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Michael Kunst | Martin Bartelheim |
Roland Gauß (eds.)

FROM THE OBJECT TO THE
MINE. PAPERS FROM THE PRO-
JECT AND CONFERENCE »PRE-
HISTORIC COPPER METALLURGY
IN ZAMBUJAL (PORTUGAL)«

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Umschlagfoto: The mine of Mocissos (Portugal) with pioneer plants, 25 April 2005. In the background the river Guadiana, the border between Portugal (left) and Spain (right), photograph: Michael Kunst.

Die Mine von Mocissos (Portugal) mit Pionierpflanzen, 25.4.2005. Im Hintergrund der Guadiana, die Grenze zwischen Portugal (links) und Spanien (rechts), Foto: Michael Kunst.

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Widmung

Mit herzlichem Glückwunsch
Herrn Prof. Dr. Dres. h. c. Hermanfrid Schubart
zu seinem 90. Geburtstag am 1. Dezember 2020



Hermanfrid Schubart, im Hintergrund der Puig Llorença – Cumbre del Sol, Benitachell, Comunidad Valenciana, Spanien
(Foto: Annie Schubart, April 2004).

Hermanfrid Schubart, no background Puig Llorença – Cumbre del Sol, Benitachell, Comunidad Valenciana, Espanha
(Foto: Annie Schubart, Abril 2004).

Die archäometallurgischen Untersuchungen, die im Zentrum dieses Bandes stehen, gingen von den Ausgrabungsergebnissen in Zambujal aus. Zambujal gehört zu den besonders intensiv erforschten kupferzeitlichen befestigten Siedlungen der Iberischen Halbinsel. Das verdanken wir Hermanfrid Schubart, der 1963 von Seiten der Madrider Abteilung des Deutschen Archäologischen Instituts die Untersuchungen in Zambujal begann und zusammen mit Edward Sangmeister und Leonel Trindade sowie einem großen, internationalen Team von 1964 bis 1973 sechs umfangreiche Ausgrabungen in dieser prähistorischen Siedlungsanlage durchführte. Ohne seine Initiative wären die interdisziplinären und internationalen Forschungen, die inzwischen schon sechs Monographien gefüllt haben, nicht möglich gewesen. Auch dieser Band wäre gar nicht zustande gekommen. Die Grabungskampagnen von 1964-1973 in Zambujal und ihre Veröffentlichung in Band 5, 1 der Madrider Beiträge markieren einen Wendepunkt in der Erforschung der Kupferzeit der Iberischen Halbinsel! Vor allem hat Hermanfrid Schubart aber einen wichtigen Grundstein zu gegenseitigem Vertrauen und zu intensiven wissenschaftlichen wie freundschaftlichen Kontakten zwischen den deutschen Wissenschaftlern und denen der Iberischen Halbinsel gelegt, Kontakte, die sich schließlich auch in der vorliegenden Veröffentlichung widerspiegeln.

As pesquisas arqueo-metalúrgicas, que constituem o tema central deste volume, partiram dos resultados das escavações de Zambujal. Zambujal apresenta-se como um dos povoados calcolíticos fortificados da Península Ibérica com investigação mais intensa. Tal devemos a Hermanfrid Schubart, que iniciou em 1963, com o Instituto Arqueológico Alemão, as investigações em Zambujal, e realizou, em conjunto com Edward Sangmeister e Leonel Trindade com uma equipa grande e internacional, seis campanhas de escavação entre 1964 e 1973 nesse povoado pré-histórico. Sem a sua iniciativa, as investigações interdisciplinares e internacionais, que, entretanto, produziram seis monografias, não teriam sido possíveis. Também este volume não se teria realizado. As campanhas de escavação de 1964 a 1973 em Zambujal e a sua publicação em volume 5,1 da série Madrider Beiträge marcam um ponto decisivo na investigação da Idade do Cobre na Península Ibérica! Sobretudo, Hermanfrid Schubart preparou um fundamento importante para a confiança mútua e para contatos intensivos científicos e amigáveis entre os científicos alemães e da Península Ibérica, contatos que, finalmente, são também refletidos nesta publicação.

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Copper Age Metallurgy at Zambujal and the Southwest Iberian Peninsula

Martin Bartelheim – Roland Gauß – Michael Kunst

1. Introduction

The fortified settlement of Zambujal (Torres Vedras, district Lisbon) lies within one of the best studied Copper Age settlement agglomerations of the Iberian Peninsula. Due to the many metal objects and production waste found at the site, the excavators Edward Sangmeister and Hermanfrid Schubart first concluded that copper metallurgy must have been of outstanding importance for the Copper Age economy¹ and connected it to the Bell Beaker phenomenon. At that time, however, the extent and the economic and social weight of the metallurgical chaîne opératoire associated with it could not yet be assessed; neither the origin of the ore, the mining and the associated work processes, the organisation of production, the distribution of the end products nor recycling were known. In order to clarify these questions, the project of the German Research Foundation (DFG) »Prähistorische Kupfermetallurgie in Zambujal (Portugal) – Von der Erzlagerstätte zum Fertigprodukt (Prehistoric Copper Metallurgy in Zambujal (Portugal) - From Ore Deposit to Finished Product)« was launched in 2003². This project consisted of surveying potential ore deposits in central and southern Portugal from a mining-archaeological point of view and characterising these deposits with the help of geochemical and isotope-geochemical methods. Through the comparison of the ore signatures with those of copper artefacts, the provenance of the Zambujal copper should be determined. In addition, analyses of the metallurgical finds of the settlement site should enable a reconstruction of the metal extraction- and processing techniques.

Several specific objectives were formulated:

a. Central to the research tasks was the mining archaeological survey and sample collection (copper ores),

the documentation of prehistoric mining traces as well as the mineralogical, geochemical and isotope-geochemical characterisation of the copper ore deposits in Central and Southern Portugal, which were possibly exploited in prehistory. Based on the geological and geographic circumstances a division into four surveying areas was planned: I. Ossa Morena Zone (Alto and Baixo Alentejo), II. Iberian Pyrite Belt (Baixo Alentejo), III. Algarve, and IV. the Portuguese Estremadura. The collected ore samples should be analysed on their mineralogical contents, element composition and lead isotope ratio. Mainly elements and element ratios which remain stable throughout the metallurgical production process were studied.

- b. The results should be compared with those of lead isotope analyses of metallurgical remains and finished products from Zambujal and its surroundings in the Portuguese Estremadura. Analyses of the element composition of some of these objects had already been carried out under the »Studien zu den Anfängen der Metallurgie« (Studies of the Beginnings of Metallurgy) project and own investigations that were conducted in preparation of the project. The new and extended data set should allow to identify those copper deposits that delivered copper to Zambujal and the other Estremadurian sites.
- c. The study of the archaeometallurgical residues from different prehistoric settlements in the Portuguese Estremadura should help to determine which manufacturing technologies were used.
- d. Finally, it was planned to compile and analyse all indications for a reconstruction of the organisation of copper extraction and processing, as well as the distribution of finished products.

¹ Sangmeister 1965, 555–556; Sangmeister 1972, 192. 196–197. 199–200; Sangmeister 1995, 4; Sangmeister – Schubart 1981, 254–

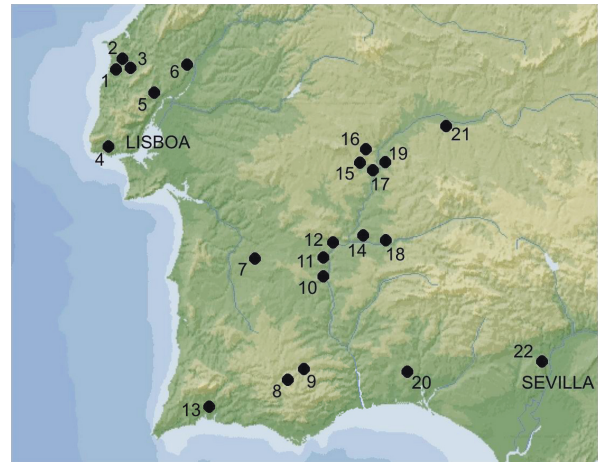
255.

² Number of refence BA 2280/1-1, PA 368/8-1.

2. The settlement context at Zambujal

The excavations by Edward Sangmeister and Hermanfrid Schubart at Zambujal from 1964 to 1973 were a milestone in the research of the Copper Age of the Iberian Peninsula³. In this time period, also other large fortified settlements were identified and excavated, especially in Andalusia⁴. Nevertheless, with its walls still reaching up to 4 metres high, Zambujal is uniquely well-preserved amongst its contemporary sites. In fact, as Zambujal is today located in an agrarian area, surrounded by vineyards, the settlement has been spared from modern constructions. Zambujal may not have had the same political importance as the biggest comparable settlements such as Valencina de la Concepción on the edge of the Guadalquivir Valley or Leceia, near Lisbon in the Tejo estuary area. However, thanks to its good preservation this site is particularly suitable for archaeological research.

The excavations showed that the fortifications of Zambujal were constructed in five phases⁵, that is, respecting different strategic defence concepts. Construction phases 1 and 2 were accompanied by ceramics of the early Portuguese Chalcolithic, whereas phases 3 and 4 pertain to the Bell Beaker times; phase 5 dates to the Early Bronze Age. The calibration of ¹⁴C-dates so far has yielded an absolute chronology between the 9th century of the 3rd millennium BC and the first half of the 2nd millennium BC⁶. Relatively little is known so far about the structures between the big fortified walls, where people settled⁷. Apart from domestic



1 Distribution of the sites with chalcolithic metallurgical finds in the southwest of the Iberian Peninsula mentioned in the text. Portugal: 1. Zambujal; 2. Fórnea; 3. Penedo; 4. Leceia; 5. Pedra do Ouro; 6. Vila Nova de São Pedro; 7. Porto Torrão; 8. Cerro do Castelo de Corte João Marques; 9. Santa Justa; 10. São Brás; 11. Três Moinhos; 12. Sala I; 13. Alcalar; 14. Porto Mourão; 15. Fonte Ferrenha; 16. São Pedro; 17. Perdigões; 18. Castelo Velho de Saffara; Spain: 19. San Blas; 20. Cabezo Juré; 21. La Pijotilla; 22. Valencina de la Concepción.

areas, there were also vacant spaces. Copper processing has been proven also for most of the other fortified settlements (see here chapter 5. and fig. 1); indeed, this is typical for the whole south of the Iberian Peninsula. Nevertheless, so far the publications about Zambujal contain several different analyses of the site's copper metallurgy, i. e. particularly of its copper finds. Not least because of this, Zambujal is still in the centre of attention of Chalcolithic research on the Iberian Peninsula and especially in Portugal.

3. Studies of the Zambujal settlement area

Many Chalcolithic sites are known from Zambujal's hinterland (settlements and graves). In the course of a coastal research project financed by the Volkswagen Foundation, geoarchaeological investigations took place in the Sizandro River Valley in 1986. The tributary stream of this river, Ribeira de Pedrulhos, forms the valley around the hilltop on which Zambujal lies. The project also focused on the settling in Zambujal's hinterland, as well as on sketching a diachronic history of the overall Sizandro

River catchment area⁸. Therefore, in the past years pedological investigations of the Ribeira de Pedrulhos Valley have been undertaken, which yielded pollen analyses, too⁹. The pedological investigations are useful on the one hand for the reconstruction of the landscape history, on the other hand they also help in the search for metal traces, mainly copper, in the prehistoric sediments. Thus, a more and more precise reconstruction of the settling and landscape structure in the Chalcolithic can be

³ Sangmeister – Schubart 1981; Parreira 1985, 209.

⁴ E. g. Márquez Romero – Jiménez Jáimez 2010; García Sanjuán et al. 2013; 2017; Aranda Jiménez et al. 2016.

⁵ See also Kunst in this volume.

⁶ See also Kunst in this volume.

⁷ Sangmeister – Schubart 1981, 255–262.

⁸ Kunst – Trindade 1990.

⁹ Dambeck et al. 2010.

created, which provides a strong basis for assessing the significance of metallurgy within Chalcolithic society.

During surveys carried out by Gerd Goldenberg and Alexander Maass the copper ore deposit of Matacães (Torres Vedras, district Lisbon), within Zambujal's settlement area, was examined. Although the survey was carried out just within a month, it provided many promising indications for a use of this deposit in prehistory,

further research could not prove this conclusively. All research attempts so far have made it clear that the significance of Zambujal can be studied only within an interdisciplinary project, in which the former environment is reconstructed. Moreover, it is important to include Zambujal's connections to nearby prehistoric settlements, as well as the provenance of different raw materials, especially copper.

4. Metallurgy in Zambujal

4.1 Why investigate metallurgy?

Throughout research history, the rise and development of Zambujal and other Chalcolithic settlements on the Iberian Peninsula (e. g. Vila Nova de São Pedro (Azambuja, Santarém), Los Millares (Almería), Leceia (Oeiras), Penedo (Torres Vedras), Fórnea (Torres Vedras); see fig. 1) have been brought in close connection with the emergence of copper metallurgy. This has to do, for one, with the relatively high amount of copper objects found there, particularly from the 3rd millennium onwards. Additionally, remains of metallurgical production were found in nearly all settlements and, in some cases, the sites are situated in a striking vicinity to copper ore deposits. Having said that, it seems to be clear, at first glance, that the intensified economic developments, demographic growth and social differentiation, which can be deduced from the archaeological findings, would be linked to the emergence of metallurgy in the region on a technological and social level. Today, it is common sense that metallurgy is complex, requires special knowledge and logistics, and has a multi-staged production chain, which needs many different raw materials. In many aspects, one would assume that metallurgy brings a new dimension of trade to a society, opening up new levels of interaction. As this innovation first becomes visible in the southwest of the Iberian Peninsula at the beginning of the 3rd millennium, practically simultaneously to the construction of fortified settlements of large dimensions, for decades it seemed a logical conclusion to state that metallurgy and fortified settling were imported by colonists from the Eastern Mediterranean (along with high quality ceramics and stone idols, see below).

However, before the start of the project, barely any more specific metallurgical investigations of the Portu-

guese assemblages had been carried out, that is, regarding the production of metal and metal objects and their provenance. Therefore, one could only speculate about the actual complexity of the metallurgical processes, the provenance of the raw materials, and thereby the economic and social role that metallurgy played in Zambujal and beyond.

4.2 Why investigate Zambujal and its assemblage?

Zambujal is one of the best studied examples among big fortified Chalcolithic settlements on the Iberian Peninsula. Thanks to the detailed documentation of its stratigraphy it offers a good case for exemplary research of the development of metallurgy, at least for the Portuguese Estremadura. Already during the excavations from 1964 to 1973, some of the ca. 900 copper objects were sampled, 363 of which were submitted to spectrometric studies¹⁰. This was carried out in the framework of the European-wide project »Studien zu den Anfängen der Metallurgie – SAM« (Studies into the Beginnings of Metallurgy), containing over 22.000 metal analyses, of the Württemberg State Museum Stuttgart. This project also analysed the results in relation to those of other Chalcolithic and Early Bronze Age sites in Portugal (another, over 700 analyses) and published them¹¹. The goal was to elaborate material groups by means of trace element signatures, which were meant to make possible both, the research of diachronic-regional typological developments as well as trans-regional sociocultural connections. One of the most important results was the description of how differ-

10 Sangmeister 1995, 37.

11 Junghans et al. 1968; 1974; Krause – Pernicka 1996.

ent the alloy development was on the Iberian Peninsula in comparison with large parts of Europe. Using the trace element distribution on chronologically relevant leading forms of the Copper- and Bronze Age metal production it was deduced that pure copper was replaced by arsenical copper in the course of the Estremadurian Copper Age. The latter remained dominant on the Iberian Peninsula until the Late Bronze Age¹². It was not possible to retrieve information regarding the production techniques, the provenience of the raw materials, or the significance of archaeometallurgical finds in terms of social organisation and economic impact. The interpretation of archaeometallurgical finds and features was still in its infancy.

The investigated material groups were repeatedly criticised by the research community. Today, it appears that the authors were well ahead of their times and that in those days it was barely possible to objectively validate and contextualise the results: neither were there similar measurements for comparison, nor computers and modern statistical methods available that could have helped the interpretation of the massive set of data¹³. Meanwhile, it has been possible to demonstrate the quality of the analysed data thanks to more recent analytical results obtained through other methods and projects¹⁴. A systematic comparison of the SAM data with the two other big analytic sets of early copper finds from the Iberian Peninsula – that of the British Museum¹⁵ and of the Project »Arqueometalurgia de la Península Ibérica« of the Consejo Superior de Investigaciones Científicas (CSIC)¹⁶ remains pending. The series of analyses of the DFG Project concerning Zambujal's metallurgy discussed here was able to confirm the validity of the SAM analyses¹⁷.

Sangmeister dedicated a separate study to the 871 copper finds of Zambujal¹⁸. He concluded that throughout the five building phases of Zambujal a continuity in the metallurgical production can be recognized, which left traces in several parts of the settlement. The regionally specific interpretation of the SAM data showed that the Chalcolithic was clearly dominated by the low-trace element of arsenical copper. In the Early Chalcolithic also pure copper seems to have been used in greater quantities, whereas in the Late Chalcolithic and Early Bronze Age arsenical copper with antimony, silver and/or nickel appears to have been more common.

Back then, it was not possible to identify traces of mining and metal extraction, neither in Zambujal nor

its surroundings. After the analyses of several slags, Gerhard Sperl suggested that there had been no smelting of copper ores in Zambujal¹⁹. Sperl argued that the microstructure of the slag samples would have indicated only a slightly reducing atmosphere in the metallurgical process, which would have been typical for casting. Indicators for metal production, such as crucibles, casting drops and clay rings, which were deemed to have been used as casting places, were found in many locations in Zambujal²⁰. Therefore it was concluded that extensive further processing of crude copper took place here²¹, defining the economic character of the settlement as a »centre of the earliest copper production«²².

4.3 A foreign or a local origin of metallurgy?

Especially in the 1960s and 1970s Zambujal and other fortifications were interpreted as colonies of Eastern Mediterranean settlers and metallurgical explorers, because of cultural elements that were perceived as foreign: the architecture and the burial rites of nearby necropolises and parts of the archaeological sites, for which parallels from the Eastern Mediterranean were found. It was assumed that these »foreigners« had been attracted by the wealth in copper of the South and West of the Iberian Peninsula. They were thought to have exploited the copper resources, which the indigenous population was not able to use due to their assumed low cultural and technological development. It was thought that the rendered copper would have been shipped to the Eastern Mediterranean region from the isolated settlements, located near the shores²³. Nevertheless, it was not clear from which deposits Zambujal's copper had been extracted. No evidence indicating large-scale mining, processing or smelting were found. Traces of copper processing were documented, but it was not possible to describe or interpret this in detail.

In the course of the introduction of ¹⁴C dating in large parts of Europe and the increasingly improving calibration throughout the 1960s and 1970s it became clear, mainly thanks to Colin Renfrew's work, that many of the elements from the Eastern Mediterranean area, which

12 Junghans et al. 1968, 127.

13 See the discussion in Pernicka 1984; 1990.

14 See Ottaway 1982; Pernicka 1984; 1987; 1990.

15 Harrison – Craddock 1981.

16 Rovira et al. 1997.

17 See Müller – Pernicka 2009; Gauß 2013.

18 Sangmeister 1995.

19 Sperl 1981.

20 Sangmeister 1995, 32–35.

21 Sangmeister 1995.

22 Sangmeister – Schubart 1981, 252.

23 Sangmeister 1960; 1975; Blance 1961; 1971; Almagro – Arribas 1963; Almagro 1966; Junghans et al. 1968; Savory 1968; Sangmeister – Schubart 1981.

had been interpreted as examples for elements found in the Iberian Peninsula, were not actually older²⁴. Thus, a substantial argument for the assumed early colonisation of the West was lost. In addition, archaeologists did not find significant amounts of imported materials from the Eastern Mediterranean in the Iberian Peninsula.

In the following decades, new discoveries showed that the fortified settlements, which had been assumed to be colonies, were not at all that isolated from their cultural surroundings²⁵. Throughout the 1980s other settlements were discovered, such as Leceia (Oeiras), Santa Justa (Alcoutim) und Alcalar (Portimão) in Portugal, in Spain Valencina de la Concepción (Sevilla), La Pijotilla (Badajoz), Albalate (Jaén), Los Alcores (Jaén), and later Marroquíes Bajos (Jaén) and San Blas (Badajoz). They showed similar characteristics and a comparable size to the known fortified settlements. Many of these sites were located in the hinterland of the coast and thus no longer complied with the criteria used in the

identification of typical colonies: vicinity to the coast, ore deposits and fortifications²⁶. Even if nowadays an Eastern Mediterranean origin of the inhabitants of those fortifications is no longer discussed, the close connection between their emergence in the early 3rd millennium with those of copper metallurgy remains striking.

Since the 1980s, local characteristics of the Chalcolithic metallurgy of the Iberian Peninsula have been emphasized. It was argued for example, that there are no indications for an external origin of the Peninsula's metallurgy, but rather that all developments that occurred during the transition from the Neolithic to the Chalcolithic were local²⁷. To support this argument one object has been mentioned specifically: a ceramic fragment with slag adherences (probably from a crucible) from the stratigraphy of the Final Neolithic settlement of Cerro Virtud (Almería, Spain). This site is located close to the famous Chalcolithic settlement of Almizaraque (Almería, Spain) and is dated to the 5th millennium BC²⁸.

5. Other sites

Contemporary to Zambujal, Vila Nova de São Pedro (VNSP) (Azambuja, Santarém) and Leceia are the other Portuguese Estremaduran Chalcolithic type-sites. Vila Nova de São Pedro plays an important role in terms of research history, that is, not only with respect to archaeometallurgy, but also Chalcolithic research generally. This site is the first fortified Chalcolithic settlement in Portugal with the characteristic semicircular towers that was excavated and published on a large scale²⁹. During these excavations many complete copper objects (mainly copper daggers, Palmela points, axes, chisels and awls) as well as square crucibles on pedestals, moulding residues, blowpipe fragments, and 13,5 kg of copper ores were found. The first metallographic and chemical analyses of these metal objects and slag residues on the crucibles were conducted as early as the 1950s³⁰. The metal finds and the metallurgical remains of VNSP were re-assessed within the context of our DFG research project³¹. Altogether, the amount of copper detected at the site was

quantified to 5–6 kg. In addition, slags and thin-walled crucibles – most likely used in copper extraction processes – were identified by chemical and mineralogical analyses. Trace element and lead isotope analyses indicate that the copper of VNSP originated from the same sources as Zambujal's copper.

Excavations at Leceia were conducted from the 1980s onwards. Remarkably, significantly fewer copper finds as in VNSP, and only one crucible fragment were retrieved from the Middle and Early Chalcolithic levels³². The material composition of a big part of the in total 130 copper samples (artefacts, casting remains, and casting lumps) were analysed via neutron activation analyses (NAA)³³. The DFG metallurgy project quantified the amounts of copper found at the site, which is less than one kilogram. Smelting slags were not identified. Trace element and lead isotope analyses indicate that also the metal of Leceia originated from the same geological sources as Zambujal copper.

24 Renfrew 1967; 1969, 1970; 1972a; 1972b; 1973.

25 Silva – Soares 1977, 261–267.

26 See Martínez Navarrete 1998; Arteaga 2001; Kunst 2001; Márquez Romero – Jiménez Jáimez 2010; García Sanjuán et al. 2017.

27 Chapman 1990; Martín de la Cruz 1994; Montero Ruiz 1994.

28 Montero Ruiz – Ruiz Taboada 1996; Ruiz Taboada – Montero Ruiz 1999; Rovira 2002; Müller et al. 2004.

29 Do Paço – Jalhay 1939; Jalhay – do Paço 1945; do Paço – Sangmeister 1956; Savory 1972; Arnaud – Gonçalves 1990; 1995.

30 Do Paço 1955; Gauß 2015.

31 Müller – Soares 2008.

32 Cardoso 1997; Müller – Cardoso 2008.

33 Cardoso – Guerra 1997/98; Müller – Cardoso 2008.

Conclusive results regarding the production of raw copper and copper objects, or the provenance of the raw materials in the Portuguese Chalcolithic were not obtained through the analyses of the SAM project or other series of analyses. Moreover, the archaeometallurgical finds were neither systematically identified nor analysed entirely. The comparative chemical analyses of copper ores and final products that were carried out by Maria da Luz Ferreira de Oliveira and João Xavier Matos for mining archaeological surveys in the south of the country³⁴ and some isolated analyses of the production of objects³⁵ are an exception. This gap of research is peculiar as the archaeologist Sebastião Philippes Martins Estácio da Veiga at the end of the 19th century treated the copper objects from the megalithic monuments of the Algarve not only as antiquarian materials, but was already also interested in material analytics³⁶. He investigated as well the remains of metal production and ores from Chalcolithic contexts, which were analysed chemically, just like the brothers Luis and Henri Siret did for the south-eastern Spanish Chalcolithic³⁷. Estácio da Veiga also pointed out that the earliest Portuguese metal finds were from settlements contexts, which were still rooted in local Neolithic traditions³⁸. Other than the Sirets, he questioned the sweeping 'Ex-Oriente-Lux-Model' already then³⁹. For the rest, archaeometallurgical research in the south of Portugal was initially practised mainly by geologists and mining engineers, as is the case for the whole southwest of the Iberian Peninsula. This happened especially after the re-opening of many old mines from the mid-19th century onwards. Especially the remains of Roman mining and metallurgical activities in the entrances of the mines came into light⁴⁰. Prehistoric mining activities, on the other hand, are considerably harder to identify than the Roman ones. This is partially due to the fact that they, especially in the case of the mining remains, leave considerably less traces as they were of a smaller scale. Such remains would be rapidly destroyed in the case of a modern (or Roman) use of the mines. Moreover, prehistoric ore mining and smelting remains are often hard to date. This is because the techniques developed very slowly at those times and thus leave us with

few indications for a chronological classification. On top of this, areas with mining activities are often located far away from prehistoric settlement contexts and yield little material that can be dated with the help of settlement chronologies, which are still the basis for chronological classifications. Claude Domergue provides us with an overview of the indications of prehistoric and antique mining in the Iberian Peninsula⁴¹.

Before the start of the project, no Chalcolithic ore mines were known from the Iberian Peninsula, except El Aramo and El Milagro in Asturias⁴². Some evidence for the processing of ores, on the other hand, were known from various sites. In the Iberian Chalcolithic mainly oxidic ores (primarily malachite, azurite, but also arsenic copper ores) were used. In Portugal this is supported mainly by ore remains collected from settlements, such as Castelo Velho de Safara (Moura), Porto Mourão (Mourão), Porto Torrão (Ferreira do Alentejo) and Perdigões (Reguengos de Monsaraz)⁴³. No smelting furnaces have been found so far. However, in some settlements slagged remains of crucibles were found, apart from the aforementioned settlements of the Estremadura, also, for example, at the sites Penedo (Torres Vedras)⁴⁴, Pedra do Ouro (Alenquer)⁴⁵, Santa Justa (Alcoutim)⁴⁶, Cerro do Castelo de Corte João Marques (Loulé)⁴⁷, Castelo Velho de Safara (Moura), Porto Mourão (Moura), Três Moinhos (Beja), Sala I (Vidigueira), São Brás (Serpa), Alcalar (Portimão), Perdigões (Reguengos de Monsaraz), Fonte Ferrenha (Redondo)⁴⁸, São Pedro (Redondo)⁴⁹ and San Blas (Spain)⁵⁰. But the question remained, in what kind of metallurgical process were these crucibles used. The DFG project identified two types of crucibles: a rather thick-walled, less vitrified crucible used for the melting and casting of copper; and a rather thin-walled, heavily vitrified and slagged crucible type used for copper extraction (smelting). Remarkably, in terms of crucible typology the Portuguese Chalcolithic metallurgy differs from that found in Andalusia and other parts of the southern Iberian Peninsula, where all kinds of domestic ware were used for smelting and casting. This difference may indicate a subtle variation in metallurgical traditions.

34 Briard et al. 1998a; Briard et al. 1998b; Oliveira – Matos 2002.

35 Pereira, F. et al. 2013; 2017; Valério et al. 2017.

36 Estácio da Veiga 1889; 1891.

37 Siret – Siret 1890.

38 Estácio da Veiga 1889, 98–101, 117.

39 Estácio da Veiga 1889, 9–10; also see Gauß 2015.

40 Domergue 1987.

41 Domergue 1987.

42 Blas 1998.

43 Soares et al. 1994, 167, 181; Lago et al. 1998; Gómez Ramos 1999; Hunt Ortiz 2003.

44 Spindler 1969, 105.

45 Leisner – Schubart 1966, Abb. 10; also Gómez Ramos 1999, 55.

46 Gonçalves 1989, 194, 278, 310.

47 Alarcão 1990, 174–175.

48 Gauß 2015; also Gauß et al. in this volume; further bibliography see Kunst 2013, 186–193; Tab 1 Nos. 85, 86, 88, 89, 90, 92; Morán 2018, 175–177.

49 Ibid.

50 Gonçalves 1989; Alarcão 1990, 175; Soares et al. 1994; Lago et al. 1998; Gómez Ramos 1999, 54–55; Hunt Ortiz 2003, 296–299, 377; Hurtado 2004; Soares 2005; Müller – Soares 2008; Gauß 2015; also Gauß et al. in this volume.

A special highlight are the blowpipes identified at the sites of Vila Nova de São Pedro, Pedra do Ouro and Três

Moinhos, although they do not contain slag adherences.⁵¹ Blow pipes are very rarely found in Chalcolithic contexts⁵².

6. Southern Spain

In southern Spain, mining archaeological and archaeometallurgical research has been practised more intensively, especially since the 1980s. Results from there can be extrapolated to the south of Portugal because of the similar landscape and cultural conditions.

The Huelva Archaeological Project, directed by Beno Rothenberg and Antonio Blanco Freijeiro, played an important role in the intensive mining archaeological and archaeometallurgical research in the south of the Iberian Peninsula. Especially the mountainous region in the hinterland of the harbour city of Huelva was key and directly connected to the Portuguese southeast border. The production centre of Riotinto, active until recent times, was a special point of focus.

In the course of their intensive mining archaeological research Rothenberg and Blanco Freijeiro established that (copper) ore mining could be traced back to the Chalcolithic for that region⁵³. They based this partially on the presence of groove mallets, which they attributed to the Chalcolithic based on analogies to the Israelian site of Timna. The accompanying of these groove mallets by ceramics in the Chinflón mine, which was thought to be Chalcolithic, strengthened this. Apart from this, the proximity of ores and megaliths is remarkable, especially in the case of Chinflón. The presence of megalithic graves in the otherwise barren landscape led them to assume that the copper resources were the cause for the local Chalcolithic presence in the form of megalithic graves. According to them this represented an important change in the economy and societal structure, that is, a strictly livestock-based nomadic lifestyle becoming settled. According to thermoluminescence datings and new typological research of the Chinflón

ceramics in the 1990s, however, it turned out that the site was to be dated to the Final Bronze Age⁵⁴.

Nevertheless, Chalcolithic metal extraction and production in this region can be proved, even if so far no datable mine has been found. Excavations in the settlement on the Cabezo Juré, northwest from Huelva, yielded not only indications of metal processing, but also copper slags, evidencing the extraction of the metal from ores⁵⁵. Some of the excavators interpreted clay rings and pits with traces of heating, which were found in the settlement, as metallurgical furnaces, which is very doubtful. No characteristic slagging traces can be distinguished on the walls and the structures are clearly too large for a prehistoric furnace reaction chamber, which would require the use of an advanced bellow technology to maintain temperature and redox conditions⁵⁶. The present structures rather seem to have been casting installations, similar to the ones found at Zambujal and other sites, or pits in which crucibles were placed to smelt copper ores. Structures found at Valencina de la Concepción, in front of the Seville gate are very similar⁵⁷. This form of smelting in reaction vessels is the only one that has been clearly identified so far and has been found rather frequently, especially in the south of the Iberian Peninsula⁵⁸.

The beginnings of metallurgy have been investigated in Spain through the broad analysis programme »Arqueometalurgia de la Península Ibérica«⁵⁹ since the 1990s, presenting and evaluating the full archaeological register of early metallurgy in regional studies⁶⁰. This was completed by the publication and discussion of all then published prehistoric metallurgic finds from the Iberian Peninsula by Pablo Gómez Ramos⁶¹ and the de-

51 See the aforementioned literature on metallurgical finds of these settlements. Cf. with the discussion in Gauß 2015.

52 One of the few sites where they were found in larger amounts is Valencina de la Concepción (Seville), see Nocete et al. 2008. Blow pipes identified at Cabezo Juré (Huelva) are very unlikely to have ever been used in a metallurgical process. They rather represent ceramic stands, see Nocete et al. 1999a.

53 Rothenberg – Blanco Freijeiro 1981.

54 Pérez Macías 1996, 157–158.

55 Nocete et al. 1999a; Nocete et al. 1999b; Sáez et al. 2001; Nocete 2004.

56 Bartelheim 2007, 357–360; Gauß 2013; Gauß 2015; see Rovira in this volume.

57 Nocete et al. 2008; Rodríguez Bayona 2008; Costa Caramé 2010; Costa Caramé 2013; see Rovira in this volume.

58 Rovira 2002; Müller et al. 2004.

59 Rovira et al. 1997, VII.

60 Rovira et al. 1997; Delibes de Castro – Montero Ruiz 1999.

61 Gómez Ramos 1999.

tailed documentation of the archaeometallurgical state of research, especially for the Iberian southwest, by Mark A. Hunt Ortiz⁶², Moisés Rodríguez Bayona⁶³ and Manuel Eleazar Costa Caramé⁶⁴ (including unpublished finds and fieldwork). From these studies it becomes

clear that, so far, it has not been possible to reconstruct completely the metallurgical production and respective social organisation in any of those regions (e. g. in Andalusia, the northern Meseta or the Comunidad Valenciana).

7. Key findings of recent archaeometallurgical research on Zambujal copper

Even if the research of the beginnings of metallurgy has made important steps forward in the past years, especially in the south of Spain⁶⁵, our state of knowledge regarding Copper Age metal production is still limited in extensive parts of the Iberian Peninsula and especially Portugal.

In the course of the DFG project a holistic research approach was implemented in order to describe and understand the beginning of the copper metallurgy innovation in Portugal from an economic and social historical point of view:

- a. *Sourcing*: Zambujal copper derives from the Ossa Morena Zone. The local, smaller occurrence of Matacães as well as the famous massive sulphide deposits of the Iberian Pyrite Belt can be excluded as major sources for Zambujal copper. This is indicated by trace element and lead isotope analyses (comparing ores and artefacts from potential source regions with those of Zambujal copper), and the mineralogy of the (few) ores and slags found at some of Portuguese Estremadurian settlements. In addition, amphibolite – the hard rock material found in large amounts in the Estremadurian settlements – originates from the Ossa Morena Zone, too. The Zambujal artefacts and metallurgy were compared to finds and structures from settlements in the Ossa Morena Zone: the finds and metallurgical debris there resemble those of Zambujal.
- b. *Mining*: For the first time, specific places can be identified where copper ores were mined during the Chal-

colithic⁶⁶. For example, at the mine of Mocissos (Alandroal) a small pit was identified below metres of waste rock, dumped in the course of the mine's multi-period lifetime. The pit, radiocarbon dated to the 3rd millennium, contained among others two polished amphibolite axes and a slagged thin-walled crucible fragment almost identical to those artefacts found at Zambujal and many other Portuguese Estremadurian settlements. Whilst this is evidence for one of the oldest metal ore mining in Iberia, mining as such can be traced back to the 6th millennium BC on the Peninsula (c.f. silex mining at Casa Montero, near Madrid; variscite mining at Gavà, nearby Barcelona)⁶⁷.

- c. *Extractive metallurgy*: In the framework of the Zambujal project it has been possible to record ›completely‹ the archaeometallurgical remains found at Zambujal and many other Chalcolithic sites and to establish criteria for a systematic division between remains of primary and secondary metallurgy⁶⁸. At Zambujal, smaller amounts of copper were most likely extracted in crucibles using oxides and carbonates. We have similar evidence from Vila Nova de São Pedro, which is the other Copper Age type site of the Estremadura. Crucible smelting, i. e. the high temperature process of turning ore into metal and slag in ceramic containers, is a well-documented process in many Copper Age settlement sites, particularly in the southern Iberian Peninsula, and many regions of the 4th and 3rd millennium Mediterranean. The Zambujal project identified almost identical metallurgical de-

62 Hunt Ortiz 2003.

63 Rodríguez Bayona 2008.

64 Costa Caramé 2010.

65 Rodríguez Bayona 2008; Costa Caramé 2010; Murillo-Barroso – Montero Ruiz 2012; Gauß 2013; Kunst 2013; Rovira – Montero Ruiz 2013; Montero Ruiz – Murillo Barroso 2014; Murillo Barroso – Montero Ruiz 2017; Murillo-Barroso et al. 2015; Orestes Vidigal et al. 2015.

66 Müller et al. 2007; Müller – Cardoso 2008; Müller – Soares 2008; Gauß 2015; see also Goldenberg – Hanning in this volume; Gauß – Mataloto – Calado in this volume; for comparison, on Bell Beaker mining evidence in other parts of Europe see Fitzpatrick 2019.

67 Consuegra Rodríguez et al. 2004; Díaz-del-Río et al. 2006; Borrell et al. 2015; Bosch et al. 1996; Villalba et al. 1986.

68 Gauß 2015.

bris in the contemporary mine of Mocissos mentioned above as well as at the small fortified site of São Pedro and the hilltop of Fonte Ferrenha near the today town of Redondo (see Gauß – Mataloto – Calado, this volume)⁶⁹. The earliest evidence for metallurgical furnaces in the Iberian Peninsula date to the Iron Age⁷⁰. The experimental work by Erica Hanning⁷¹ confirmed the idea of crucible smelting using copper oxide ores from the identified sources in the Ossa Morena Zone, which were deemed to be extracted in the Copper Age. Her experiments produced almost identical metallurgical remains as found at Zambujal and the other Chalcolithic sites.

- d. *Copper Processing*: In terms of metallurgy, copper processing was much more of a dominant activity than smelting at Zambujal and the other Portuguese Estremadurian settlements. In the beginning, copper was cast in open forms, cut, grinded and polished to produce simple objects like flat axes, awls, and thin blades. Metal specific objects were developed like saws and elongated awls and needles as well as – in the Bell Beaker context – standardized tanged daggers and Palmela points. Specific natural arsenic alloys were – once extracted – deliberately chosen to produce specific artefact types.

Based on old and new trace element analyses of copper artefacts, the material group research of the 1960s, 70s and 80s was brought back and the relation to the stratigraphy of Zambujal was established quantitatively⁷². Arsenic copper, poor in trace elements, clearly dominates the copper objects of Zambujal throughout the settlement's occupation. Apart from this, some pure copper objects were found mainly in contexts of the Early Chalcolithic, and arsenical copper with silver, antimony and/or nickel was found predominantly in contexts of the Late Chalcolithic and the Early Bronze Age.

The experimental work by Marcus Schreiner (this volume) demonstrated that the copper droplets and lumps detected at Zambujal derived from melting and casting copper in open sand moulds. Strikingly, some of the copper lumps showed a twin microstructure, indicating that these pieces of copper, most likely, had been hammered before they were remelted. If this was the case, these copper lumps would represent

remnants of a recycling process. This observation corresponds well to the fact that, indeed, many fragmented copper objects were found and that many of them showed cut marks⁷³.

Quanyu Wang and Barbara S. Ottaway (this volume) conducted another systematic study on the metallography of Zambujal copper artefacts. Using this approach, they could identify patterns in the working cycles for producing specific types of metal objects. Most of the awls were cast, cold-worked, and annealed again, which means they were left in soft state. Chisels on the contrary were mostly cold hardened at the end of the work cycle to produce a hard edge.

- e. *Social aspects of Zambujal metallurgy and its economic impact*: Reconstructing the metallurgical processes and identifying the geological source regions of the raw materials makes it possible to better understand and contextualize metallurgy as craftsmanship and a social activity. The metal arrived in the Portuguese Estremadura along a well-established, Late Neolithic amphibolite trade route, that is, most likely in exchange for goods from the coastal area, including gold, flint, and exotic items, such as ivory that originated from Africa⁷⁴. Zambujal – and the dense Estremadurian settlement network altogether – was not built because of a rich nearby copper deposit; but most likely due to its favourable position in terms of logistics, located right in the middle of an estuary and fruitful lands. The metallurgical processes were not more complex than those of other craftsmanships of the time, including the making of high quality, polished, thin-walled ceramic vessels or erecting and maintaining the complex fortification systems. Like in many other Chalcolithic sites, metallurgy took place in domestic contexts – no specific workshop was found at Zambujal, but metallurgical debris is evident in many different fireplaces across the site.

The Zambujal evidence substantiates the general picture of Chalcolithic metallurgy in Iberia: the small-scale, primitive type of copper metallurgy that dominated the 3rd and 2nd millennium seems to contradict the vast richness in metal ore deposits of the Peninsula. Even tin is abundant, but true tin bronzes are scarce until the Late Bronze Age.

69 Mataloto 2005.

70 Bartelheim 2007, 138.

71 Hanning et al. 2010 and Hanning – Goldenberg this volume.

72 Müller – Cardoso 2008; Müller – Pernicka 2009; Gauß 2015.

73 Sangmeister 1995; Gauß 2015; see Schreiner and Wang – Ottaway in this volume.

74 Schuhmacher 2016; 2017.

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Abstracts

In the course of research history, Zambujal and other comparable fortified Chalcolithic sites of the Iberian Peninsula have been associated with copper production and processing. Until the late 1970s, these sites were interpreted as colonies of Eastern Mediterranean metallurgists. However, especially thanks to the work of Colin Renfrew, it became clear that the chronological primacy of the proposed Eastern Mediterranean archetypes of these fortifications does not exist. This was shown by the introduction of ^{14}C dates and their calibration in large parts of Europe during the 1960s and 1970s. Among the big fortified settlements, Zambujal is one of the best investigated. Due to its well documented stratigraphy, it offers the possibility to investigate the development of metallurgy exemplarily, at least for the Chalcolithic Estremadura. Already during the excavations between 1964 and 1973, samples for chemical analyses were taken from the copper artefacts found at the site. After years of intensive research, at least on the Iberian Peninsula, there is a unique data set characterising the metal assemblage of a Chalcolithic site, including trace element and lead isotope data, as well as metallographic and mineralogical studies. The current paper situates the DFG (German Research Council) project on the metallurgy of Zambujal within the wider context of research history and points out some major conclusions of the recent investigations.

Keywords: Chalcolithic, Portugal, Economic History, Archaeometallurgy, Mining

Ao longo do historial de investigação, o Zambujal e outros povoados fortificados equiparáveis do Calcolítico situados na Península Ibérica, têm sido fortemente asso-

ciados ao processamento de cobre. Até ao final dos anos 1970, estes povoados eram interpretados como sendo colónias de metalurgistas provenientes do Este mediterrâneo. Com a introdução de dados de ^{14}C em extensas partes da Europa e através da sua calibração no decorrer dos anos 1960–70, tornou-se evidente, em grande parte graças à investigação de Colin Renfrew, que não se verificava de facto uma primazia cronológica dos supostos modelos do espaço oriental mediterrâneo em relação aos elementos existentes na Península Ibérica. Entre os maiores povoados fortificados destaca-se o Zambujal como um dos mais bem estudados. O elevado grau de pormenor da sua estratigrafia constitui uma boa base para o estudo do desenvolvimento da metalurgia, pelo menos no que concerne ao contexto da Estremadura portuguesa. Já durante as escavações do Zambujal de 1964 a 1973 foram recolhidas amostras dos objetos de cobre encontrados. Após vários anos de investigação exaustiva do Zambujal e do seu espólio metalúrgico, existe atualmente um conjunto de dados arqueometalúrgicos único no espaço peninsular. Este acervo inclui análises de elementos vestigiais e isótopos de chumbo, assim como estudos metalográficos e mineralógicos de artefactos em cobre e restos metalúrgicos. O presente ensaio descreve o historial da investigação do projeto científico sob a égide da DFG (Associação Alemã para a Investigação) relativo à metalurgia do Zambujal, fazendo referência às principais conclusões retiradas das mais recentes investigações.

Palavras-chave: Calcolítico, Portugal, História da Economia, Arqueometalurgia, Exploração Mineira

Zambujal und andere vergleichbare befestigte kupferzeitliche Siedlungen auf der Iberischen Halbinsel sind im Laufe der Forschungsgeschichte eng mit der Kupferproduktion in Verbindung gebracht worden. Noch bis in die späten 1970er Jahre wurden sie als Kolonien ostmediterraner Metallurgen gedeutet. Im Zuge der Einführung von ^{14}C -Daten in weiten Teilen Europas und ihrer zunehmenden Kalibration im Verlauf der 1960er und 1970er Jahre wurde vor allem durch die Arbeiten Colin Renfrews deutlich, dass das zeitliche Primat vieler als Vorbilder für entsprechende Elemente auf der Iberischen Halbinsel angesehener Befunde im ostmediterranen Raum nicht mehr bestand. Unter den großen befestigten Siedlungen ist Zambujal eines der besterforschten Exemplare und bietet durch seine detailliert dokumentierte Stratigraphie eine gute Möglichkeit, die Entwicklung der Metallurgie exemplarisch, zumindest für die portugiesische Estremadura, zu untersuchen. Bereits während der Ausgrabungen von 1964 bis 1973 wurden Proben von den dort gefundenen Kupferobjekten genommen. Nach Jahren intensiver Forschung liegt für Zambujal und seine Metallfunde mittlerweile ein zumindest für den Iberischen Raum einmaliger Satz archäometallurgi-

scher Daten vor, der Spurenelement- und Bleiisotopenanalysen sowie metallographische und mineralogische Studien von Kupferartefakten und metallurgischen Resten umfasst. Der vorliegende Aufsatz stellt den forschungsgeschichtlichen Kontext des DFG-Forschungsprojekts zur Metallurgie Zambujals dar und verweist auf einige wesentliche Schlussfolgerungen der neueren Untersuchungen.

Schlagwörter: Kupferzeit, Portugal, Wirtschaftsgeschichte, Archäometallurgie, Bergbau

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¹ The classifications and terminologies of the Bronze Age phases and their absolute chronology differ from region to region and author to author. Therefore you find here the terminology used by

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² For casting, smelting and melting in the Spanish and Portuguese texts sometimes is used fundición / fundido / fundição.

It will say: Fundición of ore = smelting; fundición of metal = melting; fundición of metal into objects = casting.

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³ See also the Geographical Index, letter M following the local name. Most of the indicated mines contain various minerals. Because of this, they are not classified as copper mines.

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The names of countries and places are given in the language of the country or in English. Differences between English, German, Portuguese and Spanish are indicated.

Abbreviations:

- AS** Archaeological site
- A** Administrative place name
- D.** District /Distrito
- G** Geography, Geology
- M** Mine, Mining region or Mining group, Mineralization

Abensberg = Arnhofen

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