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# RE-ESTABLISHING CONTEXT OF "ORPHANED" MUSEUM OBJECTS THROUGH SCIENTIFIC INVESTIGATION. A CASE STUDY FROM THE MUSEUM OF JORDANIAN HERITAGE

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***Abstract***

*Many objects in museum collections have no or inadequate information on their origin and archaeological evidence. These objects which are classified as unprovenanced or "Orphaned" represent a big ethical and technical challenge for the museums. Re-establishing the context of these objects by scientific research proves to be the best option for museums. This study main aim is to present a testing protocol that can be used to reestablish the context and determining the provenance of unprovenanced museum objects. The testing protocol was applied on a rare copper-based cauldron from the collection of the Museum of Jordanian Heritage. The object rough date, function, provenance and manufacturing technology were determined by employing an array of scientific techniques: Optical microscopy inductively coupled plasma, optical emission spectroscopy (ICP-OES), reflected microscopy and lead isotopes analysis. The obtained results enabled the museum to transfer the object from the neglect of the storeroom to its main exhibition hall.*

***Keywords**: Copper based objects; Corrosion; Bronze disease; Burial environment; Long term preservation*

## Introduction

Collections held by a museum typically come from different sources ranging from archaeological excavations to objects donated or purchased from private sources.

Museums face a big challenge to fully document the origin and provenance of all of their collections due to the lack of provenance information about some of these collections when they were initially acquired by the museums. Lack or missing of important information regarding origin, context and provenance are more frequent in the case of collections donated or purchased from private sources. However, this is even applicable, in some cases, to collections from professional excavations due to various reasons such as inaccurate field measurements, lost field notes, incomplete analyses and loss of parts of collections [1].

Unprovenanced museum objects, or as they are classified by many researchers as "orphaned objects", miss information about their history and findspot, essential for their interpretation and value analysis. "Orphaned" or unprovenanced objects are most often presumed to have been excavated illegally. These Antiquities often lost valuable information with the loss of their context [1, 2].

Despite arguments and disagreements among archaeologists, museum curators and collecting communities on how to deal with unprovenanced objects, there tend to be an agreement that valuable knowledge could nonetheless be derived from archaeological objects

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lacking a context. Research and study of these objects is a better option than to resign them to an indefinite future in storage. It is essential that these objects are made available to scholars and the public for further study and appreciation in order for these objects become artefacts [1, 3].

The systematic study of unprovenanced archaeological artefacts could lead to information about their composition and the origin of the raw materials used in manufacturing of these artefacts. Furthermore, inferences about trade routes and trade contacts among different cultures, and the development of mining techniques can also be obtained. In addition, the determination of their manufacturing technology can provide insights into their date, place of origin, and probable use [4].

All unprovenanced objects should be handled according to scientific process and must take the appropriate steps to research an object origin and to establish a plausible provenance, and then this orphaned object become eligible for possession and may find a new permanent home in a museum or private collection [5, 6].

This approach is adopted in this study which aims to investigate an orphaned object from the collections of the Museum of Jordanian Heritage. The object is kept in the museum storage under the name tag “baptizing font”. The museum has vague and incomplete information about the object origin and provenance. The only confirmed information in the museum records about the project is that it came from a village in the Jordan Valley. Even the museum has no explanation how the object was labelled as a baptizing font and on what basis. The object is kept in the museum storage despite its uniqueness as the museum possesses no parallel example in its display. The aim of this research is the re-establishment of the context of the object by determining its manufacturing technology, function, date and provenance.

## Experimental part

### *The object*

The object selected for this study is a copper-based object from the collection of the Museum of Jordanian Heritage at Yarmouk University (Fig. 1). The object has been kept in the museum storage for around 15 years. The object has a rounded body, with wide open mouth, a flaring out rim and a small disk base. The object internal surface is smooth, and external surface is tuff. It has six supporting vertical ribs that divided the external surface to six parts. The object weight and dimensions: weight is about 200kg, diameter 100cm, depth 33cm, and height 44cm.

**Fig. 1.** The Copper Based Object as it Was in the Storeroom of the Museum

## Methods and Techniques

Shape and style details of the object were investigated and recorded using optical microscopy. The object shape, dimensions and style were compared with similar object of known context. Trace elements analysis and lead isotopes analysis were employed to determine the origin of the ore from where which the copper used in the production of the object was derived. Chemical composition of the object was determined using Inductively Coupled Plasma Spectroscopy (ICP). For the purpose of this analysis, a clean surface of the artifact was drilled by a hand-held mini drill with 1.0mm diameter tungsten carbide bit. Three turnings' samples were taken three locations of the object (body, base, and rib) to ensure taking representative samples. The samples were prepared in the Analytical Chemistry Laboratory at Jordan Atomic Energy Commission, Amman using the following procedure: 0.20g from each sample was accurately taken and placed in a holder, and then 2ml of 48wt.% HF, 8mL of 65wt.% $HNO_3$ and 2mL of 30wt.% $H_2O_2$were added. The samples were digested using Milestone ETHOS1, microwave digestion system. The samples were then transferred to 50mL centrifuge test tube at room temperature; 4% of boric acid was added to remove HF effect; 1% sub boiled 65% Nitric Acid was used to the samples by a dilution factor of 10 times to reach a volume of 500mL. Chemical analysis of the solutions was performed using a Perkin Elmer Optical Emission Spectrometer OPTIMA 7000DV.

Metallographic examination was done by preparing cross sections of samples taken from base, rim and rib. The cross sections were prepared by embedding samples in an Araldite 2020 epoxy resin. The sections were polished with silicon carbide papers of successive grits until 2000. Final polishing was done with diamond pastes up to 0.25μm. Etching was done a Ferric Chloride alcohol solution (120mL distilled water: 30mL hydrochloric acid HCl: 10g Ferric Chloride $FeCl_3$). A binocular microscope (ZEISS Stemi 2000-C) was used for the metallographic examination. The Photomicrographs were taken using an Axio Cam ERc 5s camera attachment.

The isotope ratios were determined after dissolving up to 100 mg of sample material. Standard anion exchange procedures were used to extract and purified lead from the samples [7]. A Multi-collector Inductively Coupled Plasma Mass Spectrometry (NEPTUNE, Thermo Fisher Scientific) was used for the measurements of Lead isotopic ratios. Abundance ratios of 207Pb/206Pb, 208Pb/206Pb, 208Pb/204Pb, 207Pb/204 Pb, 207Pb/204 Pb, and 204Pb/206Pb were determined.

## Results and discussion

### *Stylistic Analysis*

As the object carries no inscriptions that can be used to assign its date or use, stylistic comparative analysis was the only option left to determine the object rough date and function. A search was done for well documented and dated similar examples. Fortunately, a very similar object, in terms of its appearance, shape, style and dimensions, was located at the Archaeological Museum of Ghor Al Safi. The object is shown in figure. 2. The archaeological context of this object is very well defined and documented. The object was excavated in 1980 from a Byzantine-medieval Islamic urban center of Khirbet Al Sheikh Isa, the industrial complex of Tawahines Al Sukkar (sugar mills) [8]. The object is labeled as copper Cauldron and dated based on its archaeological context and accompanied artifacts to the 13th century AD when Jordan was under the Ayyubid rule [9]. The shape, style and dimensions of the object are very similar to our unprovenanced object. This cauldron is circular in shape with 102 cm in diameter, 31 cm of depth and a weight of about 200kg. Furthermore, the flaring out rim and the six vertical ribs in the outer surface confirm that the two objects are stylistically very similar.

The function of copper cauldron at Ghor Al Safi Museum was identified as a cauldron used for boiling sugar juice. Archaeological and metallurgical evidence suggest strong links between flourishing of sugar industry in the Jordan Valley in the 12th and 13th centuries and the revival of copper smelting in Fienan. Studies prove that copper was needed to produce the cauldrons used for the boiling of cane juice [10].

Based on the very close similarities of the two objects, the unprovenanced object can be assigned to a similar date as of the copper cauldron (13th century AD) and to similar function (Cauldron for boiling sugar juice). The labeling of the object as a baptizing font by the Museum of Jordanian Heritage was unjustified as the museum has no supporting evidence for this classification. This is in agreement with the conclusions reached as archaeological excavations prove that 14 sugar mills distributed across the Jordan Valley were operational during the period 12th-14th century when sugar industry flourished.

**Fig. 2.** Copper Cauldron at Ghor Al-Safi Museum

### *Manufacturing Technology*

Microscopic investigation shows that the object was made by casting. A casting mark of flash line where the two halves of the mould were joined during casting was detected. This runs from the rim down the outside of the body, across the bottom of the vessel and up to the rim on the other side. This is a strong indication that the object was made by casting in a two-piece mould [11].

Chemical composition results are presented in table 1. The results show all three samples taken from the body have high percentages of copper (average content of 93.6%) with low content of lead (average content of 2.9%). This indicates that the cauldron was made of copper that contained low percentages of lead. The small amount of lead is an indication of unintentional addition of lead as lead of this low percentage may come from the copper ores or the fluxes used in the smelting process. The presence of lead of that percentage is good enough to enhance the fluidity of the molten alloy, an important property to facilitate the casting process [12-14].

**Table 1.** Chemical Analysis Results in wt.% as Measured by ICP-OES

| Sample | Cu | Pb | Sn | Fe | Sb | As | Co | Ni | P |
|---|---|---|---|---|---|---|---|---|---|
| 1. Rib | 94.105 | 2.622 | *- | 0.018 | 0.358 | 0.376 | 0.005 | 0.049 | 1.589 |
| 2. Base | 94.251 | 2.446 | *- | 0.029 | 0.3199 | 0.313 | 0.005 | 0.049 | 1.536 |
| 3. Body | 92.505 | 3.808 | 0.014 | 0.059 | 0.300 | 0.301 | 0.005 | 0.051 | 1.643 |

*: under detection limit

The cauldron contains small amount of iron ranging from 0.018 - 0.059%. Iron levels in ancient copper alloys can provide important information on the efficiency of the smelting and refining processes [12, 13]. Iron content averaging around 0.05% may indicate a primitive copper smelting process [12, 15]. However, trace elements pattern of the object indicates that low contents of trace elements is more likely due to efficient refining techniques of copper used in making this artifact [16].

***Microstructure***

The microstructure investigation shows alpha deformed copper dendrites with lead globules in the boundaries indicating that the object was produced by casting followed by thermal and mechanical working (Fig. 3). A different size and unequal axes re-crystallized grain that is characterized by the presence of the few annealing twins and many (numerous) strain or slip lines revealing that the manufacturing technique of the object included repeated cycles of mechanical working and thermal treatments. The few annealing twins indicates that annealing took place, but the variability in size and shape of the grains reveals that this annealing event was not sufficient to allow full recrystallization of the grains. The slip lines and strained grains indicate additional metal forming such as hammering after hot or cold-working and annealing to shape the artifact [17].


**Fig. 3.** Photomicrograph Showing Deformed Dendrites, Twins and Strain Lines

Copper and lead are two metals that are completely immiscible. Thus, lead usually presents as small, finely dispersed inclusions scattered at grain boundaries and within the grains. Black globules of lead in the microstructure are shown in figure 4.


**Fig. 4.** Photomicrograph Showing Black Globules of Lead

***Provenance***

Lead isotope results in combination with the results of trace elements patterns have been used for the determination of the provenance of the object. The calculated lead isotope abundance ratios are: $^{207}Pb/^{206}Pb$, $^{208}Pb/^{206}Pb$, $^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{204}Pb/^{206}Pb$, and $^{204}Pb/^{206}Pb$ for the three samples are presented in Table 2.

The chemical analysis results show that the lead content of the object is low indicating that lead was not an intentional addition to the alloy but a natural component of the copper core.

This means that lead isotope abundance ratios in the object reflects those in the ore which gives better correlation between the measured lead isotopes and those of the ore.

**Table 2.** Lead Isotope Ratios of the Analyzed Samples

| Sample | $^{207}Pb/^{206}Pb$ | $^{208}Pb/^{206}Pb$ | $^{208}Pb/^{204}Pb$ | $^{207}Pb/^{204}Pb$ | $^{206}Pb/^{204}Pb$ | $^{204}Pb/^{206}Pb$ |
|---|---|---|---|---|---|---|
| Body | 0.8687 | 2.1164 | 38.121 | 15.620 | 17.986 | 0.05550 |
| Rib | 0.8685 | 2.1168 | 38.132 | 15.625 | 17.983 | 0.05556 |
| Base | 0.8688 | 2.1163 | 38.124 | 15.622 | 17.984 | 0.05552 |

The variation in the lead isotope abundance ratios of the samples is very low indicating that the copper used in the manufacturing of the cauldron is from one source. The measured abundance ratios all centered around the mean (±0.1%) values of $^{207}Pb/^{206}Pb$ of 0.8686, $^{208}Pb/^{206}Pb$ of 2.1165, $^{208}Pb/^{204}Pb$ of 38.125, $^{207}Pb/^{204}Pb$ of 15.622, $^{206}Pb/^{204}Pb$ of 17.984 and $^{204}Pb/^{206}Pb$ of 0.05552.

The lead isotope signatures of the analyzed samples were compared with lead isotope ratios of various potential sources of the metal. Comparison was done with ores from Fienan, Tmina, Sinai and mines in Sinai, Turkey, Greece and Cyprus as shown in figure 5.

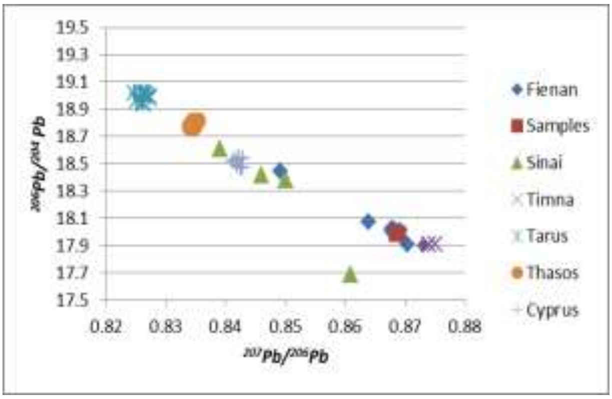


**Fig. 5.** Lead Isotope Ratios of the Samples as Compared to those of Potential Ores

There is a big variation between the cauldron cluster of lead isotope ratios and those of Cyprus, Anatolia, Sinai and Aegean. No known copper source in these places has a $^{208}Pb/^{206}Pb$ ratio that exceeds 2.10 [18-20].

The lead isotopes abundance ratios cluster of the conform with those of late Precambrian to early Cambrian copper ores. This means that many important copper mines of the East Mediterranean especially in Anatolia, Cyprus and Aegean can be eliminated as potential sources of copper used in making the object as these are of younger age [20, 21]. Another potential source that can be excluded based on mismatch of the lead isotope signatures is the famous copper mines of Sinai. Figure 5 shows the obvious divergence of lead isotope ratios of this site and those of the samples [22]

The lead isotope abundance ratios of the samples coincide very well with those of the copper ores from the sites of Fienan and Timanas shown in figure 5 [23]. This indicates that copper used in the manufacturing of the cauldron originated from one of these two sites. This result is seconded by the low levels of trace elements detected in the object which distinguish Fienan and Timna copper. The absence of tin and the low percentages of lead, nickel and cobalt support this conclusion. This is further supported by the low iron content which points also to Feinan or Timna as manganese ores were used for fluxing instead of iron ores in these two sites [22]. Furthermore, the phosphorus content matches very well with Fienan DLS ores [20].

Due to their identical geological formations, distinguishing copper of Fienan from that of Timna based on lead isotope ratios or trace elements patterns is impossible [21]. However, results of archaeometallurgical research in the area may give the needed evidence to support Fienan rather than Timna as the most probable source of the copper used in the manufacturing of the cauldron. Research results prove that a revival in copper production took place in Fienan in the first half of the 13th century after a long interruption [10]. Researchers believe that this revival was linked to the flourishing of the sugar industry in the eastern side of the Jordan Valley in the same period where 34 sugar production sites have been identified. Copper was in high demand to produce special vessels required for boiling cane juice as part of sugar manufacturing process. These vessels were made of copper. Excavations at several sugar mills sites in the Jordan Valley revealed evidence of local production and/or repair of copper cauldrons [10].

**Fig. 6**. The Cauldron as Exhibited in the Main Exhibition Hall of the Museum of Jordanian Heritage

As an outcome of this study, the cauldron was transferred in the museum storage to the focus of the main exhibition hall of the museum (Fig. 6) after its context was re-established and after conservation treatment was performed.

## Conclusion

Scientific research employing multi methods can be used to re-establish the context of unprovenanced museum objects missing essential information on their origin, function and findspot. The integrated scientific approach can transform museum objects labeled as unprovenanced or orphaned into artifacts. The effective interpretation of the scientific analysis results can provide the essential information of date, function, provenance and manufacturing technology that make the object qualified for museum exhibition.

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