish green	68.34	14.77	0.71	9.03	2.82	0.45	0.05	0.52	0.02	0.09	0.17	0.18	0.73	97.88
11	Body fragment	Greenish blue	67.86	15.22	0.74	8.76	3.19	0.56	0.02	0.44	0.03	0.10	0.12	0.12	0.85	98.01
12	Base fragment	Yellowish green	68.69	15.13	0.68	8.90	2.83	0.49	0.04	0.47	0.04	0.09	0.11	0.08	0.83	98.38
Avg.%			67.83	14.94	0.73	8.72	2.98	0.49	0.07	0.53	0.05	0.010	0.15	0.13	0.80	97.66

5. RESULTS AND DISCUSSION

5.1 Chemical characterization of glass vessel

Table 1 shows the compositions of the previously described glass fragments collected from the excavated area as provided by the aid of X-ray fluorescence spectroscopy (XRF). The results of the analyses indicate that the major components of the glass samples are: silica (SiO2 avg. 67.83%), soda (Na2O avg. 14.94%), lime (CaO avg. 8.72%) and alumina (Al2O3 avg. 2.98%). They were also characterized by low contents of potash (K2O avg. 0.73%) and magnesia (MgO avg. 0.49%).Therefore, these glasses can be classified as soda-lime-silica (Na2O-CaO-SiO2) glass, and correspond to the previously defined Levantine I glass group, the common type of ancient glass for more than three thousand years (Freestone, 2005, 2006; Tite et al., 2006; Abd-Allah, 2006; Liritzis et al., 2007; Schibille et al, 2008; Foster and Jackson, 2009; Abd-Allah, 2010; Arinat et al. 2014; Ali and Abd-Allah, 2015; Zacharias et al., 2020).

This composition revealed that the main raw materials from which these glasses were manufactured were Levantine coastal sand as a source of silica, natron (from Wadi Natrun in Egypt) as a source of alkali soda, and lime (which is already present as impurity or shell fragments in the Levantine coastal sands, thus unintentionally present lime, see, Hatton et al., 2008; Al Bawab et al., 2018) as a source of calcium (Abd-Allah, 2010; Al-Bashaireh et al., 2016). However, no evidence for a local primary production of raw glass (the preparation of fresh glass from its raw materials through fritting and melting) or a secondary production (the preparation of a quantity of hot glass by melting the primary glass in crucible, processing and finishing it into glass artefacts) at these sites has been found to date. It was stated that glass production in the first millennium AD was divided between a relatively small number of workshops that made raw glass and a large number of secondary workshops that fabricated vessels. During the Roman and later periods, glass was produced from its raw materials in massive tank furnaces in a limited number of glass production centres (potentially in the Levantine area). The unformed chunks of raw glass originating from these furnaces were then re-melted to produce glass vessels at a larger number of glass working centres (Freestone et al., 2008; Liritzis et al., 2007). According to Abd-Allah (2010) raw glass chunks were imported to secondary production centres in Northern Jordan (such as Beit Ras) for local reworking in order to produce glass vessels in large quantities.

The high content of manganese oxide in samples 3 (MnO=0.54%) indicate that manganese was intentionally used as a colorizing agent in the form of (Mn3+) ion to color the glass purple or violet. Whereas in all other transparent and colorless samples, manganese was used as decolorizing agent in the form of (Mn2+) ion which acts as an oxidizing agent and converts the iron from its reduced state (Fe2+, which is a strong greenish blue colorant) to an oxidized state (Fe3+, which has a yellowish, but much less intense, color) (Jackson, 2005; Abd-Allah, 2009).

5.2 Visual and microscopic investigation

As shown in Figure 3, the uncovered glass vessel was found intact in the square J7 but suffering from different deterioration phenomena, the others were found completely fragile, broken down into several fragments and great area of their bodies was missed.

Both the inner and outer surfaces of the glasses completely are corroded and covered with thin, milky layers of corrosion products. Eventually these layers separate slightly and, being of different and irregular thickness, refract light differently, given a colored effect known as iridescence. The layers became extremely fragile and peel off in very thin, onion skin-like pieces.

The glass vessel was found wet and covered with thick, hard layers of salty soiling and dirt, which strongly adhered to the glass surface. Moreover, the interior if the glass vessel was filled with a hard lump of soiling and dirt (Fig. 5). Optical digital microscopy examination of glass samples reveals that glass was completely corroded. It was observed that deterioration proceeding from the surface to the interior. In most cases large areas of the weathering crusts are destroyed, rich in dissolution voids and losses its glassy nature. Other aspects of deterioration were observed such as formation of weathering crusts, calcareous salt growing, soiled deposits covered glass surface, iridescence, cracking and pitting of corroded surface (Fig. 5).

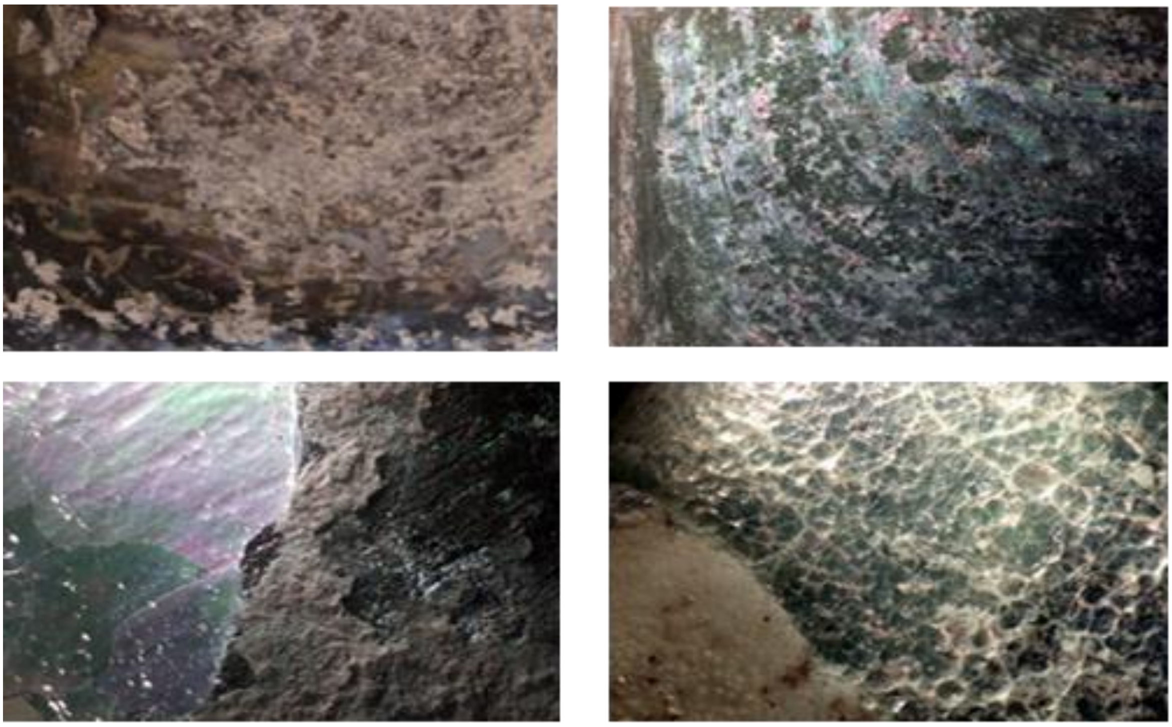

Fig. 5. (a,b,c,d). OM images of deteriorated surfaces of the glass vessel showing the aspects of damage and corrosion such as pitting, cracking, soiled deposits encrustation and iridescence.

5.3 Burial conditions assessment

Inside the square J7 at area A (Fig.6), the mentioned glass vessel was buried together with other bony, metallic and pottery remains in a damp, cohesive, salty, calcareous clay soil (Soil moisture content= 4.8 %; PH value= 7.9; Salinity (EC)= 2.8 m.mohs/cm-1; Density=2.5 gm/cm3; Porosity= 62%). Under these conditions, the glass has been broken down. Furthermore, it has been subjected to very intensive chemical deterioration; the flux is leached out preferentially to the silica, and the corrosion process is kept going on. It has been stated that the damp soil is most attack of glass rather than the dry one (Newton and Davison, 1989; Abd-Allah, 2013). Moreover, changes will resume as the complicated problem that emerged during excavation work is that these tombs have been in previous years subjected to acts of digging or theft in a random manner; resulting in a scattering of glass objects and artifacts pieces randomly and were found to overlap with many other materials in a state of weakness. Corroded glass is sensitive to moisture and should be stored in as stable an environment as possible. Ideally, the relative humidity should be 40% or less (Singley, 1981; Scichilone, 1995; Abd-Allah, 2007, Zacharias et al., 2020). In alkali- rich glass sodium and potassium are slightly soluble in some glass compositions. In the presence of high relative humidity, these components can be leached out to the surface of the glass where they are converted to carbonates. These carbonates attract moisture, and small droplets of water begin to appear on the surface of glass; hence, the name weeping glass (Hatton et al., 2008; Al Bawab et al., 2018). The leaching process causes tiny cracks to appear in the glass, and eventually the glass can be become opaque with small surface flaking. Further leaching and droplets formation will be stopped if the glass is kept at a relative humidity below 40%. If the storeroom is very damp, it may be necessary to pack glass in airtight container with silica gel. Furthermore, glass objects should be stored in a suitable boxes or cardboard containers. In addition to artifacts, supplementary scientific data, specimens, and samples are also in need of curatorial care. So those materials were packaged and identified separately from other artifact. However, dry pieces of glass should be packed in a rigid container which is well padded with acid-free tissue and a layer of moisture-absorbing silica gel should be placed in the bottom of the container before putting in the padding to prevent the glass from further corrosion. Glass should be stored in as stable an environment as possible. Ideally, the relative humidity should be 40% or less.

Fig. 6 (a,b). The burial environment, where the glass vessel was excavated in Area A, square J7.

6. CONCLUSION

Jerash, the modern village of Gerasa is considered one of the great and important Decapolis cities in ancient period in Jordan. A scientific excavation works carried out at this site reveals a great collection of glass objects with different types and typologies. The buried glass was mostly found in bad condition and subjected to intensive corrosion and other deterioration aspects such as pitting, cracking, encrustation, dulling and salt crystallization; hence, glass found dry should be kept dry as well. The results of the chemical analyses indicate that the glass does not show a clear distinction in terms of chemical composition between the late Roman and Byzantine glass from Jerash/Gerasa and the other late Roman and Byzantine sites in Northern Jordan. The resulting data shows that the analysed samples are examples of soda-lime-silica glass, with natron used as flux, which was probably mostly obtained from Wadi Natrun in Egypt. Lime or calcium carbonate was certainly unintentionally present in the composition, due to the use of lime-rich quartz sand from the Syro-Palestinian or Levantine coasts; thus, calcium carbonate was incorporated with the sand rather than added as a separate component. All the analysed glasses correspond to the so far defined Levantine I glass group.

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