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# Copper-based implements of a newly identified culture in Yemen

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**Abstract –** In March 1997 the excavation team of Edward Keall, Head of the Department of Near Eastern and Asian Civilization of the Royal Ontario Museum, Toronto (Canada) found the remains of an apparently prehistoric site in a region that was supposed to have been uninhabited until the Middle Ages. On the site there are megalithic pillars of granite and basalt, weighing around 6 tons; some were part of what looks like a rectangular building. A cache of copper-based objects – consisting of two adzes, two daggers, four points, two razors and a leaf-shaped object – was found under one of the fallen megaliths. The authors present the as yet unpublished results of the chemical analysis carried out by ICP and the observations obtained by SEM/EDX and discuss briefly the significance of the data and the problems encountered while studying the items of the newly discovered civilization. The stylistic comparisons and the chemical composition of the objects suggest a date around the end of the 3rd or the beginning of the 2nd millennium BC, while other finds on the site seem to indicate a later period. © 1999 Éditions scientifiques et médicales Elsevier SAS

**Keywords: Yemen / copper / copper-based alloys / arsenical copper / bronze / ICP analysis / SEM-EDX analysis / Bronze Age / Iron Age**

## 1. Introduction

The expedition of the Canadian Archaeological Mission of the Royal Ontario Museum (CAMROM) in Yemen, directed by E. Keall, discovered in March 1997, on the Red Sea coast, the remains of a previously unknown Yemeni culture (called by the researchers the Culture of al-Midamman), which shows a puzzling mixture of materials, elsewhere found in chronologically different traditions [1, 2]. The most impressive features of the site, on the Tihamah coast near Zabid, are standing megaliths weighing around 6 tons and other fallen pillars (monoliths) of smaller size. Some of the monolithic pillars were reused in a secondary context, i.e. in a later phase, to build up a monumental stone structure of rectangular shape.

An undisturbed cache of copper-based tools, placed around a large chunk of obsidian, was found under one of the monoliths (*figure 1*). The remains of three children's skeletons were also unearthed in the vicinities. Because of the acute deflation, there are, associated on the same stratigraphic level, obsidian finds (which could be neolithic) ceramics sherds, similar to those found on other Arabian sites dated to 1400−800 BC [3] and the copper-based

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objects, which have stylistic Near Eastern and Mediterranean parallels dated to 2400–1800 BC [4–11]. For a better understanding of the cultural *facies* of al-Midamman several studies are under way: radiocarbon dating, obsidian dating and thermoluminescence. A metallurgical study of the metal tools was undertaken as a further means of interpreting the finds and to try and date the earlier period of the site [12].

## 2. Analysis

The group of objects found under the monolith – two flat adzes of different size (*figure 2*), two daggers, four points, two razors and a thin leaf-shaped object called here 'spatula', were sampled for an ICP analysis, for metallography and for an examination by SEM/EDX.

**Figure 1.** Excavation of the tallest megalith and site where the copper-based implements were found. Photo Edward Keall (R.O.M.).

The results of the ICP analyses are given in *table I*. Some of the objects, in particular the dagger and the razor, were corroded. In this case the results should be considered semi-quantitative.

## 3. Discussion of results

The two adzes and two of the points were found to be made of unalloyed Cu. One dagger (ZP97.244) with its rivets (*figure 3*) and another point were of Cu with some arsenic (1.5–2.5 % As), while the remaining objects were of Cu containing low amounts of tin (1.5–3.5 % Sn) (*figure 4*). As small amounts of arsenic occur naturally in copper it is rather difficult to differentiate between natural alloys, obtained by smelting mixed ores, and deliberate ones. Different levels were suggested as the upper limit of natural alloys, in general an amount exceeding 1 % is considered as deliberate [13–15]; however, there is also the possibility that the low As content was due to the recycling of arsenical copper.

It is also difficult to explain the metallurgical significance of the low Sn amounts determined in the dagger and its rivets, in one of the points, in the razors and in the spatula. These small amounts do not noticeably harden the alloy, but improve the workability and the fluidity of the metal in molten state and deoxidize the alloy. It is just possible that the smiths were recycling scrap bronze, diluting it with unalloyed Cu, because of problems with the Sn supply; however, copper-based objects of similar composition, i.e. containing low amounts of Sn and As, were employed in several Eastern-Mediterranean contexts in the EB-MB period [4, 11, 15–20], etc.

The presence of Pb in one of the razors has no metallurgical reason and in this case does not seem to be intentional. However, it is important to note that in the Mediterranean Pb was used as a deliberate addition in early times, albeit without correlation with working technique and function of the objects [4, 15]. As pointed out by Philip [4, 21] scrap metal was most probably used in large amounts in the metal trade and supply, possibly as early as the Early Dynastic period (around 3000–2600 BC, cf. [15]). This fact represents of course a serious problem in the case of lead isotope provenancing studies.

## 4. Interpretation

The discovery of the tools under the monolithic pillar suggests a ceremonial deposition. From other

**Table I.** ICP analysis of Yemeni copper-based finds[a]

| Object | Exc. n. | Part | Cu | Sn | Pb | As | Zn | Fe | Sb | Ni | Ag | Au | Bi | Cd | Co | Mn | P | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adze | ZP97.224 | narr. end | 93.9 | 0.04 | 0.26 | 0.32 | 0.02 | 0.17 | 0.01 | 0.01 | 0.02 | – | 0.06 | – | 0.001 | – | 0.04 | 0.27 |
| Adze | ZP97.219 | narr. end | 94.6 | 0.03 | 0.11 | 0.16 | 0.01 | 0.21 | – | 0.01 | 0.01 | – | 0.02 | – | 0.001 | 0.001 | – | 0.05 |
| Dagger | ZP97.244 | blade | 73.3 | 0.01 | 0.03 | 0.67 | 0.03 | 0.51 | 0.01 | – | 0.01 | – | – | – | 0.002 | 0.004 | 0.02 | 0.07 |
| Rivet | ZP97.244 | head | 92.7 | 0.04 | 0.04 | 1.26 | 0.02 | 0.21 | 0.03 | – | 0.15 | – | 0.01 | 0.002 | 0.001 | 0.001 | 0.03 | 0.11 |
| Rivet | ZP97.244 | head | 69.4 | 0.03 | – | 1.19 | 0.06 | 0.93 | 0.03 | 0.01 | 0.09 | – | – | – | 0.001 | 0.011 | 0.03 | 0.35 |
| Dagger | ZP97.232 | blade | 78.9 | 2.12 | 0.15 | 0.27 | 0.02 | 0.57 | 0.01 | 0.01 | 0.02 | – | 0.04 | – | 0.001 | 0.004 | 0.04 | 0.49 |
| Rivet | ZP97.232 | head | 78.7 | 2.82 | 0.38 | 0.18 | 0.01 | 0.23 | 0.01 | 0.01 | 0.02 | – | 0.07 | – | 0.001 | 0.003 | 0.02 | 0.18 |
| Rivet | ZP97.232 | head | 81.5 | 2.58 | 0.55 | 0.21 | 0.02 | 0.39 | 0.01 | 0.01 | 0.01 | – | 0.05 | – | 0.002 | 0.003 | 0.05 | 0.22 |
| Point | ZP97.216 | tang | 88.6 | 0.01 | – | 2.21 | 0.01 | 0.41 | – | 0.01 | 0.09 | – | 0.01 | 0.001 | 0.002 | 0.001 | 0.02 | 0.12 |
| Point | ZP97.237 | broad p. | 87.5 | 0.01 | 0.08 | 0.25 | 0.01 | 0.09 | – | – | 0.41 | – | – | – | – | – | – | 0.12 |
| Point | ZP97231a | broad p. | 94.8 | 1.46 | 0.37 | 0.17 | 0.01 | 0.07 | 0.01 | – | 0.02 | – | 0.05 | – | – | – | 0.15 | 0.39 |
| Point | ZP97231b | tang | 90.8 | – | – | 0.29 | 0.01 | 0.03 | – | – | 0.06 | 0.002 | 0.01 | – | – | – | – | 0.07 |
| Razor | ZP97.218 | handle | 84.6 | 3.04 | 0.48 | 0.12 | 0.01 | 0.21 | 0.01 | 0.01 | 0.05 | – | 0.07 | – | 0.002 | 0.001 | 0.02 | 0.33 |
| Razor | ZP97.110 | handle | 50.1 | 0.18 | 0.01 | 0.02 | 0.39 | 1.71 | – | 0.01 | – | – | – | – | 0.005 | 0.012 | 0.05 | 1.96 |
| Razor | ZP97.110 | blade | 78.1 | 2.15 | 2.44 | 0.17 | 0.03 | 0.17 | 0.01 | – | – | 0.001 | 0.06 | – | – | 0.002 | 0.09 | 0.25 |
| Spatula | ZP97.111 | handle | 73.8 | 3.31 | 0.42 | 0.15 | 0.03 | 0.21 | 0.09 | 0.01 | 0.01 | – | 0.05 | – | 0.001 | 0.002 | 0.04 | 0.19 |

[a] The results given in the table have a precision of approx. ± 1–2 % for Cu, ± 5 % for elements present at levels greater than 1 %. but deteriorating to ± 50 % at the respective detection limits.


**Figure 2.** The adze of smaller size belonging to the cache of objects found under the pillar. The metal used for both adzes is unalloyed copper. Photo Susan Stock (R.O.M.).


**Figure 3.** Dagger (ZP97.244): the ICP analysis has shown that it is made of copper containing over 1 % of arsenic. This could be an intentional alloy; the addition of this element improves the properties of the alloy and deoxidizes it. The other dagger was made of a low-tin bronze with around 2.5 % of tin. The burial under the pillar suggests a ceremonial deposition, but the blades were hardened and are functional. Photo Susan Stock (R.O.M.).

cultures we know about offerings of objects which were not functional and had a mere symbolic value. In these cases the artisans took whatever metal was at hand, the alloys were metallurgically wrong and not significant for the period (cf. for example [22]). Metallographic samples of one of the daggers (ZP97.244) and of one of the points (ZP97.237) were examined under the metallographer and SEM and showed that the metal had been worked and the objects were functional (*figure 5*). The SEM examination of a corrosion fragment from the second dagger, carried out in London by A. Shugar showed a similar metallographic structure.

The analysis of a cache of only 11 objects is not statistically significant and cannot determine with any sort of accuracy the date of the site. The analysis of a greater number of local artefacts could perhaps radically change the situation; however, at this stage of the research the characteristics of the tools and their composition allow the items to be placed into a cluster of Near Eastern finds with similar distinctive features, which are diagnostic for


**Figure 4.** Two of the four points. The larger example was found to be of low-tin bronze, the smaller was of unalloyed copper. The other two points were made of unalloyed copper and of arsenical copper, respectively. Photo Susan Stock (R.O.M.).

a long but definite period between the end of the 3rd millennium and the middle of the 2nd. The low content of alloying elements, the inverse correlation between As and Sn, the use of unalloyed Cu and the lack of elements such as antimony, bismuth, nickel and silver in the copper – which could also signify that the presence of As was accidental – seem to indicate a date to this transition period, in which arsenical copper, low tin bronzes and unalloyed copper coexisted.

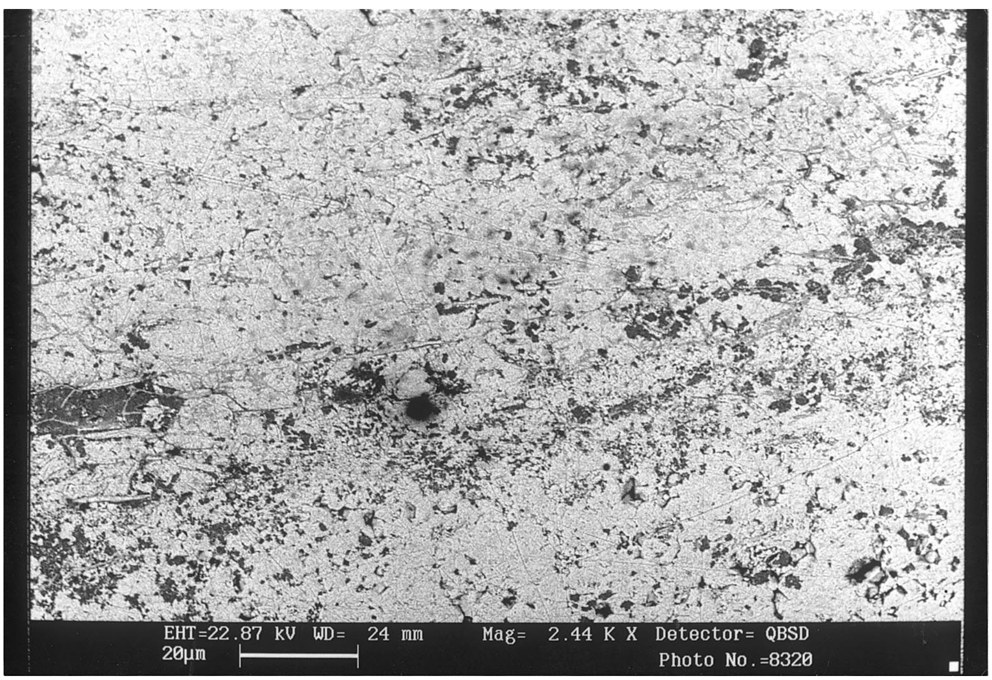


**Figure 5.** Scanning electron microscope (SEM) picture of a sample from the tip of dagger ZP97.232. Some distorted annealing twins and many elongated grains are visible. The structure shows that the dagger was cast and repeatedly hammered and annealed. The last stage was cold working. Photo Alessandra Giumlia-Mair (Università di Udine).

From what we know from the few analyses carried out on Anatolian and Near- and Middle-East finds (for example [4] and [23]) this phase lasted for over a millennium.

Of course we cannot be sure that the same parameters are also true in Yemen, where obsidian and Bronze Age metal technology seem to coexist. Insufficient data exist yet on the Yemeni metallurgical tradition and typological parallels are not sufficient to date the site: in remote regions the shapes of tools can last for very long periods. Also, very little is known on the typology of artefacts and the technology of countries such as Pakistan, India or of those on the other side of the Red Sea – for example the kingdom of Kush and Ethiopia – which could very well be the origin of the al-Midamman metal technology, or could at least have had some influence on it. An important parallel for the copper-based items analysed here comes from Sabr, near Aden, where similar tools were discovered by Vogt [3], in a stratum for which radiocarbon dating gave as a result 1400–900 BC. However, it should be noted that the apparently contemporary buildings found at Sabr, are similar to the monumental building, which at al-Midamman belongs to the second phase and must therefore be later than the tools. At least at this stage a date towards the end of the 3rd/beginning of the 2nd millennium seems to be the most appropriate.

The finds from Ras al-Khaimah [18], on the other side of the peninsula, show compositional similarities with the material from al-Midamman, but the trace elements are different: most objects from the Oman area contain very high Ni levels, while at al-Midamman the nickel content is very low. In the finds from Tell Selenkihiyye in Syria [20], the Ni and often also the Sn percentages are much higher than at al-Midamman. Anatolian material contains more As, Ni and Sb [23, 24], while Egyptian material [15] and Palestinian finds [11] contain both As and Sn. The relatively pure Cu used for the Yemeni tools is combined either with As or with Sn. The differences in the trace element pattern indicates perhaps a different metal tradition, i.e. also different supplies and a different sphere of political influence.

## 5. Ancient texts and possible connections with other civilizations

Several maritime trading centres on the other side of the Arabian Peninsula, on the coast of the Persian Gulf, are mentioned in cuneiform texts dated 2340–1750 BC (between Sargon and Hammurabi): these are Dilmun (Bahrein), Magan (Oman?) and Melukhkha (possibly Makrān in Pakistan). These centres seem to have been independent from the Sumerian and Accadic civilizations, but economically in contact with Iran and India [25]. At the end of the 3rd millennium the influence of Accadic Mesopotamia apparently spread to the Arabic coast: Lukhkhiššan, king of Elam, was defeated by Sargon and later the capital of Elam, Awan/An Shan, was destroyed by Manishtushu (2274–2260 BC), son of Sargon, who on this occasion also subjugated the 'king of Magan'. This suggests of course that in this period 'Magan' was subordinated by Elam.

Fattovich [26] dates the megalith stones ordered in circles or in lines in the South of Yemen to the 2nd millennium BC "and possibly earlier". He connects the Yemeni megaliths with the dolmens in the area of Harar and postulates the existence of contacts between the Arabian and the African populations as early as the 3rd millinnium BC. He mentions the existence of paintings and incisions on the stones in the Hidjaz desert, very similar to those found in the Ogaden, as a proof that the African populations were able to cross the Red Sea very early (as confirmed by a wiltonian industry in the Dahlak islands). His hypothesis is that they regularly traded in incense and myrrh between the Mediterranean and both sides of the Red Sea, where these plants were to be found. He supposes the existence of three trade routes. One was the maritime route down the western coast of the Red Sea, but there should also be a land route down the Nile valley and a second one along the western Arabic Peninsula.

This trade seems to have lasted for a long period: late texts – the lists of Tuthmes III – mention the Gnb-tjw, which are identified as the inhabitants of Quataban in Yemen. Other texts of the same period mention the import of incense from Syro-Palestinian areas, which Fattovich believes to be Yemen [26]. The ancient texts and Fattovich's theories seem to suggest that eastern Arabia gravitated towards Mesopotamia, while the western coast shared its culture and economy with the eastern coast of Africa. The results of the metallurgical researches seem to point in the same direction.

## 6. Conclusions

The research on the al-Midamman culture is still at the beginning and very little is known about the origin of the culture and to which economical sphere it belonged. The general impression is that a group of people, belonging to a still unidentified *facies*, lived in this area, most likely without interruption, from about the end of the 3rd millennium or the first centuries of the 2nd millennium BC and for well over one thousand years, apparently employing both a lithic and a Bronze Age metal tradition.

The metallurgical analyses seem to give some circumstantial proof of a metal tradition different from those of the better known neighbouring civilizations of the Near East. The possibility that the metal and the metallurgical tradition of al-Midamman had its origins on the other side of the Red Sea should be taken into account in the course of further research.

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