On the authenticity of the gold finds from Bernstorf, community of Kranzberg, Freising district, Bavaria

Ernst Pernicka

Abstract

At the hamlet of Bernstorf near the small town of Kranzberg, Freising district, in Bavaria a number of finds made from gold foil were found near a Late Bronze Age structure in 1998. They were interpreted as clear evidence for contacts between Mycenae and Bavaria in the Late Bronze Age. Furthermore, it was suggested that the gold derives from Egypt based on comparison with gold foil from an Egyptian sarcophagus supposedly belonging to Akhenaten (KV 55, a tomb in the Valley of the Kings in Egypt). However, since this conclusion was at variance with previously published data on the composition of the gold from KV 55, it was re-analysed with LA-ICP-MS together with the gold finds from Bernstorf. It turned out that the Bernstorf gold is exceptionally pure which is not only unknown in natural gold but also in all prehistoric gold objects hitherto analysed. It is therefore concluded that the finds from Bernstorf were made from modern gold foil which is supported by radiocarbon dates of adhering resin and organic debris in the soil coating in which the objects were found.

Introduction

The gold finds from Bernstorf (Gebhard u. a. 2014, 768 Abb. 8) were first published by Gebhard (1999). They were initially reported by amateur archaeologists, who allegedly found them enclosed in lumps of soil between uprooted trees in an area that was cleared for gravel mining. The composition of the finds was first determined by XRF without a clear description of the methodical parameters, but it was noted that the silver concentration was »less than 0.2 %« and both copper and tin concentrations were »less than 0.5 %«. It was further remarked that gold of such purity is virtually non-existent in nature so that it must be assumed that the separation of gold and silver by the cementation process was already practiced in the Central European Late Bronze Age. This will be further discussed below. The very low concentrations of silver and copper were confirmed by later analyses with an electron microprobe on small samples from all parts of the Bernstorf complex as well as with laser ablation coupled with inductively-coupled plasma mass spectrometry (LA-ICP-MS, Bähr u. a. 2012). Again, the analytical methodology was only vaguely described and the results were plotted only in a graph, but at least it was stated that silver and copper occur only at trace levels with silver in the mg/kg range and copper in the µg/kg range. Furthermore, it was concluded that the presence of four elements in the range of several hundred mg/kg (sulphur, antimony, mercury, and bismuth) would exclude the identification of modern, purified gold.

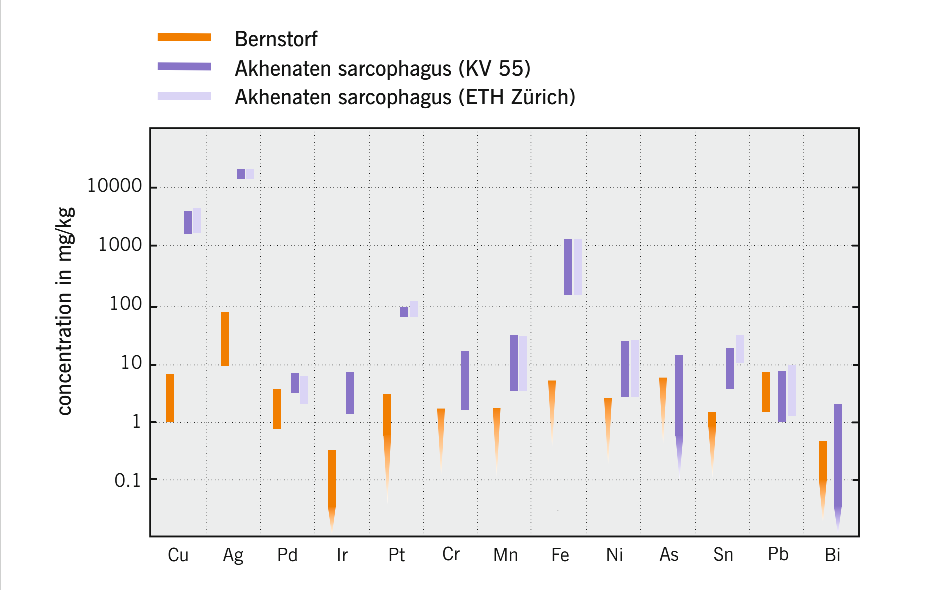

Fig. 1 Comparison of the elemental composition of gold finds from Bernstorf with the gold foils from the Akhenaten sarcophagus (KV 55). Downward arrows indicate upper limits of detection for the specific elements, i. e. the true concentration is lower than the top of the arrows. The same samples of the Akhenaten sarcophagus that were analysed in the Curt-Engelhorn-Zentrum Archäometrie in Mannheim were also analysed in the Laboratory for Inorganic Chemistry of the ETH Zürich with excellent agreement.

Somewhat disturbing was the statement in Bähr u. a. (2012) that the trace element pattern of the Bernstorf gold was remarkably similar to one object of presumed Egyptian origin – the so-called Akhenaten sarcophagus (KV 55, a tomb in the Valley of the Kings in Egypt) which had disappeared from the Egyptian Museum in Cairo and later re-appeared in Paris in bad condition. It was restored in Munich between 1998 and 2002 and then returned to Egypt. The gold foils from this sarcophagus were analysed by Junk and Pernicka (2001) and the results published by Klemm/Gebhard (2001). None of the four elements considered so characteristic of the Bernstorf gold were measured at similar concentration levels in KV 55; indeed, antimony and bismuth were below the mg/kg level. In order to resolve this obvious discrepancy the author asked for a re-analysis of the Bernstorf gold and the same samples that were previously analysed at the University of Frankfurt were analysed with LA-ICP-MS at the Curt-Engelhorn Centre for Archaeometry in Mannheim (Pernicka 2014). Details of the analytical method are described and results are given in numerical form in this publication. Here it may suffice to present the data again in graphical form together with the new analyses of the Akhenaten sarcophagus, which were confirmed independently by LA-ICP-MS in the laboratory of Prof. D. Günther at the EHT Zürich (Fig. 1). Neither in the Bernstorf gold nor in the one from KV 55 are antimony and bismuth measured in the stated concentration range. Indeed, both elements were at or below the detection limit of about 0.5 mg/kg in all samples. Mercury was occasionally detected at low concentrations but not quantified and sulphur was not measured. In any case, the assumed similarity of the gold from the Egyptian sarcophagus and the Bernstorf gold could not be confirmed.

Here it may be added that the authors of the study by Bähr u. a. (2012) conceded that at least the published bismuth concentrations were wrong (Gebhard u. a. 2014). This means that even according to their own analyses the purity of the gold should now be considered as at least 99.9 %.

Separation of gold and silver in antiquity

Naturally occurring gold is usually rather pure with the exception of silver. In primary deposits the silver concentration ranges between 5 und 40 % (Jones/Fleischer 1969) while alluvial gold has a tendency to contain less than 20 % silver (Smith 1941). In Fig. 2 some 1500 analyses of silver and copper in native gold from primary and alluvial deposits (Schmiderer 2009) are plotted together with the concentration ranges of the Bernstorf gold. It confirms Gebhard's suggestion that it is unlikely that such gold occurs in nature and that some kind of technical process must be responsible for its composition. Following Hartmann (1970 and 1982) he suggested that the so-called cementation process

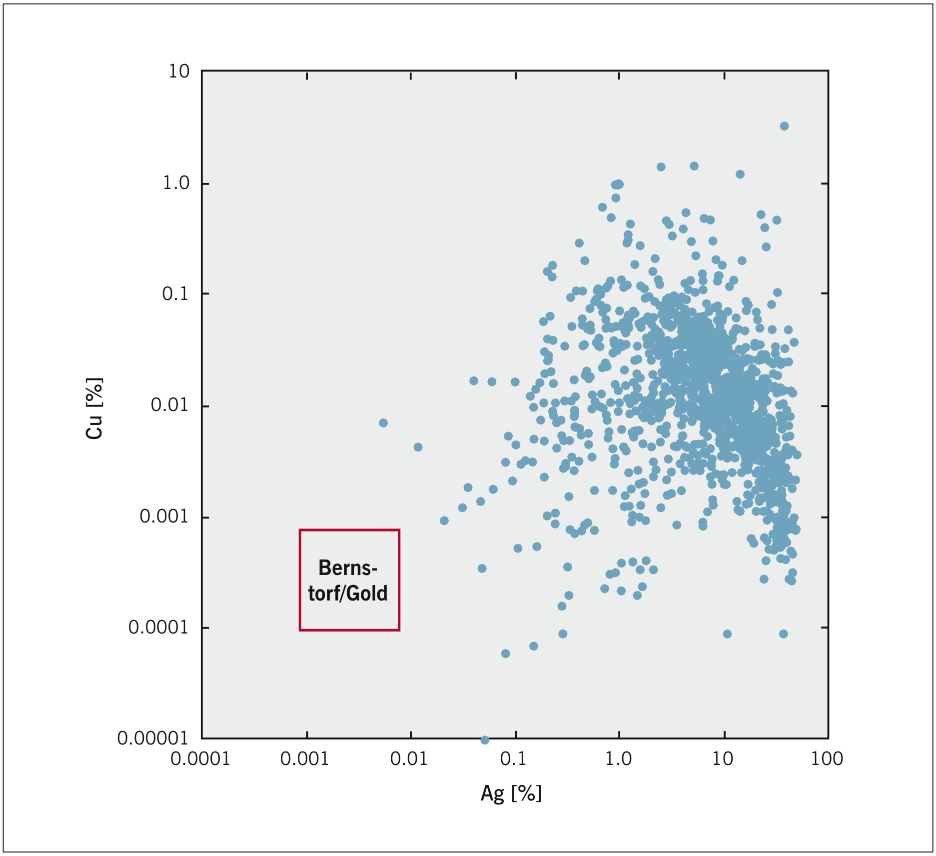

Fig. 2 Comparison of the silver and gold concentrations of gold finds from Bernstorf (red quadrangle) with 1460 analyses of native gold from central and southeastern Europe.

for parting gold and silver may have been known and practiced already in the Late Bronze Age, although the earliest archaeological evidence is dated to the sixth century BC (Ramage/Craddock 2000). In this process argentiferous gold is heated in the form of thin foils together with salt (sodium chloride) and fireclay at around 800°C for a few hours. Salt dissociates to chlorine which attacks the silver and volatilizes it as silver chloride which is partly soaked up by the fireclay. This process was already described in antiquity, e. g. by Plinius in his Naturalis Historia (33, 29).

In support of this suggestion Gebhard cites altogether seven gold finds out of several thousand analysed by Hartmann (1970 and 1982) with less than 1 % silver. Of those are five practically without context, namely two from »Susa«, Iran, from early excavations with unclear stratigraphy, and two from Dendra, Greece, a chamber tomb which was plundered in 1960, amongst them a sword with a golden hilt decoration bought by the Danish National Museum in Luzern, Switzerland, in 1962. It is quite possible that modern gold was added after the Dendra plundering to increase the value of the find. Furthermore, two objects from Ireland contained about 1 % and 0.28 % silver (Au963 and Au1076 in Hartmann 1970). The first object is without context and acquired in 1875, the find circumstances of the second have yet to be checked. Lastly, the Early Bronze Age gold disc from Moordorf near Aurich in Lower Saxony is considered the closest parallel to the finds from Bernstorf. However, it was eventually acquired from an antiquities dealer in Munich who presented a story of the disc having been found in a grave that on later excavation proved to date to the Early Bronze Age. In summary, all this cannot be considered as hard evidence for parting gold and silver in the Late Bronze Age. Even in the eastern Mediterranean there is no evidence for parting in the second millennium BC as indicated by the composition of Mycenaean and Minoan gold seals (Pernicka 2014) and Egyptian gold artefacts of the New Kingdom (Troalen et al. 2014).

Indeed, there is actually no incentive for such practice in the Bronze Age when only the colour of the gold was important. It was certainly recognized that depending on its silver content gold exhibits different colouring and it is possible that the colour could be altered with mordants as is suggested by various adjectives in Mesopotamian texts which relate to the colour of gold. Some Mesopotamian gold objects indeed show signs of surface depletion that would indicate such alterations. However, when coinage was introduced in the sixth century BC, it became necessary to purify gold in order to obtain a standard composition guaranteed by an authority identified by a stamp on the piece of metal. It should come as no surprise therefore that the earliest archaeological evidence for parting appears in the same region where the first coins appear, i. e. Sardis in western Anatolia.

But how pure was the gold produced by the cementation process? There are two approaches to answer this question. One is the analysis of ancient gold from periods when regular parting of gold and silver can safely be assumed. An almost ideal case is represented by Roman gold coins and fortunately there exist some 600 analyses of such from the Republican era to the end of the Roman Empire (Kraut 2001). Although most of those coins consist of rather pure gold none exceeds a purity of 99.8 %.

The alternative approach is experimental in that the relatively simple cementation process is simulated in the laboratory. Such experiments have been performed since the late 18th century and were summarized by Craddock (2000). In order to test the possibility of producing gold with similarly low concentrations of silver and copper as the Bernstorf

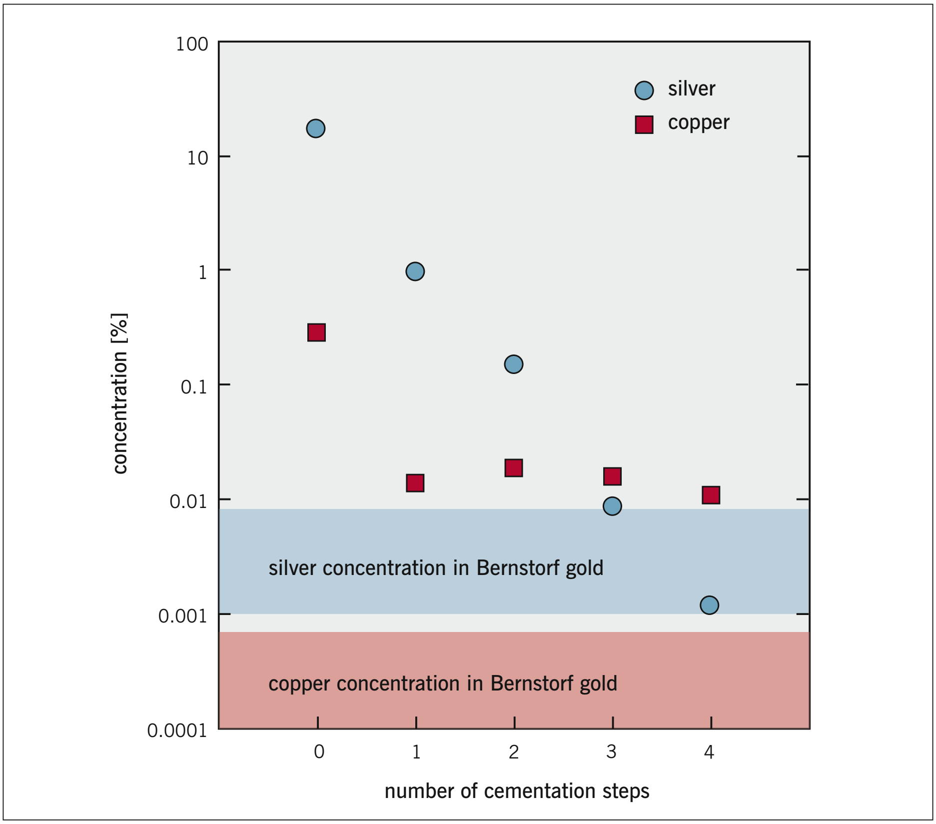

Fig. 3 Silver and copper concentrations in gold samples from cementation experiments. The starting composition was 17.1 % silver and 0.29 % copper besides gold. In each consecutive cementation step (12 hours at 850° C) the silver concentration decreases by a similar factor so that after three or four repetitions the low silver concentration of the Bernstorf gold is reached. However, the copper concentration remains constant above 0.01 % whereas the copper concentrations in Bernstorf gold range from 0.0001 to 0.0008 %.

gold Wunderlich u. a. (2014) performed another series of experiments the results of which are presented in Fig. 3. Incidentally, in one series of experiments the behaviour of bismuth was also tested and it turned out that this element is completely removed from the gold as can be expected due to the fact that bismuth chloride is highly volatile.

As can be seen from Fig. 3 it is indeed possible to reduce the silver concentration by cementation to the level found in the gold objects from Bernstorf. However, at least three to four consecutive applications of the process are required and for this there is no incentive conceivable. The colour of the gold does not change visibly after the first cementation step but in each step one is faced with a small loss of gold. Even more indicative is the behaviour of copper: Its concentration is significantly reduced in the first cementation step but remains at a concentration of around 0.01 % in the following ones. This is about two orders of magnitude above the level found in the Bernstorf objects thus it can be concluded that parting gold and silver by cementation cannot produce gold of such composition. On the other hand, the concentrations of silver, copper, and several trace

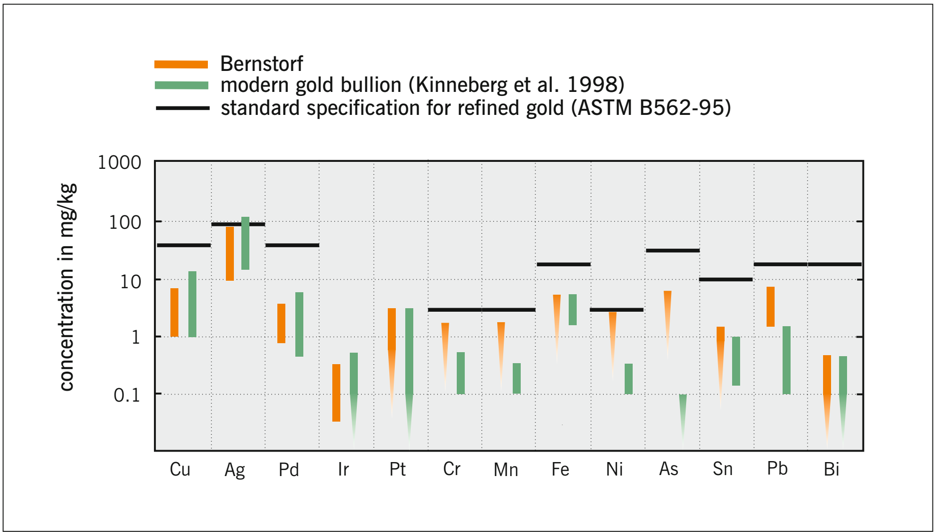

Fig. 4 Comparison of the trace element pattern of the Bernstorf gold with gold bullion of 99.95 and 99.99 % stated purity from eight different producers (Kinneberg et al. 1998). Also indicated are the standard specifications for such gold as defined by the American Society for Testing and Materials (ASTM).

elements are suspiciously similar to modern gold from eight suppliers of high purity gold (Fig. 4), which complies with the standards set by the American Society for Testing and Materials (ASTM). In summary, there is a high probability that the gold objects from Bernstorf were made from modern gold foil, which is commercially available in this purity.

This is, however, not the only evidence for a modern deposition of these finds. At the international conference on »Gold and Amber finds from Bernstorf – Authenticity and Context in the European Bronze Age« at the Archaeological Collection of the Bavarian State in Munich from 12–14 October 2014 a poster was presented by Bähr and Krause (2014) which showed all 29 radiocarbon dates of material from Bernstorf. Of special interest in this context is the date of organic material from the soil coating of the amber seal with a Linear B inscription. The material exhibited a high concentration of organic material (2.59 %). When the largest piece preserved of the coating (ca. 1.8 cm x 3.5 cm) was divided into two halves a mineralized needle of a conifer and a flat unidentified organic material were discovered which yielded a clearly modern radiocarbon age (113 ± 0.3 pMC or percent Modern Carbon, see below). In the same paragraph it was made clear that it can be ruled out that these materials were introduced or grew into the coating. The authenticity of the amber seal has frequently been questioned (e. g. Hughes-Brock 2011) and there were two small gold strips with identical composition and trace element pattern as the other pieces of the Bernstorf gold stuck in the bore hole of the seal. Thus there are three components in one object, the composition of the gold, the engravings on the seal and the modern material in the coating, which all point to a modern origin.

It may be worthwhile to explain this result in more detail. Above-ground nuclear testing after World War II has released large numbers of neutrons and thus increased

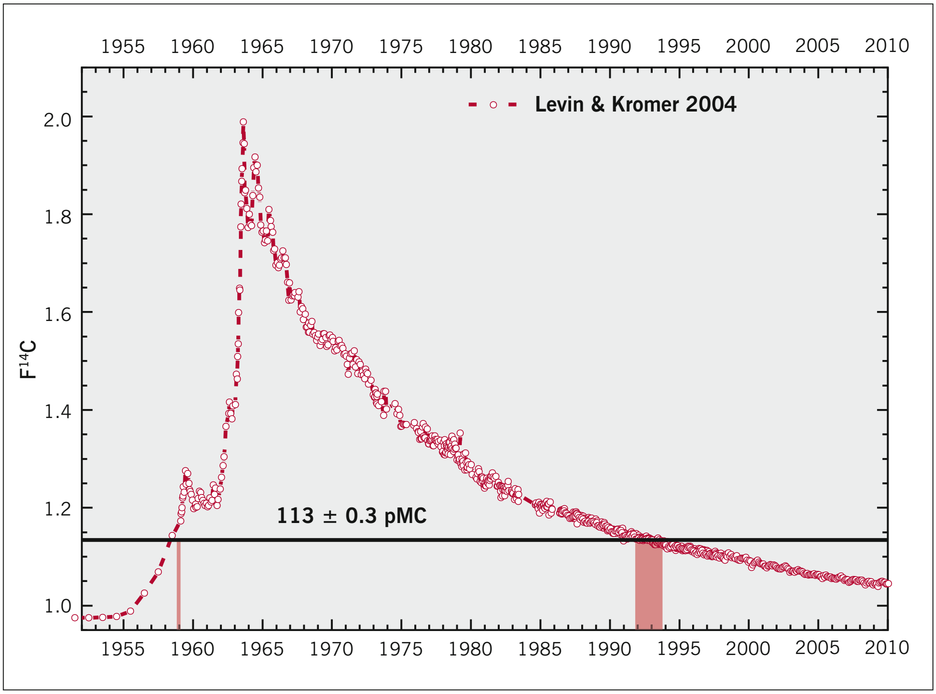

Fig. 5 Radioactivity levels of ^{14}C in the troposphere after 1955 (Levin and Kromer 2004). $F^{14}C$ is equivalent to pMC. The value of 113 pMC for the conifer needle from the soil cover of the Bernstorf seal indicates its growth either around 1959 or 1993.

the ^{14}C concentration in the atmosphere by almost a factor of two. When atmospheric nuclear testing was banned in 1963 the production of ^{14}C in addition to the one by cosmic radiation came to a halt and its concentration level has since dropped, because the radioactivity is slowly distributed over the whole carbon reservoir by natural processes. Accordingly, it was agreed to define »modern carbon« as material with the ^{14}C radioactivity of 1950, which by convention is year 0 BP in radiocarbon dating. A higher radioactivity level can thus only be found in samples that were in equilibrium with the atmosphere after 1950 due to the bomb effect. Since the radioactivity of the atmosphere first increased and then decreased there are usually two calendar dates possible as shown in Fig. 5. Accordingly, the date of the conifer needle from the soil coating of the amber seal from Bernstorf could date either around 1959 or 1992 to 1994.

Furthermore, at the same conference it was reported by R. Krause that a small resinous sample from one of the gold objects from Bernstorf yielded a calibrated radiocarbon age between about 1000 and 1600 AD. This is most readily explained as a mixing age of some 90 % modern and 10 % fossil material. Such mixtures actually exist and are commercially available, such as moulding cement (composed of colophonium, terpentine, paraffine, and powdered fireclay) or dental wax (a mixture of carnauba wax and mineralic waxes like paraffine and ceresine).

Conclusion

The chemical compositions of the gold objects from Bernstorf, community of Kranzberg, Freising district, and the gold foils from the Akhenaten sarcophagus (KV 55) are clearly different. This stands in contrast to the conclusion drawn by Bähr u. a. (2012) based on the assumed similarity with gold deriving from Egypt. Furthermore, the analyses of the Bernstorf gold published by Bähr u. a. (2012) could not be confirmed. The purity of the Bernstorf gold is even higher than stated, namely 99.99 %, which is in line with a partial withdrawal of the earlier analyses by Gebhard u. a. (2014). The proposed explanation that the purity of the gold from Bernstorf may be due to parting with NaCl, the so-called cementation process, is in disagreement with the composition of Roman gold coins, which most likely consist of desilvered gold. None has the same purity as Bernstorf gold. However, such gold is regularly purified by electrolysis in modern times and commercially available. Further evidence for a modern date of the Bernstorf gold comes from the soil coating of an amber seal, which contained a modern conifer needle, and also from two small gold strips with the same composition as the other gold finds from Bernstorf in its bore hole.

Zusammenfassung

Die chemische Zusammensetzung des Goldes von Bernstorf, Gem. Kranzberg, Lkr. Freising, und der Goldauflagen des so genannten Sarges des Echnaton (KV 55) weisen erhebliche Unterschiede auf. Insofern ist die Herkunftsaussage in Bähr u. a. (2012) nicht haltbar. Die in Bähr u. a. (2012) veröffentlichten Analyseergebnisse konnten nicht bestätigt werden. Das Gold von Bernstorf ist noch reiner als in dieser Publikation dargestellt. Die Argumentation der Autoren, dass es sich um durch Zementation mit NaCl gereinigtes Gold handelt, ist nicht haltbar, wenn man das Gold von Bernstorf mit römischen Goldmünzen vergleicht, deren Metall mit hoher Wahrscheinlichkeit diesem Prozess unterworfen wurde. Solch reines Gold wie das von Bernstorf wird nur in moderner Zeit hergestellt und durch Elektrolyse gereinigt. Es ist daher sehr wahrscheinlich, dass es sich bei den Goldfunden von Bernstorf um moderne Imitationen handelt.

References

Bähr u. a. 2012
V. Bähr/R. Krause/R. Gebhard, Neue Forschungen zu den Befestigungen auf dem Bernstorfer Berg bei Kranzberg im Landkreis Freising (Oberbayern). Mit Beiträgen von Christoph Lühr und Christoph Herbig. Bayer. Vorgeschbl. 77, 2012, 1–18.

Bähr/Krause 2014
V. Bähr/R. Krause, Naturwissenschaftliche Datierungen vom Bernstorfer Berg, Bernstorf, Gde. Kranzberg, Lkr. Freising. Poster presented at the international conference on »Gold and Amber finds from Bernstorf – authenticity and context in the European Bronze Age« at the Archaeological Collection of the Bavarian State in Munich from 12 to 14 October 2014.

Craddock 2000
P. T. Craddock, Replication Experiments and the Chemistry of Gold Refining. In: A. Ramage/ P. Craddock (eds.), King Croesus‘ Gold. Excavations at Sardis and the History of Gold Refining. Arch. Exploration of Sardis 11 (London 2000) 175–183.

Gebhard 1999
R. Gebhard, Der Goldfund von Bernstorf. Mit einem Beitrag von Manfred Moosauer. Bayer. Vorgeschbl. 64, 1999, 1–18.

Gebhard u. a. 2014
R. Gebhard/R. Krause/A. Röpke/V. Bähr, Das Gold von Bernstorf – Authentizität und Kontext in der mittleren Bronzezeit Europas. In: H. Meller/ R. Risch/E. Pernicka (Hrsg./eds.), Metalle der

Macht – Frühes Gold und Silber/Metals of power – Early gold and silver. 6. Mitteldeutscher Archäologentag vom 17. bis 19. Oktober 2013 in Halle (Saale)/6th Archaeological Conference of Central Germany, October 17–19, 2013 in Halle (Saale). Tagungen des Landesmuseums für Vorgeschichte Halle 11 (Halle [Saale] 2014) 761–776.

Hartmann 1970
A. Hartmann, Prähistorische Goldfunde aus Europa I. Spektralanalytische Untersuchungen und deren Auswertung. Stud. Anfänge Metallurgie 3 (Berlin 1970).

Hartmann 1982
A. Hartmann, Prähistorische Goldfunde aus Europa II. Spektralanalytische Untersuchungen und deren Auswertung. Stud. Anfänge Metallurgie 5 (Berlin 1982).

Hughes-Brock 2011
H. Hughes-Brock, Exotic Materials and Objects Sent to – and from? – the Bronze Age Aegean. Some recent work and some observations. In: Andrea Vianello (ed.), Exotica in the Prehistoric Mediterranean (Oxford 2011) 99–114.

Jacob-Friesen 1931
K.-H. Jacob-Friesen, Die Goldscheibe von Moordorf und ihre britischen und nordischen Parallelen. Ipek 7, 1931, 25–44.

Jones/Fleischer 1969
R. S. Jones/M. Fleischer, Gold in Minerals and the Composition of Native Gold. U. S. Geological Survey Circular 612 (Washington DC 1969).

Junk/Pernicka 2001
S. Junk/E. Pernicka, Goldanalysen der Proben Dr. Grimm, München: L20010703/1 – 6. Unpublished report, Institut für Archäometallurgie, Bergakademie Freiberg.

Kinneberg et al. 1998
D. J. Kinneberg/S. R. Williams/D. P. Agarwal, Origin and Effects of Impurities in High Purity Gold. Gold Bulletin 31(2), 1998, 58–67.

Klemm/Gebhard 2001
D. D. Klemm/R. Gebhard, Anhang II, Analyse des Goldes; R. Gebhard, Anhang III, Analyse der Vergoldung. In: A. Grimm/S. Schoske (Hrsg.), Das Geheimnis des goldenen Sarges – Echnaton und das Ende der Amarnazeit (München 2001) 80–86.

Kraut 2001
J. Kraut, Zerstörungsfreie Analyse römischer und byzantinischer Goldmünzen des ersten bis elften Jahrhunderts (Diss. Univ. Basel 2001).

Levin/Kromer 2004
I. Levin/B. Kromer, The Tropospheric $^{14}CO_2$ level in Mid-Latitudes of the Northern Hemisphere (1959–2003). Radiocarbon 46(3), 2004,1261–1272.

Pernicka 2014
E. Pernicka, Zur Frage der Echtheit der Bernstorfer Goldfunde. In: H. Meller/R. Risch/E. Pernicka (Hrsg./eds.), Metalle der Macht – Frühes Gold und Silber/Metals of power – Early gold and silver. 6. Mitteldeutscher Archäologentag vom 17. bis 19. Oktober 2013 in Halle (Saale)/6th Archaeological Conference of Central Germany, October 17–19, 2013 in Halle (Saale). Tagungen des Landesmuseums für Vorgeschichte Halle 11 (Halle [Saale] 2014) 247–256.

Ramage/Craddock 2000
A. Ramage/P. Craddock, King Croesus' Gold. Excavations at Sardis and the History of Gold Refining. Arch. Exploration of Sardis 11 (London 2000).

Schmiderer 2009
A. Schmiderer, Geochemische Charakterisierung von Goldvorkommen in Europa. PhD thesis. Elektronische Hochschulschriften Martin-Luther-University Halle-Wittenberg. Universitäts- und Landesbibliothek Sachsen-Anhalt, Halle (Saale), 2009, 140 p. [Online-Ressource Halle 2009].

Smith 1941
P. S. Smith, Fineness of gold from Alaska placers. In: P. S. Smith/J. B. Mertie jr. (eds.), Mineral Resources of Alaska. Report on Progress of Investigations in 1937. U. S. Geological Survey Bull. 910-C (Washington DC 1941) 147–272.

Troalen et al. 2014
L. G. Troalen/J. Tate/M. F. Guerra, Goldwork in Ancient Egypt: workshop practices at Qurneh in the 2nd Intermediate Period. Journal Arch. Scien. 50, 2014, 219–226.

Wunderlich u. a. 2014
C.-H. Wunderlich/N. Lockhoff/E. Pernicka, De Cementatione oder: Von der Kunst, das Gold nach Art der Alten zu reinigen. In: H. Meller/R. Risch/E. Pernicka (Hrsg./eds.), Metalle der Macht – Frühes Gold und Silber/Metals of power – Early gold and silver. 6. Mitteldeutscher Archäologentag vom 17. bis 19. Oktober 2013 in Halle (Saale)/6th Archaeological Conference of Central Germany, October 17–19, 2013 in Halle (Saale). Tagungen des Landesmuseums für Vorgeschichte Halle 11 (Halle [Saale] 2014) 353–370.

Source of figures

1 E. Pernicka
2 E. Pernicka, data from Schmiderer 2008
3–5 E. Pernicka

Anschrift

Prof. Dr. Ernst Pernicka
Curt-Engelhorn-Zentrum Archäometrie
D-68159 Mannheim
and
Institut für Geowissenschaften,
Universität Heidelberg
Im Neuenheimer Feld 234–236
D-69120 Heidelberg