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The Emergence of Copper-Based Metallurgy in the Maltese Archipelago: an archaeometric perspective

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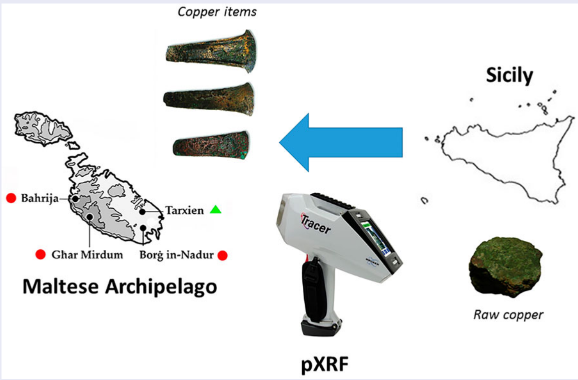
ABSTRACT

The amount of prehistoric metal items discovered in the Maltese archipelago during the BronzeAge very limited in number. The majority of the artifacts are traditionally considered Aegean imports from nearby Sicily. Nineteen objects, currently on display in the National Archaeological Museum of Valletta, and dated between the 17th and 12th century BCE, represent the main evidence of metalwork in Malta during the Bronze Age. Daggers, axes, vessels, rings, pins and an ingot were found in Early and Middle/Late Bronze Age sites and were traditionally interpreted as made from bronze solely on the account of a direct visual exam. The aim of this contribution is to present the results of research carried out on those artifacts applying non-destructive portable X-ray fluorescence spectrometry (pXRF) in order to ascertain their chemical composition, to compare the data with those available for Sicily and the Aegean and discuss the archaeological implications of such outcomes.



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Malta; copper; pXRF; Sicily; Aegean; trade

1. Introduction

Since 1836, when Christian Jurgen Thomsen, curator of the then Museum of Northern Antiquities and now the Danish National Museum, outlined the *theory of three ages* in the preface of his museum guidebook (Rafn, Petersen, and Thomsen 1836), the traditional distinction between Stone, Bronze and Iron Age has been accepted by the academic community. However, in recent times, it has become clear that the simple use and production of certain materials cannot characterize eras and that the emergence of metallurgy was not a synchronous cultural phenomenon in the Mediterranean region. Therefore, new indicators have been identified to mark the drastic passages between ages. For the Iron Age, for example, it has been suggested to replace iron working with writing as the characterizing trait of such a transitional period between prehistory and history and to focus more on socio-economic features instead of mere chronology to define periods or cultural phases (Van Dommelen and Roppa 2013).

In this perspective, recent work on the emergence and development of copper-based metallurgy in prehistoric Sicily, based on a large-scale campaign of portable X-ray fluorescence (pXRF) analyses has proved that even if "non-destructive surface analysis is not suitable to provide exact quantities of the original chemical bulk composition … it is adequate for the aims of recognizing intentionally added alloys and estimating the amounts" (Vianello and Tykot 2017, 400). Specifically, the study showed how pure copper was still largely used in the Early and Middle Bronze Ages together with tin bronze, emphasizing that there is no significant gap between the introduction of unalloyed copper and tin bronze availability in Sicily. The presence of copper artifacts may be intentional or due to difficulties in obtaining enough tin, but do represent

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a stage in the local development of copper-based metallurgy. The functional and typological analyses demonstrate however that there was no experimentation in Sicily: particular classes of artifacts are made using a limited number of copper-based alloys (arsenic and tin), and this demonstrates some advanced knowledge of metallurgy and prior experience in determining which alloys work best for different artifacts. As a result, the case for the importation of metallurgical technology and raw metals is very strong (Vianello and Tykot 2017).

The successful application of the archaeometric approach led to new data that warranted the reconsideration of cultural dynamics in the case study of Sicilian prehistoric metallurgy, and led to a similar investigation of the evidence of the Maltese archipelago, the history and prehistory of which is intertwined with that of Sicily.

The evidence of metalworking and the circulation of copper-based items in the Maltese Bronze Age is, however, very poor and limited to a few significant cases. The absence of ore sources in the archipelago implies that the development of local production as well as the introduction of bronze items must be related to the above-mentioned system of commercial exchanges of which Malta was part (Evans 1971, 224–228). The sites which provided the most significant evidence in Malta are Tarxien, Borġ in-Nadur and Ghar Mirdum (Figure 1).

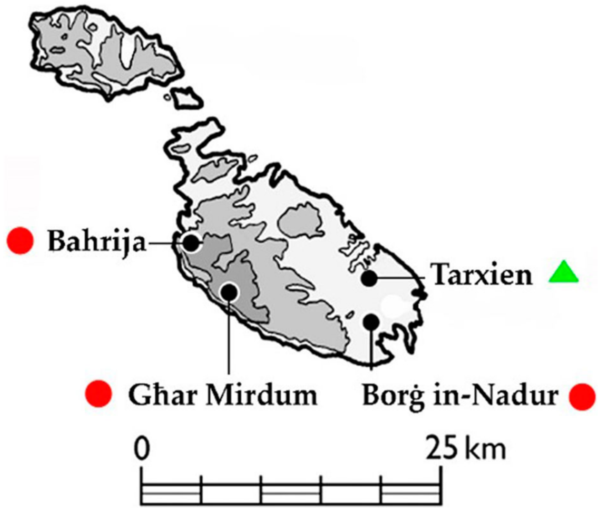

Figure 1. Map of the Maltese archipelago with sites which provided copper-based artifacts.

For the Maltese Early Bronze Age (2000–1500 BCE), the only site which provided any evidence of copper-based artifacts is Tarxien, where, during the reuse of the megalithic temple as a cemetery, several burials showed interesting metal assemblages. Eight axes, eight daggers including one in poor condition, three whole awls plus many other fragmentary ones and lumps of copper-based metal objects were in fact recovered (Murray 1934; Evans 1971, 163–164) (Figure 2). With respect to the typology of the weapons (Magro Conti 1999, 200), axes have flat or flanged bodies and slim blades with a

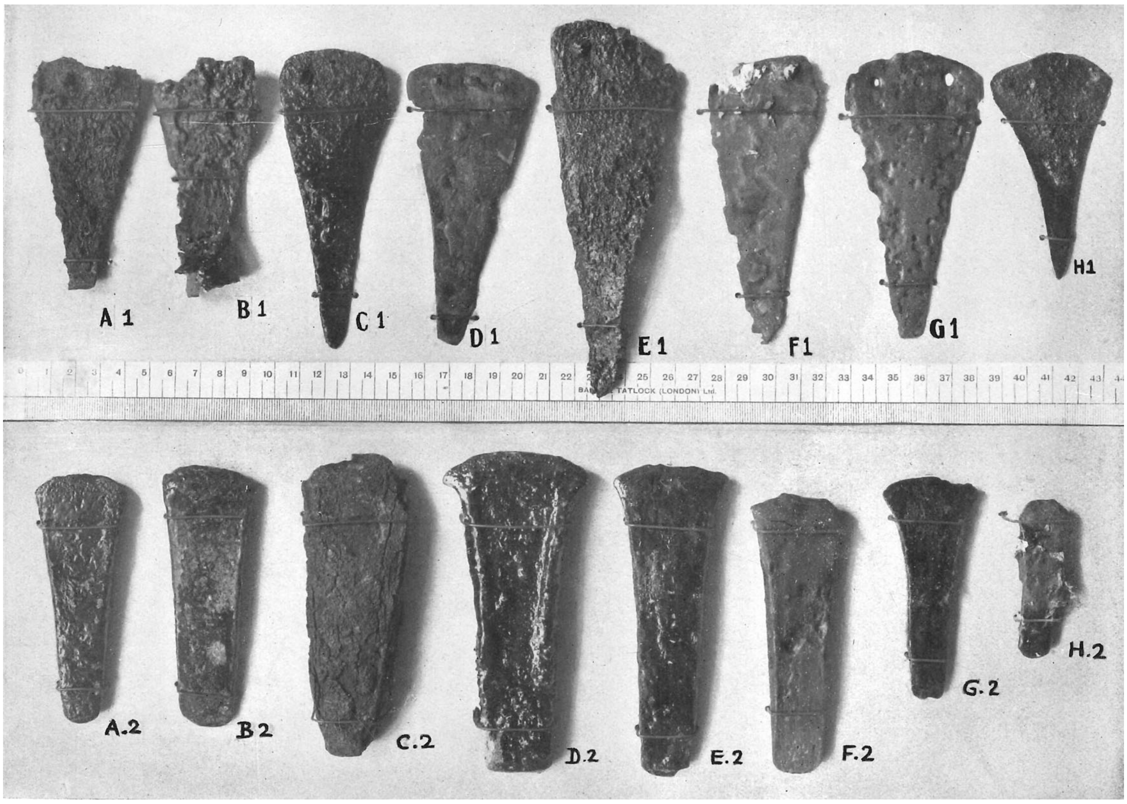

Figure 2. Axes and daggers from burials in the Tarxien Cemetery (Murray 1934).

narrow cutting edge, ranging from 8.8 cm to 12.4 cm in length, 3.7 cm to 5.8 cm in width and 0.7 cm to 1.6 cm in thickness and were probably meant to fit into a socketed wooden haft. The Maltese examples find striking parallels with a group of Sicilian copper axes from Agrigento, nowadays kept at the British Museum, belonging to two typological categories (type 5b flat flanged and winged axes, and types 6–7 flanged axe) (Bietti Sestieri and Macnamara 2007, 9–10). Daggers have a triangular shape, varying in length from 9 to 13.2 cm and from 4.5 to 5.5. cm in width, and two to four rivets to attach them to a wooden or bone handle. This specific typology of daggers is largely attested in some Early Bronze Age sites (Castelluccio *facies*) of southeastern Sicily, such as Monte Racello and Coste di Santa Febronia (Maniscalco 2000, 161). Two Sicilian examples were also tested by X-ray fluorescence and the results showed that one dagger from Monte Racello was composed of copper with a high presence of arsenic; and dagger no. 4341 from Coste di Santa Febronia was pure copper, while two other daggers from the same site were instead made of copper with high concentrations of antimony (Maniscalco 2000, 164).

Figure 4. Metal sheet likely related to a metal vessel from the Borġ in-Nadur temple (photo D. Tanasi).

For the Middle/Late Bronze Age (ca. 1500–700 BCE), the major evidence comes from the eponymous site of the Borġ in-Nadur culture. Several bronze objects have been found at the Borġ in-Nadur temple: a small bronze rod, two hollow gold-plated tubular rings (Figure 3), a portion of a metal vessel (Figure 4) (Murray 1923, 43, 1929, 17, pl. XVIII, 7; Tanasi 2009, 16), a thick lead foil (Evans 1971, 226) and a shapeless lump of metal. A significant find is a small limestone mould (Figure 5) for the production of an ornament found in chamber B of the Double Chapel, an area of the temple characterized by numerous Bronze Age finds (Murray 1929, pls. VIII,3, XIX,1), which until now was the only clue of metalworking activities in the Maltese archipelago. A massive bronze rivet, probably related to a metal vessel, was also found in layer 2B of trench B, opened by D. H. Trump at the settlement of Borġ in-Nadur (Tanasi 2009, 17). Also remarkable are the items found at Ghar Mirdum (Tanasi 2014). The exploration of chamber M/N brought the discovery of a few very prominent artifacts: a bronze pin was reported (Mallia 1964); a bronze dagger blade, to which was related a bone hilt (Figure 6) (Magro Conti 1999, 202); a massive rough bronze ingot weighing 629 gr (Figure 7); and two bronze rivets (Figure 8), dimensionally not compatible with the hilt and the dagger, interpreted as belonging to a metal vessel (Tanasi 2009, 17). The peculiar decoration of the bone hilt and the technical features of the rivets, both having parallels in the Sicilian Early and Middle Bronze

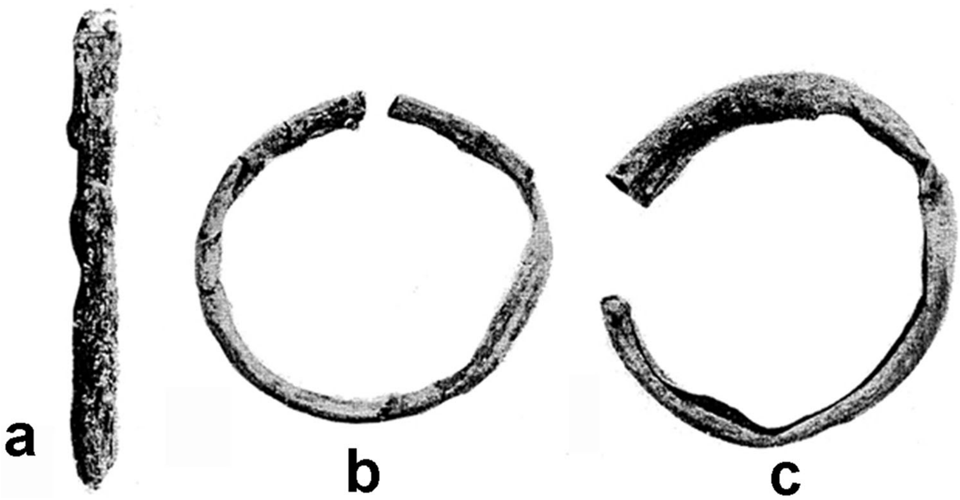

Figure 3. Metal rod and gold-plated tubular rings from the Borġ in-Nadur temple (Evans 1971).

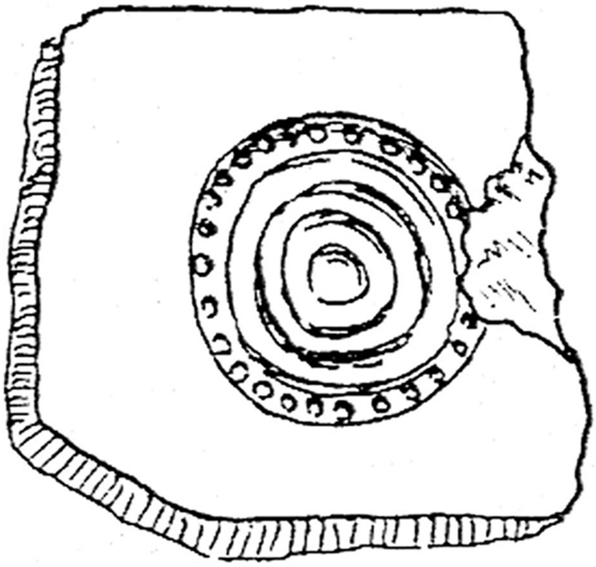

Figure 5. Limestone mould from chamber B of the Double Chapel at the Borġ in-Nadur temple (Evans 1971).

Ages suggest that they could have been possibly imported from Sicily (Tanasi 2018, 195). In this perspective, it may be suggested that the ingot from Ghar Mirdum was also imported from Sicily, considering the occurrence of fragmentary ingots of ox-hide type in Sicily at Thapsos, Ognina and Cannatello (Alberti 2008, 136).

Figure 6. Copper-based dagger with bone hilt from Room M/N of Ghar Mirdum (photo D. Tanasi).

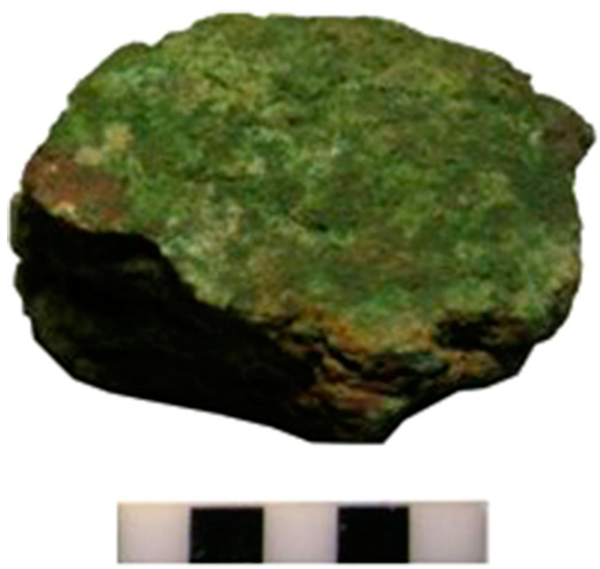

Figure 7. Copper-based ingot from Room M/N of Ghar Mirdum (photo D. Tanasi).

Figure 8. Copper-based rivets from Room M/N of Ghar Mirdum (photo D. Tanasi).

At a later stage of the Middle/Late Bronze Age are dated some metal items from the site of Bahrija, namely a finger ring and a needle (Trump 1961, 262), a fragment of a bracelet, and a shapeless lump of metal (Evans 1971, 106). Finally, extremely significant is the recent discovery of an Iron Age serpentine bow fibula with a curved pin of Sicilian type (Cassibile *facies*) at the site of Tas Silġ North (Cazzella and Recchia 2012, 24), in association with Late Borġ in-Nadur and Bahrija pottery.

In order to refine the interpretation of this evidence and contextualize it within the framework of the Malta-Sicily-Aegean relationship, non-destructive chemical analyses were carried out on a selection of representative artifacts in order to compare the experience of the emergence of metallurgy in the Maltese archipelago with that of Sicily, much better know with regard to elemental characterization aspects (Vianello and Tykot 2017).

2. Materials and methods

The National Museum of Archaeology at Valletta displays a permanent exhibition of materials from the Bronze Age with four showcases dedicated to a total of 19 metal artifacts. This group comprises 13 objects from the Tarxien Cemetery (seven axes, four daggers, two awls), dated to the Early Bronze Age; four from Ghar Mirdum (one dagger, one ingot, two rivets) dated to an initial phase of the Middle/Late Bronze Age; and 2 from Bahrija (one ring, one needle) dated to a later phase of the Middle/Late Bronze Age (Table 1). In comparison with the brief description of the totality of the Bronze Age artifacts discovered, these 19 objects represent just those which are less controversial in terms of their context, in better condition and still available at the time of the setup of the exhibitions.

Table 1. List of the copper-based artifacts exhibited at the National Museum of Archaeology at Valletta and tested in this study.

Site	Object	Inv. No.	Chronology
Tarxien Cemetery	Axe	5639	Early Bronze Age
Tarxien Cemetery	Axe	5641	Early Bronze Age
Tarxien Cemetery	Axe	5644	Early Bronze Age
Tarxien Cemetery	Dagger	6845	Early Bronze Age
Tarxien Cemetery	Dagger	5640	Early Bronze Age
Tarxien Cemetery	Dagger	6844	Early Bronze Age
Tarxien Cemetery	Dagger	5642	Early Bronze Age
Tarxien Cemetery	Axe	5699	Early Bronze Age
Tarxien Cemetery	Axe	5643	Early Bronze Age
Tarxien Cemetery	Axe	5638	Early Bronze Age
Tarxien Cemetery	Awl	5646	Early Bronze Age
Tarxien Cemetery	Awl	5647	Early Bronze Age
Tarxien Cemetery	Axe	5645	Early Bronze Age
Ghar Mirdum	Dagger	2648	Middle/Late Bronze Age
Ghar Mirdum	Rivet	2646	Middle/Late Bronze Age
Ghar Mirdum	Rivet	2645	Middle/Late Bronze Age
Ghar Mirdum	Ingot	6843	Middle/Late Bronze Age
Bahrija	Ring	2700	Middle/Late Bronze Age
Bahrija	Needle	2701	Middle/Late Bronze Age

To determine the function of the metal items known from prehistoric Malta and to infer indirectly new hypotheses about their production, elemental analyses using an X-ray fluorescence spectrometer were carried out in June 2017 at the Museum of Valletta on 19 selected artifacts (Figure 9). A future comparison of the chemical fingerprints with other Mediterranean and European artifacts may also help in recognizing non-destructively the potential provenance of the alloys by finding areas where the same alloy technology was employed. For the task, a Bruker Tracer 5*i* was employed, with an 8 mm diameter beam, a filter made of 12 mil Al and 1 mil Ti to enhance the precision of the readings, analysis settings of 50 kV and 5 μA, with a run time of 15 s for each spot tested. This non-destructive surface analysis was carried out with multiple readings per each sample taken to test for potential heterogeneity. The raw data were calibrated using an established calibration program for copper-based metals (Tykot 2016).

While both the precision and accuracy of the analyses conducted are quantitative, one must nevertheless consider that the depth of penetration of X-rays on metals is quite minimal, so that these non-destructive analyses represent the surface of the objects. While surface patinas and degradation can potentially alter the composition, the testing of multiple spots was done specifically to look for inconsistencies. Our samples had patina but little extensive corrosion, resulting in a typical state of preservation from the typical Sicilian or Maltese contexts, which is very different from what is "average" across the world (see Nørgaard 2017 in particular for types of corrosion detected using a pXRF that are simply not present in our artifacts). Only one object (USF 31986, Inv. 2646) had noticeably different tin concentrations between the two spots tested, and may present corrosion. We have therefore performed XRF analyses with attention to exclude (or report if uncertain as for object USF 31986) corroded objects, as has been done in similar research projects (see Giumlia-Mair and Albanese Procelli 2010 for an example) within the same area. When artifacts were too small or corrosion appeared to be present besides a superficial patina, only one or two analyses were carried out, as was possible. The choice of performing pXRF analyses is never a preferred

Figure 9. Robert Tykot analyzing items at the National Museum of Archaeology of Valletta with a portable X-ray fluorescence spectrometer (photo D. Tanasi).

choice among all existing techniques, but was necessary to keep the study non-destructive. Several studies have been carried out using a pXRF on metals, and it has been proven that even with limits, pXRF analyses are informative and valuable when destructive analyses are impossible (see Shugar and Mass 2012 and Frahm and Doonan 2013 for general discussions, and Charalambous 2016; Asderaki-Tzoumerkioti et al. 2017, and Martinón-Torres et al. 2012 for case studies).

There are recent studies on the problem of corrosion (Oudbashi et al. 2013; Horn and von Holstein 2017), and in all the cases corrosion is detected by finding inconsistencies in the elemental composition. Since in our study only one artifact appears to have been corroded, the methodology has been kept simple and lean, but it is understood that this situation is due to preservation in a particular microclimate and most artifacts cannot be analyzed with the same method. The results with the current method, which is limited by surface measurements and potential mistakes due to the patina, are semi-quantitative at best, but provide a comparable set of data among these objects and the distinction between non-alloyed and alloyed copper objects without causing any destruction. Whilst only destructive analyses may provide data that are truly quantitative, the impossibility to sample destructively these artifacts must suffice as reason to apply the current methodology.

The particular case of elemental concentrations of an artifact being possibly skewed due to corrosion and therefore the data being invalid provides a strong reason to avoid this method when destructive analyses are possible, which is not our case. The sole defense here is that it would be improbable for corrosion to be homogenous in all spots. Corrosion in copper-only artifacts would not affect the percent of copper. For the few artifacts that are not non-alloyed copper, the values presented in this work are sufficiently clear to discriminate between tin bronze (Cu+Sn) and bronze with lead (Cu+Sn+Pb), but the data cannot be considered to represent exact quantities.

3. Results

The limited number of artifacts available for this study prevents the use of any statistical approach. The following table (Table 2) summarizes the data, which show a stark contrast between the earliest period, Early Bronze Age, where just copper-based artifacts were available with variable small amounts of arsenic, perhaps due to differences in ore sources, production or recycling, and the subsequent Middle/Late Bronze Ages. The other six artifacts from Ghar Mirdum and Bahrija, dating to the Middle/Late Bronze Age, are made of tin bronze except for the ingot (Figure 10). The multipoint pXRF analyses have shown a clear presence of alloys already at the spectrum stage (uncalibrated, Figure 11). In some cases, where only one analysis was possible due to size and geometry of the artifacts, the results match our expectations.

For the Early Bronze Age, all but one of the objects tested was 99% copper, with slight differences in the amount of arsenic detected. Significant is awl 5646, which contains some traces of tin and lead, and slightly more arsenic than the other objects. This is probably due to recycling of artifacts circulating around the Middle Bronze Age (very late phase of the primarily Early Bronze Age Tarxien Cemetery). The detectable amounts of lead, arsenic and tin suggests indeed that this alloy could have been produced from recycled bronze and copper artifacts since the amount of lead and tin are too low to have been added intentionally. Alternatively, it is possible that some different sources of copper were used, each containing a different small amount of arsenic in the ore. There are no copper ores in Malta, and no ores used in prehistory are known in Sicily, resulting in the possibility of using multiple sources from far away to be less likely than recycling.

Table 2. Table of the copper-based artifacts tested and the elemental data obtained by pXRF (in %). The 13 Tarxien objects are all copper, while all but one of the 6 others tested are bronze. "nd" = not detected.

Site	Object	Inv. No.	USF #	Tests	Cu	Sn	Pb	Zn	As	Fe	Total
Tarxien Cemetery	Axe	TC 5639	31,980	3	99.6	nd	nd	nd	0.3	nd	100.0
Tarxien Cemetery	Axe	TC 5641	31,981	3	99.9	nd	nd	nd	0.1	nd	100.0
Tarxien Cemetery	Axe	TC 5644	31,982	2	99.3	nd	nd	nd	0.7	nd	100.0
Tarxien Cemetery	Dagger	TC 6845	31,983	3	99.6	nd	nd	nd	0.4	nd	100.0
Tarxien Cemetery	Dagger	TC 5640	31,984	5	99.4	nd	nd	nd	0.6	nd	100.0
Tarxien Cemetery	Needle	TC 6844	31,988	4	99.9	nd	nd	nd	0.1	nd	100.0
Tarxien Cemetery	Needle	TC 5642	31,989	4	99.8	nd	nd	nd	0.1	nd	100.0
Tarxien Cemetery	Axe	TC 5699	31,990	2	99.9	nd	nd	nd	0.1	nd	100.0
Tarxien Cemetery	Axe	TC 5643	31,991	1	99.2	nd	nd	nd	0.8	nd	100.0
Tarxien Cemetery	Axe	TC 5638	31,992	2	99.6	nd	nd	nd	0.4	nd	100.0
Tarxien Cemetery	Awl	TC 5646	31,993	1	98.4	0.3	0.1	nd	1.3	nd	100.0
Tarxien Cemetery	Awl	TC 5647	31,994	1	99.7	nd	nd	nd	0.2	0.1	100.0
Tarxien Cemetery	Axe	TC 5645	31,998	1	99.6	nd	nd	nd	0.4	nd	100.0
Ghar Mirdum	Dagger	GM 2648	31,985	3	93.0	6.9	nd	nd	0.1	nd	100.0
Ghar Mirdum	Rivet	GM 2646	31,986	2	87.5	8.1	4.4	nd	nd	nd	100.0
Ghar Mirdum	Rivet	GM 2645	31,987	3	91.8	2.6	5.1	nd	0.4	nd	100.0
Ghar Mirdum	Ingot	GM 6843	31,997	2	99.5	0.2	nd	nd	0.1	0.2	100.0
Bahrija	Ring	B 2700	31,995	2	92.6	7.0	0.2	nd	0.1	0.1	100.0
Bahrija	Needle	B 2701	31,996	1	88.2	10.7	0.6	nd	0.1	0.4	100.0

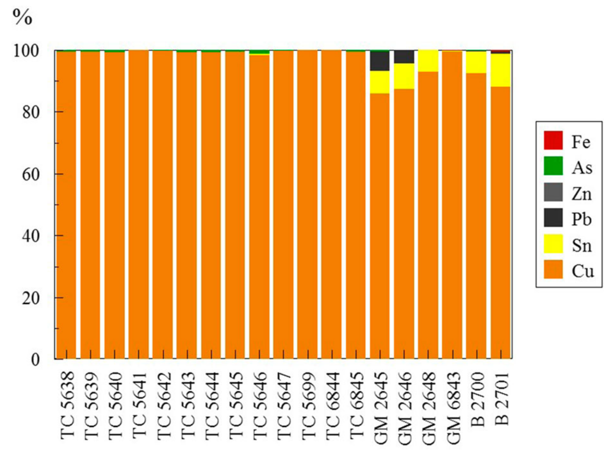

Figure 10. Bar chart showing the very high percentage of copper in Tarxien artifacts, significant tin in most others, and two from Ghar Mirdum which also contain lead.

The ingot from Ghar Mirdum (6843) also contains some tin, but mostly likely coming from an ore source which includes some tin rather than recycling.

Rivet 2646 from Ghar Mirdum appears to be composite, with the measurements (Table 3), taken at the two extremities, quite different. It is likely that it was repaired. Besides this particular rivet and the ingot, which is likely made of non-alloyed copper with more impurities than expected, there are no inconsistencies. The rarity of ingots in the Maltese archipelago do not allow a debate on whether specific copper ores were selected.

4. Discussion

The chemical analyses have for the first time confirmed what common sense and visual assessments convinced scholars of, that the Early Bronze artifacts from Tarxien Cemetery are made out of copper and that the Middle/Late Bronze Age objects from Ghar Mirdum and Bahrija are mostly in bronze, with the exception of an ingot which is of copper. Besides simple generalizations, however, these results are not simple to contextualize. In fact, the recent results of pXRF analyses on artifacts from Early and Middle Bronze Age Sicily have demonstrated that the majority of the samples are made of copper rather than bronze, shifting to a later date the beginning of copper alloy working in Sicily (Vianello and Tykot 2017). In this perspective, even in consideration of the cultural analogies described above, it seems likely to consider the bronze artifacts from Ghar Mirdum as Sicilian imports. With respect to the artifacts from Bahrija, the discovery of the Sicilian type bronze fibula at Tas-Silġ North demonstrates that there was at least some circulation of metal items from Sicily to Malta. Therefore, in our opinion, even in the case of Bahrija the two items are likely imported from Sicily. Yet the specific chronology, types, and contexts in which the materials tested were found must be taken into careful consideration in drawing interpretations about raw material access, metallurgical technology and practice, and the trade and economic systems in place for specific time periods.

There are no ores in Malta, and therefore all artifacts were likely imported. In Sicily, the limited copper and lead were not used before the Late Bronze Age (Giardino 1995, 134), but moulds have been found at several sites (Maniscalco 2000; Albanese Procelli 2004; Giannitrapani 2014) clearly indicating local production. The nearest copper ores known to be in use during the prehistoric period are in Calabria (La Rocca and Levato 2013).

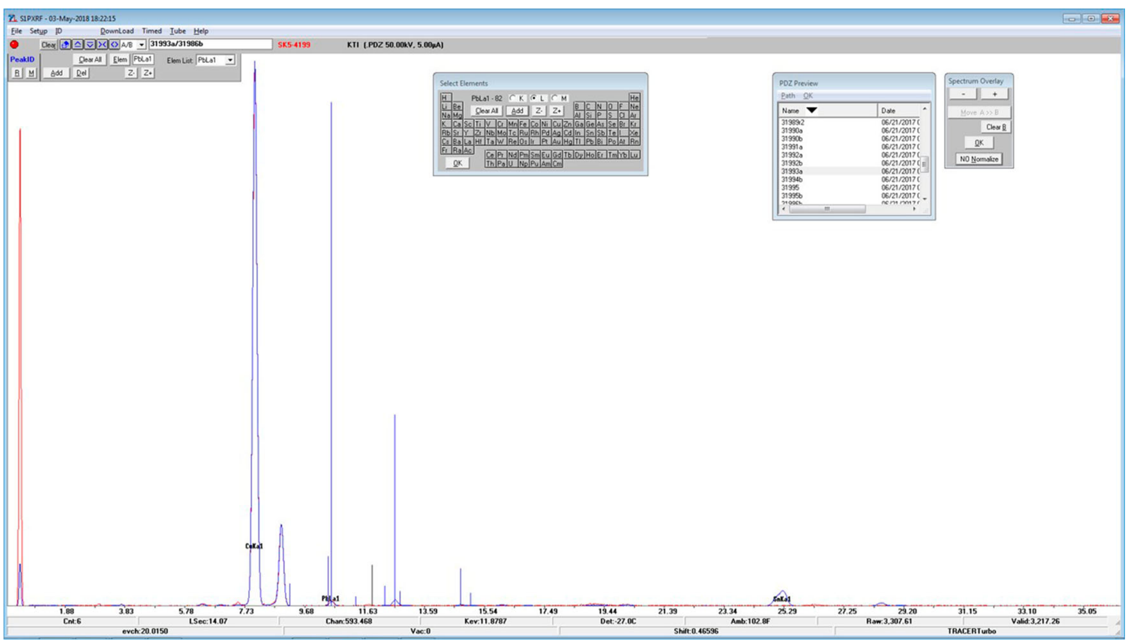

Figure 11. Detail of spectrum overlay of an awl (inv. no. 5646) from Tarxien Cemetery, in red, and a rivet (inv. No. 2646) from Ghar Mirdum, in blue, showing their differences in tin and lead.

Table 3. Table of individual analyses of copper-based artifacts tested and the elemental data obtained by pXRF (in %). "nd" = not detected.

Site	Inv. No.	USF #	Cu	Sn	Pb	Zn	As	Fe	Mn	Total
Tarxien Cemetery	TC 5639	31,980a	99.3	nd	nd	nd	0.7	nd	nd	100.0
Tarxien Cemetery	TC 5639	31,980b	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 5639	31,980c	99.8	nd	nd	nd	0.2	nd	nd	100.0
Tarxien Cemetery	TC 5641	31,981a	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 5641	31,981b	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 5641	31,981c	99.8	nd	nd	nd	0.2	nd	nd	100.0
Tarxien Cemetery	TC 5644	31,982a	99.3	nd	nd	nd	0.7	nd	nd	100.0
Tarxien Cemetery	TC 5644	31,982c	99.3	nd	nd	nd	0.7	nd	nd	100.0
Tarxien Cemetery	TC 6845	31,983a	99.7	nd	nd	nd	0.3	nd	nd	100.0
Tarxien Cemetery	TC 6845	31,983b	99.4	0.0	nd	nd	0.6	nd	nd	100.0
Tarxien Cemetery	TC 6845	31,983c	99.6	0.1	nd	nd	0.3	nd	nd	100.0
Tarxien Cemetery	TC 5640	31,984a	99.1	nd	nd	nd	0.9	nd	nd	100.0
Tarxien Cemetery	TC 5640	31,984b	99.2	nd	nd	nd	0.8	nd	nd	100.0
Tarxien Cemetery	TC 5640	31,984c	99.4	nd	nd	nd	0.6	nd	nd	100.0
Tarxien Cemetery	TC 5640	31,984rc	99.7	nd	nd	nd	0.3	nd	nd	100.0
Tarxien Cemetery	TC 5640	31,984rl	99.7	nd	nd	nd	0.2	nd	nd	100.0
Tarxien Cemetery	TC 6844	31,988a	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 6844	31,988b	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 6844	31,988c	99.8	nd	nd	nd	0.2	nd	nd	100.0
Tarxien Cemetery	TC 6844	31,988r	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 5642	31,989a	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 5642	31,989b	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 5642	31,989r1	99.7	nd	nd	nd	0.3	nd	nd	100.0
Tarxien Cemetery	TC 5642	31,989r2	99.8	nd	nd	nd	0.1	0.1	nd	100.0
Tarxien Cemetery	TC 5699	31,990a	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 5699	31,990b	99.9	nd	nd	nd	0.1	nd	nd	100.0
Tarxien Cemetery	TC 5643	31,991a	99.2	nd	nd	nd	0.8	nd	nd	100.0
Tarxien Cemetery	TC 5638	31,992a	99.7	nd	nd	nd	0.3	nd	nd	100.0
Tarxien Cemetery	TC 5638	31,992b	99.4	0.2	nd	nd	0.4	nd	nd	100.0
Tarxien Cemetery	TC 5646	31,993a	98.4	0.3	0.1	nd	1.3	nd	nd	100.0
Tarxien Cemetery	TC 5647	31,994b	99.7	nd	nd	nd	0.2	0.1	nd	100.0
Tarxien Cemetery	TC 5645	31,998b	99.7	nd	nd	nd	0.3	nd	nd	100.0
Tarxien Cemetery	TC 5645	31,998c	99.6	nd	nd	nd	0.4	nd	nd	100.0
Ghar Mirdum	GM 2648	31,985a	93.0	6.9	nd	nd	0.1	nd	nd	100.0
Ghar Mirdum	GM 2648	31,985b	92.4	7.4	nd	nd	0.1	nd	nd	100.0
Ghar Mirdum	GM 2648	31,985c	93.5	6.5	nd	nd	nd	nd	nd	100.0
Ghar Mirdum	GM 2646	31,986a	91.7	2.1	6.3	nd	nd	nd	nd	100.0
Ghar Mirdum	GM 2646	31,986b	83.2	14.2	2.5	nd	nd	nd	nd	100.0
Ghar Mirdum	GM 2645	31,987a1	78.8	12.8	7.8	nd	0.5	0.1	nd	100.0
Ghar Mirdum	GM 2645	31,987a2	81.4	11.2	7.1	0.1	0.0	0.1	nd	100.0
Ghar Mirdum	GM 2645	31,987b	91.8	2.6	5.1	nd	0.4	nd	nd	100.0
Ghar Mirdum	GM 6843	31,997a	99.1	0.4	0.0	nd	0.1	0.3	nd	100.0
Ghar Mirdum	GM 6843	31,997b	99.8	nd	nd	nd	0.1	0.1	nd	100.0
Bahrija	B 2700	31,995a	93.0	6.9	0.0	nd	nd	0.1	nd	100.0
Bahrija	B 2700	31,995b	92.3	7.1	0.3	nd	0.1	0.1	nd	100.0
Bahrija	B 2701	31,996b	88.2	10.7	0.6	nd	0.1	0.4	nd	100.0

In the light of such new data, Maltese metallurgy appears to be firmly part of the cultural region that includes at least Sicily and Calabria. The material culture in these regions is often comparable during the prehistoric period, suggesting that there were intense exchanges across the region, as demonstrated by the distribution of obsidian from Pantelleria and Lipari in Sicily and Malta (Tykot 2015, 2017, 2019). Given the geographic location of Malta, a group of small islands south of Sicily, and evidence across its material culture, it appears that all early metals could only have come via Sicily (and probably originating from there), while from the later Middle Bronze Age onward also from the Aegean. Malta is the last area to have introduced metallurgy from the progressive introduction of metallurgy in the Italian peninsula from north to south (Dolfini 2013, 2014). Early metals are generally rare in Sicily, and became abundant only in the later phases of the Middle Bronze Age, when local production is detected. A similar pattern, with possibly even more recent dates for the introduction of metals here, seems to happen in Malta, where the only ingot that could be studied suggests that not only metal artifacts were exchanged, but also copper-based artifacts casted locally used exchanged copper.

There are still unalloyed copper objects until the end of the Middle Bronze Age, when tin bronze and a variety of other alloys appear, incrementing significantly the count of artifacts. There is no doubt that the region benefited then from joining a long-distance exchange network and it is possible that some of the later artifacts may have originated outside the technologically homogenous region identified here. There is however little evidence that metallurgy was introduced from a different region. Tin bronze was in existence in neighboring regions (the Aegean in particular), but we have no archaeometric evidence that it was circulating in our region during the early periods, and it is not possible to identify a single point of origin because of significant differences in alloys that appear in the archaeological record from the end of the Middle Bronze Age. There is no obvious reason that would have prevented the people of Malta to access the Aegean or other regions for metals if unalloyed copper artifacts proved unsatisfactory.

However, considering the evidence of intense interactions between Sicily and Malta documented by the distribution of the Maltese Borġ in-Nadur pottery type in Sicily (Tanasi 2011a, 2015) and of Sicilian Middle and Late Bronze age artifacts in the Maltese archipelago (Tanasi 2011b), it seems likely that metallurgy was introduced in Malta via Sicily, which was more exposed to contacts with Mycenaean travelers.

6. Conclusions

Comparing the evidence obtained with pXRF analyses on these Maltese artifacts with the results of the same analytical approach to the Sicilian prehistoric metal items (Vianello and Tykot 2017), it appears that there was not any presence or circulation of tin bronze in the Maltese Early Bronze Age. It is just with the Middle/Late Bronze Age that the first examples of tin bronze are attested at Ghar Mirdum and Bahrija. The lack of metal ores in the Maltese archipelago and its peripheral role in the Mycenaean commercial system in the central Mediterranean makes Malta totally dependent on Sicily in terms of supplying metal raw materials (Tanasi 2010). That dependency can explain the delayed introduction of tin bronze in the archipelago: after tin bronze metallurgy was fully established in Sicily in the Late Bronze Age, the techniques and the copper were subsequently exported to Malta, as the stone mold from Borġ in-Nadur and the copper ingot from Ghar Mirdum seem to indicate.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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