Rewriting the Central European Early Bronze Age Chronology: Evidence from Large-Scale Radiocarbon Dating

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Abstract

The transition from the Neolithic to the Early Bronze Age in Central Europe has often been considered as a supra-regional uniform process, which led to the growing mastery of the new bronze technology. Since the 1920s, archaeologists have divided the Early Bronze Age into two chronological phases (Bronze A1 and A2), which were also seen as stages of technical progress. On the basis of the early radiocarbon dates from the cemetery of Singen, southern Germany, the beginning of the Early Bronze Age in Central Europe was originally dated around 2300/2200 BC and the transition to more complex casting techniques (i.e., Bronze A2) around 2000 BC. On the basis of 140 newly radiocarbon dated human remains from Final Neolithic, Early and Middle Bronze Age cemeteries south of Augsburg (Bavaria) and a re-dating of ten graves from the cemetery of Singen, we propose a significantly different dating range, which forces us to re-think the traditional relative and absolute chronologies as well as the narrative of technical development. We are now able to date the beginning of the Early Bronze Age to around 2150 BC and its end to around 1700 BC. Moreover, there is no transition between Bronze (Bz) A1 and Bronze (Bz) A2, but a complete overlap between the type objects of the two phases from 1900–1700 BC. We thus present a revised chronology of the assumed diagnostic type objects of the Early Bronze Age and recommend a radiocarbon-based view on the development of the material culture. Finally, we propose that the traditional phases Bz A1 and Bz A2 do not represent a chronological sequence, but regionally different social phenomena connected to the willingness of local actors to appropriate the new bronze technology.
Introduction

The impact of technical innovations on the development of societies has been of central interest since the beginning of archaeological research. V. Gordon Childe (1925) [1] already considered technical innovation as a crucial factor for societal changes in prehistory. However, the notion that past societies immediately accepted innovations is highly problematic and deeply rooted in modern notions of progress. The transition from the Late Neolithic (LN) to the Early Bronze Age (EBA) in Central Europe has long been considered as a linear evolutionary development that led to a growing mastery of the new technology. Paul Reinecke [2] was the first to define the Central European EBA as Bz A and some years later further divided this phase into two chronological sub-phases—namely Bz A1 and Bz A2—which were also seen as states of technical progress [3]. All subsequent chronological discussion has been based on Reinecke’s work and many scholars have also kept the idea of a gradual development of the technology from hammered metal objects—consisting mostly of copper with hardly any tin in Bz A1—up to perfectly alloyed bronze with 90% of copper and 10% of tin and refined casting techniques in Bz A2. Critics have argued for a more complex, non-linear history of the spread and appropriation of bronze technology [4][5][6][7]. They have emphasized the relevance of social factors in this process and pointed to cases of belated appropriation of metallurgy. Moreover, scholars have already pointed to the fact that differences within Únětic material culture could be the result of social or spatial phenomena rather than chronological ones [8][9][10]. Others have doubted the applicability of the Reinecke system for the area of the Únětic culture [11]. Nevertheless, the small number of existing 14C dates have not so far substantiated these important doubts. Despite these critical voices, researchers have continuously tried to synchronize the Reinecke system with the chronologies of the Únětic culture [12][13]. With regard to Early Bronze Age material culture from Central Europe, a similar evolutionist perspective still prevails: simple bone objects—especially pins—were proposed to be the starting point of this development as their shapes seemed to foreshadow the later metal shapes [14]. Walter Ruckdeschel presented a more detailed view in 1978 [15]. He proposed a further subdivision of Bz A1 and A2 on the basis of particular types of pins, which still is the basis of today’s relative chronology for southern Germany. However, as no grave contained more than one pin, the supposed development of the pins could not be crosschecked with the help of associations of different types of pins. Since the 1990s, Stephan Möslein [16] and Wolfgang David [17] have tried to further develop and refine Ruckdeschel’s chronology by taking hoard finds and pottery from settlements into account, but did not question the general chronological sequence of the pins as suggested by Ruckdeschel. Since then, it has already been acknowledged that only a large series of 14C-dated contexts may enable us to solve these long-standing problems of understanding cultural developments in the EBA.

The linking of the relative chronological system with absolute dates is of major importance to understand the temporal dimension of the respective phases. Until the 1980s, the beginning of the EBA in Central Europe was dated to around 1700 BC on the basis of long-distance connections with the Mediterranean (for an overview cf. [18]). Since the late 1980s, a growing number of radiocarbon-dated contexts have enabled us to obtain scientifically determined dates of various phases. When Rüdiger Krause [19] published the radiocarbon dates for the Bz A1 cemetery of Singen in southern Germany, archaeologists were electrified by the surprisingly old dates for the beginning of the EBA. Following Becker et al. [20] it soon became common sense to locate the beginning of the EBA around 2300 BC or 2200 BC in central Europe at the very latest [21],[22]. As these dates enabled archaeologists to replace the insecurities of long-distance dating by the seemingly scientific truth of 14C dates, the new early dates were accepted widely and found their way into museum exhibitions as well as popular literature. At the same
time in the late 1980s, dendrochronological dating of the so-called princely grave of Leubingen in Saxony-Anhalt helped to identify the beginning of Bz A2 in the 20th century BC and dendro-dates from Alpine lakeside settlements suggested an end of the EBA in the 16th century BC [23], [24]. Therefore, it seemed natural to date the transition from Bz A1 to Bz A2 to around 2000 BC.

Since then, new radiocarbon dates have produced more problems rather than improving our understanding of the connection between the relative and absolute chronology: 22 graves from the area around Stuttgart in southern Germany, which were typologically attributed to Bz A1, were dated to the 20th and 19th centuries BC and, therefore, seemingly too young [20], [25]. On the other hand, contexts with Bz A2 type objects in the area of the Únětice culture (Aunjetitzer Kultur) in eastern Germany were dated to the centuries before 2000 BC [26], [10], [27]: e.g. Quenstedt grave 34 with an Ösenkopfnadel (eyelet pin): 2350–1907 BC (90.7% probability); hoard II of Melz: 2205–1952 BC (95.4% probability). These results also met criticism, as it seemed impossible to have such early dates for sophistically cast bronze objects [28], though the early date for a grave with Bz A2 bronzes from Feuersbrunn in Austria – 2198–2162 BC (8.4% probability) and 2152–1960 BC (87.0% probability) – further underlines the early appearance of Bz A2 types [29]. However, these contradicting results have not found adequate explanation so far. Moreover, the rarity of Bz A1 types in eastern Germany and the rare Bz A2 types in southern Germany should have already raised the question, whether the traditional EBA relative chronology can be applied for the whole of Central Europe without further modification [30]. Until now, the lack of radiocarbon dated Bz A1 and A2 type objects from different contexts from southern respectively eastern Germany has prevented us from better understanding EBA chronology as well as social and cultural developments.

Materials and Methods

Since the 1980s a large number of Late Neolithic (LN) and Early Bronze Age (EBA) graves were excavated south of the present-day city of Augsburg (Bavaria, Germany) (Fig 1), (Fig 2). The LN and EBA cemeteries are arranged like pearls on a necklace and located just outside the eastern and western fringe of a large and extremely fertile loess terrace in the middle of the Lech valley. As a consequence, the cemeteries are placed in a very similar topographic position. On the eastern side of the loess terrace, several cemeteries are associated with a small hamlet placed to the west. Therefore, at least theoretically, all settlements had access to the same natural resources. On the western side of the loess terrace, only cemeteries are known whereas the related settlements have not yet been located. The 32 burial places vary largely in size—from single burials and small cemeteries (such as three EBA graves in Augsburg-Haunstetten, Unterer Talweg 85) up to 63 of them in Kleinaittingen (Table 1). They are either restricted to one chronological phase—LN or EBA up to the beginning Middle Bronze Age (MBA)—or span a longer period of time with Late Neolithic Bell Beaker Phenomenon (BBP) and EBA burials close by each other. Consisting of 390 burials, it presents one of the largest concentrations of LN/EBA/early MBA burials in central Europe. Furthermore, the graves are remarkable for the good preservation of collagen in the bone material as well as rich grave goods—especially metal objects. In contrast to other EBA cemeteries, neither large-scale grave robbery nor insufficiently documented excavations reduce the significance of the evidence.

We selected 140 individuals from 132 LN and EBA burials (eight of them double burials) for radiocarbon dating. The skeletal material from the cemeteries of Haunstetten (Unterer Talweg 58–62; Unterer Talweg 85; Postillionstraße) and Augsburg (Hugo-Eckener-Straße) is stored at the Stadttarchäologie Augsburg; that from Königsbrunn (Obere Kreuzstraße; Ampack), Kleinaittingen and Oberottmarshausen is kept in the Archäologisches Museum.
Konigsbrunn, and the material from Wehringen was situated at the Bayerisches Landesamt für Denkmalpflege, Dienststelle Thierhaupten, at the time of our sampling. All necessary permits were obtained for the described study, which complied with all relevant regulations (Augsburg: permit from 23rd April 2014 by Michaela Hermann; Königsbrunn: permit from 23rd April 2014 by Rainer Linke; Thierhaupten: permit from 18th July 2013 by Hanns Dietrich). The material from Augsburg and Königsbrunn is accessible upon request in the respective collections; that from Wehringen can meanwhile be found in the Anthropologische Staatssammlung, Munich.

Based on archaeological criteria, 19 of them were attributed to the BBP, 102 to the EBA and 19 to the EBA/early MBA in order to establish their chronology. The selection of samples was guided by several considerations: in the case of small cemeteries (e.g. Haunstetten, Unterer Talweg 85), we sampled all individuals with sufficient bone preservation. In the case of larger cemeteries (e.g. Kleinaitingen, Gewerbegebiet Nord), we selected individuals due to the following criteria: burials with chronologically significant or remarkable grave goods (especially pins, daggers and other weapons, Ösenhalssringe, elaborated head adornments etc.) as well as a representative number of samples from definable groups of graves and children as well as adults—irrespective of the presence of grave goods. Unfortunately, there is a significant difference of graves with objects datable to Bz A1 and Bz A2, respectively, as the number of graves with Bz A2 type objects is small in the Augsburg region—similar to the rest of southern Germany. As the 2σ calibrated ranges of burials in the Augsburg region cover the complete period of time defined as Early Bronze Age, this lack of Bz A2 type objects must be explained in their infrequent selection as grave goods.

Fig 1. Map of important sites in Germany and Bohemia mentioned in the text.

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Our first results from Augsburg contradicted some of the older radiocarbon dates from Singen analyzed by radiometric measurement with proportional gas counters (decay counting of $^{14}$C) in the 1980s [19], especially as the grave goods seemed to be almost identical (e.g. large
Therefore, we decided to re-evaluate the burials from Singen, which played a crucial role in the understanding of the chronological and cultural development of the EBA [19]. We re-sampled the same individuals, which had already been analyzed in the 1980s [31], and were now able to apply AMS dating. The skeletal material from Singen is currently stored and accessible in the Hegau-Museum in Singen and our sampling was permitted by Joachim Wahl and Jürgen Hald (permit from 10th July 2014). Only the skeletal remains of grave 82 from Singen could not be localized in the archive and could not be dated again. Grave 69 was sampled in addition to the old series (cf. [20], 431 Fig 1 erroneously attributes Hd-8974-9155 to grave 69, although it belongs to grave 65; [19], 171 Tab. 5 is correct).

### Table 1. Cemeteries from the Augsburg region, the total number of graves and of sampled graves, respectively.

| Site                                              | Total number of graves | Sampled graves |
|---------------------------------------------------|------------------------|----------------|
| **Corded Ware Complex**                           |                        |                |
| Haunstetten, Siemens-Gelände                      | 2                      | 0              |
| Haunstetten, Unterer Talweg 89                    | 1                      | 0              |
| Haunstetten, Unterer Talweg 121                   | 1                      | 0              |
| **Bell Beaker Phenomenon**                        |                        |                |
| Augsburg, Bürgermeister-Ulrich-Straße              | 12                     | 0              |
| Augsburg, Hugo-Eckener-Straße                      | 11                     | 10             |
| Augsburg, Universitätsgelände                      | 24                     | 0              |
| Haunstetten, Im Tal 6                             | 6                      | 0              |
| Haunstetten, Unterer Talweg 58–62                 | 2                      | 2              |
| Haunstetten, Unterer Talweg 85 I (Northern group) | 3 or 5                 | 3              |
| Haunstetten, Unterer Talweg 85 II (Southern group)| 2                      | 2              |
| Inningen, Libellenweg                             | 2                      | 0              |
| Königsbrunn, Ampack                               | 5                      | 1              |
| Oberottmarshausen, Kiesgrube Lauter               | 1                      | 0              |
| Wehringen, Hochfeld                               | 1                      | 1              |
| **Early Bronze Age**                              |                        |                |
| Friedberg, Kissingen Weg (Metzgerwäldchen)        | 1                      | 0              |
| Friedberg, Rathaus                                | 1                      | 0              |
| Gößgingen, Gerhard-Hauptmannstraße                | 1                      | 0              |
| Gößgingen, Richard-Wagner-Straße                  | 1                      | 0              |
| Haunstetten, Postillionstraße                     | 41                     | 22             |
| Haunstetten, Unterer Talweg 58–62                 | 10                     | 7              |
| Haunstetten, Unterer Talweg 85                    | 3                      | 3              |
| Haunstetten, Unterer Talweg 111                   | 10                     | 0              |
| Kleinaitingen, Gewerbegebiet Nord                 | 63                     | 32             |
| Kleinaitingen, Herbst- und Friedensstraße         | 29                     | 0              |
| Königsbrunn, Kiesgrube Burkhart                   | 13                     | 0              |
| Königsbrunn, Obere Kreuzstraße                    | 48                     | 23             |
| Königsbrunn, Simpertstraße                        | 2                      | 0              |
| Königsbrunn, Steiniskistengrab "Oberes Feld"     | 1                      | 0              |
| Wehringen, Hochfeld                               | 14                     | 9              |
| Wehringen, Mittelunterfeld                        | 1                      | 0              |
| **Early and Middle Bronze Age**                   |                        |                |
| Königsbrunn, Afra- and Augustusstraße             | 44                     | 0              |
| Oberottmarshausen, Kiesgrube Lauter               | 32                     | 21             |

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The old radiometric dates from Singen were obtained in the radiocarbon laboratory of the Heidelberg Academy of Sciences (samples using lab codes Hd), and the new series using AMS was measured in the Klaus-Tschira-Archaeometry-Center, Mannheim, Germany (samples using lab codes MAMS).

The pretreatment procedure for radiometric analysis of the samples included decalcification in weak HCl over several days up to one week and dialysis to remove proteins below 10 kD. The resulting sample material was combusted to CO₂. The gas was purified and the radiocarbon age was determined radiometrically by decay counting for up to one week in gas proportional counters [32].

The new bone samples taken for AMS dating were decalcified. Bone collagen was obtained in a modified Longin extraction [33], followed by ultrafiltration (30 kD) and freeze-drying. Collagen was conducted in an Elemental Analyzer (Elementar Micocube). CO₂ was collected cryogenically and converted to graphite using Fe as catalyst. The samples were measured using the MICA-DAS AMS system of the Mannheim facility [34]. In the Elemental Analyzer the C:N ratio can be determined. For all samples the C:N ratio was in the accepted range of well-preserved bone (2.9–3.6) [35]. The data were calibrated using Oxcal v4.2.24 [36] and IntCal13 [37].

We applied Bayesian modeling (for the method cf. [38] and [36]) in order to calculate the degree of overlap between the different phases on a statistical basis. By combining archaeological information (e.g. the attribution to archaeologically defined entities) with a series of chronometric dates, Bayesian modeling can delineate transitions between phases better than the individual ¹⁴C dates. In order to study the transition between BBP and EBA, we built a multiphase model allowing for overlap between these two phases (using Oxcal v.4.2.24 [34]).

Extensive consumption of aquatic food, such as fish or mollusks, may have contributed ¹⁴C-depleted carbon to the human diet resulting in apparently too old radiocarbon dates. This so-called reservoir effect is well-known for marine diets [33]. It is also a possible concern at inland localities, where carbonates of geological origin contribute carbon with a significantly lower ¹⁴C concentration to freshwater habitats [39], [40]. The analysis of stable carbon and nitrogen isotope ratios (δ¹³C and δ¹⁵N) of bone collagen is a well-established method for human diet reconstruction and may indicate significant contribution of aquatic food items [41]. In order to identify individuals whose dietary habits may have influenced the results of radiocarbon dating we determined the stable isotope ratios of bone collagen of 43 individuals from the Augsburg region. They include all individuals of the BBP with sufficient collagen preservation (n = 18) and a selection of 25 EBA individuals with diagnostic pin types. The light stable isotope analyses for Singen were conducted at the Max Planck Institute for Evolutionary Anthropology in Leipzig and published in summary in [42]. Four individual values were adapted from [43].

The stable isotope analyses for the individuals from the Augsburg region were carried out on collagen extracts remaining after radiocarbon dating. C and N contents were determined by elemental analyzer (vario EL III, Elementar Analytical Systems) and isotope compositions by an IsoPrime High Performance IRMS (VG Instruments) at the Institute for Organic Chemistry at the University of Mainz, Germany. All measurements were performed in duplicate, and the results reported in δ-notation in ‰ relative to VPDB for carbon and to AIR for nitrogen. The raw data were normalized using two-point calibrations based on USGS 40 and IAEA N2 for nitrogen and IAEA CH6 and CH7 for carbon [44]. Measurement errors are less than ± 0.2 ‰ for nitrogen and ± 0.1 ‰ for carbon.

Results

In the discussion that follows, we present the results of the radiocarbon dating in chronological order for the Augsburg region. We bring them together with the traditional archaeological...
division of the respective phases in order to connect traditional relative-chronological phases with the absolute-chronological evidence. These results are then compared with the old and new dates from Singen.

Augsburg Region

The earliest dates for graves of the BBP in the Augsburg region start with their 2σ calibrated range already in the 25th century BC—e.g. Königsbrunn, Ampack gr. 1: 2478–2339 BC (94.4% probability) and 2317–2310 BC (1.0% probability); Augsburg, Hugo-Eckener-Str. gr. 5: double grave, combined calibration of both burials: 2469–2310 BC (95.4% probability) (Table 2). The three latest dates for BBP graves derive from the cemetery Hugo-Eckener-Str. (graves 1, 9 and 10) and are almost identical in their dating with the latest 2σ calibrated time span ending in 2039 BC (grave 1). All the other dates for BBP graves are evenly distributed between the oldest and the youngest date (Fig 3). The sequence of clusters of BBP dates in Fig 3 does not correspond with any archaeological division of the BBP, but only results from a sequence of small plateaus of the calibration curve.

At first, it seems difficult to decide whether there is a significant overlap between the latest BBP and the earliest EBA burials. If one supposes that the three latest BBP burials were buried at almost the same time (the three related uncalibrated dates fall within a range of seven years: 3748–3741 14C BP), one can calculate a combined calibrated age, which significantly narrows the time range with the highest probability: 2201–2133 BC (93.0% probability) and 2076–2064 BC (2.4% probability). This indicates that the last BBP burials in the Augsburg region were most probably not laid down after the early second half of the 22nd century (Fig 4).

The oldest EBA dates all derive from the cemetery Haunstetten, Postillonstraße, namely graves 4, 5 and 14 (the three related uncalibrated dates fall within a range of 20 years: 3717–3697 14C BP). The narrow time range of their deposition makes it possible to calculate a combined calibrated age. The 2σ calibrated range spans 2141–2112 BC (22.8% probability) and 2103–2036 BC (72.6% probability) BC.

Calculating the overlap of the two phases (BBP and EBA) using a multi-phase model in Oxcal v4.2.24 [36] with IntCal13 [37] strengthens the argument of a sequence (Fig 5). Modeled values of “Boundary End 1” (end of BBP) and “Boundary Start 2” (beginning of EBA) do not overlap more than 20 years.

Therefore, one can assume that there is hardly any overlap or no overlap at all between the latest BBP and the earliest EBA burials. At least in the Augsburg region, there is definitely no indication for either a substantial overlap or a hiatus between both periods. The data suggest a continuous and fluent sequence from the BBP to the EBA.

The new dates also help to better understand the development of the EBA itself. We are able to connect the traditional division of Bz A into the sub-phases Bz A1 and A2 with absolute dates for the respective type objects. Ruckdeschel defined the following pin types as type objects for Bz A1 (with its sub-phases Bz A1a and Bz A1b) and Bz A2 (with its sub-phases Bz A2a, Bz A2b and Bz A2c) [15] (see below):

Bz A1a: Ruädkopfnadeln (with large or small head), bone pins and boar tusk pins
Bz A1a–A1b: Scheibenkopfnadeln
Bz A1b: Schleifenkopfnadeln and Horkheimer Nadeln.

Bz A2a: Ösenkopfnadel, Hülsenkopfnadel and schräg durchlochte Kugelkopfnadel.

We were not able to date graves with Bz A2b and Bz A2c type objects, which are very rare in southern Germany (cf. [17]). The Lochhalsnadel type Paarstädtl was dated by Ruckdeschel to
Table 2. Burials from the Augsburg cemeteries and their radiocarbon dates (na = not analyzed).

| Name of site             | GraveNo. after | Feat. No. | Ind. | LaborNo. | C14 Age ± (68.2% probability) | Cal 1 sigma (95.4% probability) | Cal 2 sigma (95.4% probability) | C: N | %C |
|-------------------------|----------------|-----------|------|----------|-------------------------------|---------------------------------|---------------------------------|------|-----|
| Augsburg, Hugo-Eckener-Straße | 1              | Kociumaka 167 | MAMS 18912 | 3741 | 24 cal BC 2199–2062          | cal BC 2270–2039                 | 3.3 36.9                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 3              | Kociumaka 168 | MAMS 18913 | 3788 | 23 cal BC 2280–2148          | cal BC 2289–2141                 | 3.3 37.3                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 5              | Kociumaka 169 skeleton 1 | MAMS 18914 | 3942 | 25 cal BC 2487–2350          | cal BC 2562–2345                 | 3.1 53.4                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 5              | Kociumaka 169 skeleton 2 | MAMS 18915 | 3863 | 25 cal BC 2453–2289          | cal BC 2361–2211                 | 3.3 53.1                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 6              | Kociumaka 170 | MAMS 18916 | 3774 | 24 cal BC 2274–2142          | cal BC 2288–2066                 | 3.3 43.2                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 7              | Kociumaka 171 | MAMS 18917 | 3815 | 25 cal BC 2289–2206          | cal BC 2387–2146                 | 3.3 30.4                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 8              | Kociumaka 180 skeleton 1 | MAMS 18918 | 3860 | 25 cal BC 2453–2287          | cal BC 2461–2210                 | 3.3 47.3                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 8              | Kociumaka 180 skeleton 2 | MAMS 18919 | 3871 | 25 cal BC 2453–2295          | cal BC 2463–2235                 | 3.3 45.1                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 9              | Kociumaka 183 | MAMS 18920 | 3743 | 19 cal BC 2199–2066          | cal BC 2204–2043                 | 3.3 53.7                        |      |     |
| Augsburg, Hugo-Eckener-Straße | 10             | Kociumaka 190 | MAMS 18921 | 3748 | 19 cal BC 2199–2138          | cal BC 2268–2046                 | 3.3 47.8                        |      |     |
| Haunstetten, Postillionstraße | 3              | Massy 24  | MAMS 18959 | 3679 | 20 cal BC 2131–2029          | cal BC 2137–1980                 | 3.3 45.5                        |      |     |
| Haunstetten, Postillionstraße | 4              | Massy 12  | MAMS 18956 | 3697 | 20 cal BC 2134–2037          | cal BC 2190–2028                 | 3.3 54.3                        |      |     |
| Haunstetten, Postillionstraße | 5              | Massy 38  | MAMS 18963 | 3717 | 23 cal BC 2191–2042          | cal BC 2197–2034                 | 3.3 52.7                        |      |     |
| Haunstetten, Postillionstraße | 6              | Massy 44  | MAMS 18964 | 3681 | 23 cal BC 2131–2029          | cal BC 2139–1979                 | 3.1 49.0                        |      |     |
| Haunstetten, Postillionstraße | 8              | Massy 140 | MAMS 18973 | 3631 | 20 cal BC 2024–1963          | cal BC 2114–1926                 | 3.3 47.0                        |      |     |
| Haunstetten, Postillionstraße | 9              | Massy 28  | MAMS 18960 | 3608 | 20 cal BC 2016–1936          | cal BC 2027–1906                 | 3.3 35.5                        |      |     |
| Haunstetten, Postillionstraße | 11             | Massy 32  | MAMS 18961 | 3619 | 20 cal BC 2020–1948          | cal BC 2032–1916                 | 3.3 45.4                        |      |     |
| Haunstetten, Postillionstraße | 12             | Massy 35  | MAMS 18962 | 3621 | 20 cal BC 2021–1951          | cal BC 2033–1918                 | 3.3 44.5                        |      |     |
| Haunstetten, Postillionstraße | 13             | Massy 47  | MAMS 18965 | 3662 | 24 cal BC 2126–1979          | cal BC 2134–1956                 | 3.3 54.7                        |      |     |
| Haunstetten, Postillionstraße | 14             | Massy 50  | MAMS 18966 | 3707 | 24 cal BC 2138–2040          | cal BC 2196–2029                 | 3.3 48.5                        |      |     |
| Haunstetten, Postillionstraße | 16             | Massy 84  | MAMS 18967 | 3638 | 24 cal BC 2030–1962          | cal BC 2126–1928                 | 3.3 49.1                        |      |     |
| Haunstetten, Postillionstraße | 19             | Massy 131 | MAMS 18971 | 3635 | 20 cal BC 2027–1965          | cal BC 2120–1938                 | 3.3 51.3                        |      |     |
| Haunstetten, Postillionstraße | 21             | Massy 85  | MAMS 18968 | 3631 | 24 cal BC 2026–1959          | cal BC 2120–1921                 | 3.3 46.9                        |      |     |
| Haunstetten, Postillionstraße | 24             | Massy 137 | MAMS 18972 | 3613 | 20 cal BC 2017–1941          | cal BC 2029–1912                 | 3.3 43.9                        |      |     |
| Haunstetten, Postillionstraße | 30             | Massy 111 | MAMS 18970 | 3639 | 20 cal BC 2031–1966          | cal BC 2122–1941                 | 3.3 51.7                        |      |     |
| Haunstetten, Postillionstraße | 32             | Massy 99  | MAMS 18969 | 3641 | 25 cal BC 2033–1960          | cal BC 2130–1930                 | 3.3 40.0                        |      |     |

(Continued)
Table 2. (Continued)

| Name of site | GraveNo. | GraveNo. after | Feat. No. | Ind. LaborNo. | C14 Age ± Cal 1 sigma (68.2% probability) | Cal 2 sigma (95.4% probability) | C: N | %C |
|--------------|----------|----------------|-----------|---------------|------------------------------------------|---------------------------------|------|-----|
| Haunstetten, Postillionstraße | 35 | Massy 16 | MAMS 18957 | 3612 | 20 cal BC 2018–1941 cal BC 2029–1911 | 3.3 41.6 |
| Haunstetten, Postillionstraße | 36 | Massy 6 | MAMS 18955 | 3574 | 19 cal BC 1942–1895 cal BC 2009–1883 | 3.3 49.0 |
| Haunstetten, Postillionstraße | 38 | Massy 3 | MAMS 18954 | 3592 | 19 cal BC 2006–1911 cal BC 2019–1890 | 3.3 52.0 |
| Haunstetten, Postillionstraße | 39 | Massy 21 | MAMS 18958 | 3606 | 20 cal BC 2014–1931 cal BC 2025–1903 | 3.1 47.0 |
| Haunstetten, Postillionstraße | 40 | Massy 1 | MAMS 18952 | 3583 | 28 cal BC 1964–1892 cal BC 2024–1882 | 3.3 49.5 |
| Haunstetten, Postillionstraße | 41 | Massy 2 | MAMS 18953 | 3648 | 19 cal BC 2111–1975 cal BC 2126–1948 | 3.4 54.5 |
| Haunstetten, Unterer Talweg 58–62 | 3 | Massy 153 | MAMS 18943 | 3553 | 24 cal BC 1941–1836 cal BC 1971–1776 | 3.3 53.1 |
| Haunstetten, Unterer Talweg 58–62 | 4 | Massy 152 skeleton | MAMS 18942 | 3558 | 23 cal BC 1939–1885 cal BC 2007–1779 | 3.3 51.8 |
| Haunstetten, Unterer Talweg 58–62 | 5 | Massy 151 | MAMS 18940 | 3568 | 24 cal BC 1943–1890 cal BC 2016–1782 | 3.1 35.5 |
| Haunstetten, Unterer Talweg 58–62 | 5 | Massy 151 | MAMS 18941 | 3557 | 20 cal BC 1931–1886 cal BC 1961–1781 | 3.1 40.5 |
| Haunstetten, Unterer Talweg 58–62 | 5 | Massy 151 | MAMS 18940 skeleton 1 +18941 combined | 3566 | 11 cal BC 1930–1894 cal BC 1946–1886 | na na |
| Haunstetten, Unterer Talweg 58–62 | 6 | Massy 150 | MAMS 18939 | 3559 | 24 cal BC 1939–1885 cal BC 2009–1780 | 3.3 54.3 |
| Haunstetten, Unterer Talweg 58–62 | 7 | Kociumaka 67 | MAMS 18934 | 3840 | 20 cal BC 2340–2211 cal BC 2455–2204 | 3.3 67.6 |
| Haunstetten, Unterer Talweg 58–62 | 7 | Massy 149 | MAMS 18938 | 3597 | 24 cal BC 2011–1917 cal BC 2023–1892 | 3.3 47.9 |
| Haunstetten, Unterer Talweg 58–62 | 8 | Kociumaka 68 skeleton 2 | MAMS 18935 | 3910 | 20 cal BC 2466–2349 cal BC 2470–2310 | 3.3 52.2 |
| Haunstetten, Unterer Talweg 58–62 | 9 | Massy 147 | MAMS 18937 | 3612 | 25 cal BC 2020–1938 cal BC 2031–1900 | 3.3 53.8 |
| Haunstetten, Unterer Talweg 58–62 | 10 | Massy 146 | MAMS 18933 | 3570 | 19 cal BC 1940–1894 cal BC 2009–1881 | 3.3 41.7 |
| Haunstetten, Unterer Talweg 85 | 1 | Massy 1163 | MAMS 18946 | 3586 | 24 cal BC 1961–1895 cal BC 2021–1885 | 3.3 43.6 |
| Haunstetten, Unterer Talweg 85 | 2 | Massy 1410 | MAMS 18950 | 3549 | 25 cal BC 1940–1829 cal BC 1960–1774 | 3.3 47.9 |
| Haunstetten, Unterer Talweg 85 | 3 | Massy 1412 | MAMS 18951 | 3602 | 25 cal BC 2014–1923 cal BC 2025–1895 | 3.0 54.2 |
| Haunstetten, Unterer Talweg 85 | I/1 | Kociumaka 1334 | MAMS 18947 | 3827 | 25 cal BC 2331–2206 cal BC 2453–2152 | 3.2 26.1 |
| Haunstetten, Unterer Talweg 85 | I/2 | Kociumaka 1336 | MAMS 18948 | 3893 | 22 cal BC 2458–2347 cal BC 2465–2300 | 3.3 51.6 |
| Haunstetten, Unterer Talweg 85 | I/3 | Kociumaka 1343 | MAMS 18949 | 3819 | 24 cal BC 2291–2206 cal BC 2397–2149 | 3.3 47.5 |
| Haunstetten, Unterer Talweg 85 | II/1 | Kociumaka 113 | MAMS 18945 | 3831 | 24 cal BC 2334–2207 cal BC 2456–2155 | 3.1 52.3 |
| Haunstetten, Unterer Talweg 85 | II/2 | Kociumaka 110 | MAMS 18944 | 3789 | 24 cal BC 2281–2149 cal BC 2290–2141 | 3.3 43.0 |

(Continued)
### Table 2. (Continued)

| Name of site | GraveNo. after | Feat. No. | Ind. | LaborNo. | C14 ± Cal 1 sigma (68.2% probability) | Cal 2 sigma (95.4% probability) | C: N | %C |
|--------------|----------------|-----------|------|----------|--------------------------------------|-------------------------------|------|-----|
| Kleinaitingen, Gewerbegebiet Nord | 2 | Massy | 3 | MAMS 21563 | 3616 | 28 cal BC 2021–1942 | cal BC 2111–1895 | 3.3 | 38.9 |
| Kleinaitingen, Gewerbegebiet Nord | 3 | Massy | 2 | MAMS 21562 | 3477 | 28 cal BC 1876–1750 | cal BC 1884–1698 | 3.3 | 23.9 |
| Kleinaitingen, Gewerbegebiet Nord | 4 | Massy | 5 | MAMS 21564 | 3493 | 28 cal BC 1878–1771 | cal BC 1892–1704 | 3.3 | 20.9 |
| Kleinaitingen, Gewerbegebiet Nord | 6 | Massy | 37 | MAMS 21569 | 3560 | 28 cal BC 1946–1883 | cal BC 2013–1777 | 3.3 | 36.9 |
| Kleinaitingen, Gewerbegebiet Nord | 9 | Massy | 33 | MAMS 21566 | 3364 | 28 cal BC 1687–1626 | cal BC 1742–1562 | 3.1 | 39.8 |
| Kleinaitingen, Gewerbegebiet Nord | 10 | Massy | 40 | MAMS 21570 | 3469 | 28 cal BC 1875–1705 | cal BC 1882–1695 | 3.3 | 13.3 |
| Kleinaitingen, Gewerbegebiet Nord | 11 | Massy | 35 | MAMS 21567 | 3582 | 28 cal BC 1962–1891 | cal BC 2026–1880 | 3.3 | 36.3 |
| Kleinaitingen, Gewerbegebiet Nord | 12 | Massy | 32 | MAMS 21565 | 3454 | 28 cal BC 1871–1696 | cal BC 1878–1691 | na | na |
| Kleinaitingen, Gewerbegebiet Nord | 13 | Massy | 50 | MAMS 21572 | 3505 | 33 cal BC 1884–1773 | cal BC 1920–1705 | 3.3 | 38.9 |
| Kleinaitingen, Gewerbegebiet Nord | 14 | Massy | 36 | MAMS 21568 | 3552 | 27 cal BC 1943–1830 | cal BC 2006–1774 | 3.3 | 40.6 |
| Kleinaitingen, Gewerbegebiet Nord | 15 | Massy | 51 | MAMS 21573 | 3531 | 34 cal BC 1919–1777 | cal BC 1946–1754 | 3.1 | 39.4 |
| Kleinaitingen, Gewerbegebiet Nord | 17 | Massy | 53 | MAMS 21574 | 3492 | 33 cal BC 1878–1770 | cal BC 1901–1698 | 3.1 | 39.6 |
| Kleinaitingen, Gewerbegebiet Nord | 21 | Massy | 43 | MAMS 21571 | 3486 | 27 cal BC 1877–1761 | cal BC 1888–1701 | 3.1 | 30.4 |
| Kleinaitingen, Gewerbegebiet Nord | 22 | Massy | 55 | MAMS 21575 | 3504 | 33 cal BC 1884–1773 | cal BC 1919–1705 | na | 18.8 |
| Kleinaitingen, Gewerbegebiet Nord | 23 | Massy | 69 | MAMS 21581 | 3294 | 34 cal BC 1613–1531 | cal BC 1657–1500 | 3.4 | 17.4 |
| Kleinaitingen, Gewerbegebiet Nord | 24 | Massy | 62 | skeleton A | MAMS 21576 | 3459 | 34 cal BC 1874–1697 | cal BC 1881–1691 | 2.5 | 30.2 |
| Kleinaitingen, Gewerbegebiet Nord | 24 | Massy | 62 | skeleton B | MAMS 21577 | 3478 | 33 cal BC 1877–1749 | cal BC 1889–1695 | 3.4 | 27.2 |
| Kleinaitingen, Gewerbegebiet Nord | 26 | Massy | 66 | | MAMS 21580 | 3489 | 34 cal BC 1878–1767 | cal BC 1899–1696 | 3.3 | 40.9 |
| Kleinaitingen, Gewerbegebiet Nord | 28 | Massy | 77 | skeleton A | MAMS 21584 | 3548 | 34 cal BC 1943–1782 | cal BC 2008–1769 | na | na |
| Kleinaitingen, Gewerbegebiet Nord | 28 | Massy | 77 | skeleton B | MAMS 21585 | 3469 | 35 cal BC 1876–1702 | cal BC 1885–1693 | 3.1 | 38.3 |
| Kleinaitingen, Gewerbegebiet Nord | 29 | Massy | 78 | | MAMS 21586 | 3474 | 34 cal BC 1877–1746 | cal BC 1887–1694 | na | 22.0 |
| Kleinaitingen, Gewerbegebiet Nord | 34 | Massy | 87 | | MAMS 21588 | 3433 | 28 cal BC 1767–1690 | cal BC 1876–1660 | 3.4 | 23.8 |
| Kleinaitingen, Gewerbegebiet Nord | 35 | Massy | 86 | | MAMS 21587 | 3480 | 34 cal BC 1877–1750 | cal BC 1891–1694 | na | na |
| Kleinaitingen, Gewerbegebiet Nord | 37 | Massy | 119 | | MAMS 21594 | 3470 | 27 cal BC 1876–1745 | cal BC 1882–1696 | 3.3 | 24.0 |
| Kleinaitingen, Gewerbegebiet Nord | 38 | Massy | 120 | | MAMS 21595 | 3417 | 27 cal BC 1748–1684 | cal BC 1866–1638 | 3.4 | 14.9 |

(Continued)
| Name of site, Gewerbegebiet Nord | GraveNo. | Feature. No. | Ind. LaborNo. | C14 Age ± Cal 1 sigma (68.2% probability) | Cal 2 sigma (95.4% probability) | C: N | %C |
|---------------------------------|----------|--------------|---------------|------------------------------------------|-------------------------------|------|-----|
| Kleinaitingen, Gewerbegebiet Nord | 40       | Massy 72     | MAMS 21583    | 3508 34 cal BC 1886–1773                 | cal BC 1926–1705             | 3.3  | 19.5 |
| Kleinaitingen, Gewerbegebiet Nord | 41       | Massy 70     | MAMS 21582    | 3594 37 cal BC 2013–1899                 | cal BC 2116–1785             | 3.1  | 39.5 |
| Kleinaitingen, Gewerbegebiet Nord | 43       | Massy 65 adult | MAMS 21578    | 3456 34 cal BC 1873–1695                 | cal BC 1881–1690             | 3.4  | 33.0 |
| Kleinaitingen, Gewerbegebiet Nord | 43       | Massy 65 child | MAMS 21579    | 3329 35 cal BC 1660–1536                 | cal BC 1690–1514             | 3.4  | 38.4 |
| Kleinaitingen, Gewerbegebiet Nord | 47       | Massy 98     | MAMS 21592    | 3370 27 cal BC 1688–1629                 | cal BC 1742–1613             | 3.3  | 16.0 |
| Kleinaitingen, Gewerbegebiet Nord | 48       | Massy 92     | MAMS 21590    | 3489 28 cal BC 1878–1768                 | cal BC 1889–1701             | 3.3  | 21.5 |
| Kleinaitingen, Gewerbegebiet Nord | 56       | Massy 114    | MAMS 21593    | 3563 28 cal BC 1948–1883                 | cal BC 2015–1778             | na   | 18.3 |
| Kleinaitingen, Gewerbegebiet Nord | 60       | Massy 95     | MAMS 21591    | 3422 28 cal BC 1754–1685                 | cal BC 1870–1640             | na   | 15.6 |
| Kleinaitingen, Gewerbegebiet Nord | 62       | Massy 89     | MAMS 21589    | 3292 28 cal BC 1611–1532                 | cal BC 1627–1505             | 3.3  | 22.6 |
| Königsbrunn, Ampack             | 1        | Kociumaka none | MAMS 18887    | 3924 23 cal BC 2471–2350                 | cal BC 2476–2310             | 3.2  | 47.8 |
| Königsbrunn, Obere Kreuzstraße  | 2        | Massy 96     | MAMS 18910    | 3567 23 cal BC 1942–1889                 | cal BC 2013–1784             | 3.3  | 53.6 |
| Königsbrunn, Obere Kreuzstraße  | 3        | Massy 47     | MAMS 18894    | 3671 22 cal BC 2129–1983                 | cal BC 2136–1777             | 3.2  | 48.4 |
| Königsbrunn, Obere Kreuzstraße  | 6        | Massy 2      | MAMS 18888    | 3599 22 cal BC 2011–1920                 | cal BC 2023–1894             | 3.2  | 48.7 |
| Königsbrunn, Obere Kreuzstraße  | 9        | Massy 95     | MAMS 18909    | 3608 23 cal BC 2016–1931                 | cal BC 2027–1901             | 3.3  | 54.1 |
| Königsbrunn, Obere Kreuzstraße  | 14       | Massy 5      | MAMS 18889    | 3626 22 cal BC 2023–1954                 | cal BC 2113–1917             | 3.2  | 38.5 |
| Königsbrunn, Obere Kreuzstraße  | 15       | Massy 6      | MAMS 18890    | 3611 23 cal BC 2019–1938                 | cal BC 2029–1903             | 3.2  | 42.6 |
| Königsbrunn, Obere Kreuzstraße  | 17       | Massy 50     | MAMS 18895    | 3623 23 cal BC 2022–1951                 | cal BC 2112–1912             | 3.2  | 48.1 |
| Königsbrunn, Obere Kreuzstraße  | 23       | Massy 80     | MAMS 18901    | 3664 24 cal BC 2127–1980                 | cal BC 2134–1959             | 3.1  | 53.5 |
| Königsbrunn, Obere Kreuzstraße  | 24       | Massy 66     | MAMS 18896    | 3609 22 cal BC 2018–1936                 | cal BC 2028–1903             | 3.2  | 44.8 |
| Königsbrunn, Obere Kreuzstraße  | 25       | Massy 67     | MAMS 18897    | 3599 22 cal BC 2011–1920                 | cal BC 2023–1894             | 3.3  | 53.9 |
| Königsbrunn, Obere Kreuzstraße  | 29       | Massy 93     | MAMS 18908    | 3621 23 cal BC 2022–1948                 | cal BC 2111–1907             | 3.3  | 54.4 |
| Königsbrunn, Obere Kreuzstraße  | 31       | Massy 76     | MAMS 18899    | 3567 23 cal BC 1941–1889                 | cal BC 2013–1785             | 3.3  | 52.3 |
| Königsbrunn, Obere Kreuzstraße  | 33       | Massy 9 skeleton A | MAMS 18891    | 3596 22 cal BC 2010–1918                 | cal BC 2022–1892             | 3.2  | 47.1 |
| Königsbrunn, Obere Kreuzstraße  | 33       | Massy 9 skeleton B | MAMS 18892    | 3616 23 cal BC 2021–1943                 | cal BC 2032–1903             | 3.2  | 47.2 |
| Königsbrunn, Obere Kreuzstraße  | 35       | Massy 84     | MAMS 18905    | 3575 25 cal BC 1949–1891                 | cal BC 2021–1830             | 3.1  | 52.6 |

(Continued)
| Name of site            | GraveNo. | GraveNo. after | Feat. No. | Ind. LaborNo. | C14 Age | ± Cal 1 sigma (68.2% probability) | Cal 2 sigma (95.4% probability) | C: N | %C |
|------------------------|----------|----------------|-----------|---------------|---------|----------------------------------|----------------------------------|------|-----|
| Königsbrunn, Obere Kreuzstraße | 36       | Massy 73       | MAMS 18898 | 3603          | 23      | cal BC 2013–1924                 | cal BC 2024–1897                | 3.1  | 54.6 |
| Königsbrunn, Obere Kreuzstraße | 38       | Massy 83       | MAMS 18904 | 3562          | 24      | cal BC 1941–1886                 | cal BC 2011–1780                | 3.3  | 52.1 |
| Königsbrunn, Obere Kreuzstraße | 39       | Massy 82       | MAMS 18903 | 3600          | 24      | cal BC 2012–1921                 | cal BC 2023–1894                | 3.3  | 53.0 |
| Königsbrunn, Obere Kreuzstraße | 40       | Massy 81       | MAMS 18902 | 3602          | 24      | cal BC 2013–1923                 | cal BC 2024–1896                | 3.3  | 53.4 |
| Königsbrunn, Obere Kreuzstraße | 43       | Massy 86       | MAMS 18907 | 3615          | 24      | cal BC 2021–1942                 | cal BC 2032–1901                | 3.3  | 48.6 |
| Königsbrunn, Obere Kreuzstraße | 45       | Massy 79       | MAMS 18900 | 3581          | 23      | cal BC 1953–1894                 | cal BC 2018–1883                | 3.3  | 52.6 |
| Königsbrunn, Obere Kreuzstraße | 46       | Massy 85       | MAMS 18906 | 3625          | 23      | cal BC 2023–1953                 | cal BC 2113–1915                | 3.3  | 53.8 |
| Königsbrunn, Obere Kreuzstraße | 47       | Massy 117      | MAMS 18911 | 3581          | 23      | cal BC 1953–1894                 | cal BC 2019–1883                | 3.3  | 54.1 |
| Königsbrunn, Obere Kreuzstraße | 48       | Massy 26       | MAMS 18893 | 3618          | 22      | cal BC 2021–1946                 | cal BC 2033–1907                | 3.2  | 40.8 |
| Oberottmarshausen, Kiesgrube Lauter | 1        | Massy 87       | MAMS 21544 | 3324          | 34      | cal BC 1643–1534                 | cal BC 1687–1517                | 3.3  | 32.6 |
| Oberottmarshausen, Kiesgrube Lauter | 2        | Massy 92       | MAMS 21546 | 3132          | 42      | cal BC 1449–1308                 | cal BC 1497–1293                | 3.3  | 37.9 |
| Oberottmarshausen, Kiesgrube Lauter | 3        | Massy 91       | MAMS 21545 | 3075          | 41      | cal BC 1399–1289                 | cal BC 1426–1230                | 3.4  | 9.7  |
| Oberottmarshausen, Kiesgrube Lauter | 5        | Massy 109      | MAMS 21550 | 3360          | 37      | cal BC 1728–1615                 | cal BC 1743–1534                | 3.3  | 19.9 |
| Oberottmarshausen, Kiesgrube Lauter | 7        | Massy 110      | MAMS 21551 | 3207          | 37      | cal BC 1504–1437                 | cal BC 1605–1412                | 3.3  | 14.7 |
| Oberottmarshausen, Kiesgrube Lauter | 9        | Massy 100      | MAMS 21549 | 3225          | 36      | cal BC 1526–1448                 | cal BC 1608–1427                | 3.3  | 10.7 |
| Oberottmarshausen, Kiesgrube Lauter | 12       | Massy 94       | MAMS 21547 | 3124          | 36      | cal BC 1435–1309                 | cal BC 1493–1287                | 3.3  | 12.9 |
| Oberottmarshausen, Kiesgrube Lauter | 14       | Massy 79       | MAMS 21541 | 3227          | 33      | cal BC 1526–1450                 | cal BC 1608–1430                | 3.0  | 37.2 |
| Oberottmarshausen, Kiesgrube Lauter | 17       | Massy 84       | MAMS 21543 | 3283          | 32      | cal BC 1610–1527                 | cal BC 1636–1465                | 3.3  | 38.8 |
| Oberottmarshausen, Kiesgrube Lauter | 18       | Massy 97       | MAMS 21548 | 3310          | 37      | cal BC 1627–1531                 | cal BC 1682–1505                | 3.3  | 40.5 |
| Oberottmarshausen, Kiesgrube Lauter | 19       | Massy 81       | MAMS 21542 | 3277          | 33      | cal BC 1609–1511                 | cal BC 1630–1459                | na   | 22.3 |
| Oberottmarshausen, Kiesgrube Lauter | 21       | Massy 142      | MAMS 21554 | 3309          | 37      | cal BC 1625–1531                 | cal BC 1682–1504                | 3.3  | 14.6 |
| Oberottmarshausen, Kiesgrube Lauter | 25       | Massy 151      | skeleton 1 | MAMS 21555    | 3370    | cal BC 1732–1623                 | cal BC 1749–1535                | 3.1  | 38.9 |
| Oberottmarshausen, Kiesgrube Lauter | 25       | Massy 151      | skeleton 2 | MAMS 21556    | 3288    | cal BC 1610–1530                 | cal BC 1623–1504                | 3.3  | 38.1 |
| Oberottmarshausen, Kiesgrube Lauter | 26       | Massy 141      | adult      | MAMS 21552    | 3297    | cal BC 1616–1530                 | cal BC 1681–1499                | 3.3  | 9.8  |
| Oberottmarshausen, Kiesgrube Lauter | 26       | Massy 141      | child      | MAMS 21553    | 3296    | cal BC 1615–1530                 | cal BC 1664–1498                | 3.3  | 37.9 |

(Continued)
Bz A2c, but it has meanwhile been dated to the beginning of the Middle Bronze Age (Bz B) by other authors [45], [17]. We agree with the Bz B date for this type of pin, also because the specimen dated by us was associated with a most characteristic Bz B dagger in one of the burials (Oberottmarshausen gr. 5). Therefore, we see the following pin types from our grave inventories as characteristic of Bz B:

- Lochhalsnadel type Paarstadl
- Dreiringnadel type Muschenheim
- Rollenkopfnadeln mit tordiertem Schaft

...but continue well into the later MBA [46].

We could date altogether 36 graves with Bz A1 pins, three graves with Bz A2 pins and five graves with MBA pin types (Fig 6).

Graves with Bz A1a pins are among the oldest EBA graves analyzed within our project (Haunstetten, Postillonstr. gr. 14). Several 2σ calibrated ranges start shortly after 2200 BC, but the 2σ calibrated range of most of these graves spans the second half of the 21st century and the complete 20th century BC. Therefore, we propose a period of deposition of these pins from ca 2150/2100 BC until 1900 BC for the Augsburg region. The 2σ calibrated ranges of the two type objects of Bz A1b start in the late 21st century BC (Wehringen, Hochfeld grave 7: 2030–1916).
BC with 95.4% probability). However, these pin types have a much longer period of use and were still deposited after 1900 BC and probably even until 1700 BC (e.g. Kleinaitingen, Gewerbegebiet Nord grave 10: 1883–1736 BC with 87.5% probability and 1716–1695 BC with 7.9% probability). It is clear that Bz A1a and Bz A1b are contemporaneous for around 150 years. Taken together, Bz A1 can be dated in the Augsburg region to the centuries between 2150/2100 and 1750/1700 BC.

The three dates with classical Bz A2 pin types (i.e. Bz A2a in the Ruckdeschel system) all from Kleinaitingen—were extremely similar with almost the same uncalibrated dates and indicate a deposition between ca 1900 BC and the years around 1700 BC. Compared with the Bz A1 dates, it seems that Bz A2 pins were worn and deposited contemporaneously with Bz A1b pins, whereas Bz A1a pins could have been replaced by Bz A2 types (Fig 7).

The oldest burial with type objects of Bz B (the first phase of the MBA) is Oberottmarshausen, grave 5 (1744–1598 BC with 84.0% probability and 1586–1533 BC with 11.4% probability). It contains a Lochhalsnadel type Paarstadl and a dagger with trapezoid hilt (i.e. [47]: series K34 or Q60). Therefore, it is most probable that the deposition of clear Bz B type objects started already in the 17th century BC in the Augsburg region. The other grave with a Bz B pin type, i.e. Oberottmarshausen grave 18, dates to the 17th or 16th century BC. However, the small number of graves with Bz B type objects does not allow further insights into the chronological position and duration of Bz B. Unfortunately, the Rollenkopfnadeln mit tordiertem Schafft are not of typological significance, as they start in Bz B (and in Switzerland even late in Bz A2; cf. [46]) and continue further into the MBA.

Considerations about the absolute dating of relative chronological phases and periods of depositions of diagnostic artifacts need to consider reservoir effects, which may have shifted the radiocarbon ages by several hundred years (Table 3). Overall, the 14C data of the bone collagen of the BBP burials and especially those who were associated with certain EBA pin types appear comparatively consistent [48], [49]. They lack outliers towards older dates, which may...
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Modelled date (BC)  Graphic: Ken Massy
have been caused by remarkable consumption of marine or freshwater food sources. This is in agreement with the stable carbon and nitrogen isotope ratios of bone collagen (Table 2). Despite the proximity of the Lech and Wertach Rivers, the δ¹³C values of between -21.3 and -19.8 ‰ and δ¹⁵N values of between 8.7 and 10.8 ‰ point to a predominance of terrestrial food sources, including crops as well as meat and dairy products of domestic animals. As to be expected for the inland location of the study area, there is no indication of any contribution of marine food sources. The data are also largely in agreement with previously investigated Final Neolithic to Early Bronze Age burials from southern Bavaria for which fish consumption was essentially excluded [50], [51]. Fig 8A illustrates the wide overlaps of the δ¹³C data of individuals of the BBP and those buried with diagnostic EBA pins (Fig 8). There is no correlation between old ¹⁴C ages and high δ¹⁵N or low δ¹³C values, which would indicate freshwater fish consumption [52]. The δ¹⁵N values of the individuals of the EBA shown in Fig 8B are more variable (range: 8.8–10.7 ‰) than those of the BBP which concentrate between comparatively low values of 8.7 and 10.0 ‰ (Fig 8). This pattern indicates that the older radiocarbon ages of the BBP burials are indeed due to their earlier calendaric age instead of resulting from extensive freshwater fish consumption. The light stable isotope ratios and ¹⁴C ages of the individuals buried with diagnostic Bz A1a and A1b pins overlap widely. Apparently independent of the ¹⁴C ages and grave goods, the δ¹⁵N and δ¹³C values tend to cluster by sites. Despite the very similar environmental conditions, this points to community-specific proportions of plant and animal-derived food and/or landuse and soil management, such as manuring [53], [54]. Overall, the light stable isotope ratios and the spread of the radiocarbon dates do not hint on possible overestimations of the periods of deposition of certain pin types due to different extents of reservoir effects among the investigated individuals.

To conclude: at least for the Augsburg region, our data propose an absolute date for Bz A from 2150/2100 BC until at least 1700 BC. Bz A1a and Bz A2a pin types indeed represent a sequence (Fig 7). It seems that the so-called Bz A1b pin types are used during the complete EBA and cannot be used for any chronological subdivision. Compared with the traditional dating of Bz A between 2300/2200 BC and 1600/1550 BC, our results imply a substantial narrowing of the duration of the Early Bronze Age from 750/700 years to possibly 450 years. The MBA, however, seems to start already in the 17th century. Therefore, even if we have not been able to date graves with Bz A2b or Bz A2c type objects, there is not much time for a continuation of Bz A into the 17th century, unless one supposes a period of overlap between Bz A and Bz B.

The cemetery of Singen

Our (re-)evaluation of 10 graves from Singen revealed surprising results (Fig 9). The original dating of five graves (80, 7, 79, 74, 63) (Table 4) was confirmed in our study. The re-dating of grave 68 has to be considered with caution. Although the C:N ratio points to a good quality of the extracted collagen, the overall amount of carbon in the sample (4.7%) is rather low and there still is a chance that not all conservation chemicals have been removed. Most interestingly, the three earliest dates of the original series, i.e. graves 65, 70 and 19, shifted to a much younger date. The reason for this discrepancy remains unclear. It is possible that curators treated some of the bones immediately after the excavation and before the first sampling for ¹⁴C analysis. It should be noted that for radiometric ¹⁴C dating in the 1980ies rather large quantities of bone (50 grams and more) were required, which severely limits selective sampling
to avoid contaminated bone. In contrast, the small sample size for AMS dating (typically 1 gram) allows for more rigorous sampling. In addition the ultrafiltration step in the AMS pretreatment sequence may have eliminated contamination more reliably. The observation that 5 out of 8 results agree well between the two techniques may in fact indicate the potential of contamination for the three older radiometric dates.

Our results force us to lower the starting point of the Singen cemetery from 2300 BC to 2200 BC at the earliest (with grave 63 as the oldest: 2200–2027 BC with 95.4% probability). It is even more likely that Singen rather started around 2150 BC (see sum calibration Fig 9). Excluding the unreliable result for grave 68, the latest 2σ calibrated ranges end around 1900 BC.

Comparison of Augsburg region, Singen and the Neckar region

Our new results from Singen fit very well to the results from the Augsburg region. The oldest dates from Singen (grave 63: 3712±1214C BP) and the Augsburg region (Haunstetten, Postillonstraße, grave 5: 3717±2314C BP) are almost identical as is the period of use of Singen and Haunstetten, Postillonstraße.

The dates for Bz A type objects from both regions provide a coherent view (Fig 6). The Ruderkopfnadeln (with small or large head) are identical in date and seem to have been used in both places at the same time. The much later date for Singen, grave 65, and the Ruderkopfnadel with large head from the grave fit perfectly to the time span for this type of pin from the Augsburg region. A difference can be seen in the early date for a Horkheimer Nadel from Singen, grave 79, which suggests a use of this type object in the 21st and possibly already in the late 22nd century BC, and, therefore, clearly earlier than in the Augsburg region. As the old dating of grave 79 was confirmed by the new measurement, the early position of this Horkheimer Nadel...
Table 3. Light stable isotope data of the burials of the BBP and those with diagnostic artifacts of the EBA. The data for the burials from Singen are adopted from [43].

| Name of site                  | GraveNo. after | GraveNo. feat. | Archaeological dating | Diagnostic artifact | % N| % C| C/N atom | δ13C (‰ VPDB) | δ15N (‰ AIR) |
|------------------------------|----------------|----------------|-----------------------|---------------------|----|----|----------|----------------|---------------|
| Augsburg, Hugo-Eckener-Straße| 1              | Kociumaka      | BBP                   |                      | 1.9| 11.3| 31.0     | -20.4          | 9.5           |
| Augsburg, Hugo-Eckener-Straße| 3              | Kociumaka      | BBP                   |                      | 1.2| 11.2| 30.9     | -21.0          | 9.3           |
| Augsburg, Hugo-Eckener-Straße| 5              | Kociumaka      | BBP                   |                      | 1.1| 16.5| 44.0     | -21.0          | 9.2           |
| Augsburg, Hugo-Eckener-Straße| 5              | Kociumaka      | BBP                   |                      | 1.6| 16.4| 43.9     | -20.8          | 9.0           |
| Augsburg, Hugo-Eckener-Straße| 6              | Kociumaka      | BBP                   |                      | 2.4| 13.3| 36.4     | -20.3          | 9.2           |
| Augsburg, Hugo-Eckener-Straße| 7              | Kociumaka      | BBP                   |                      | 0.9| 9.9 | 27.4     | -21.0          | 8.7           |
| Augsburg, Hugo-Eckener-Straße| 8              | Kociumaka      | BBP                   |                      | 1.6| 14.3| 38.7     | -20.4          | 9.4           |
| Augsburg, Hugo-Eckener-Straße| 8              | Kociumaka      | BBP                   |                      | 1.3| 14.0| 37.7     | -20.2          | 9.5           |
| Augsburg, Hugo-Eckener-Straße| 9              | Kociumaka      | BBP                   |                      | 2.1| 16.4| 44.3     | -21.0          | 9.5           |
| Augsburg, Hugo-Eckener-Straße| 10             | Kociumaka      | BBP                   |                      | 2.0| 14.4| 39.4     | -21.1          | 10.0          |
| Haunstetten, Unterer Talweg 58–62| 8             | Kociumaka      | BBP                   |                      | 2.1| 16.0| 43.9     | -20.4          | 9.8           |
| Haunstetten, Unterer Talweg 85| I/1            | Kociumaka      | BBP                   |                      | 3.1| 11.1| 30.5     | -20.0          | 9.1           |
| Haunstetten, Unterer Talweg 85| I/2            | Kociumaka      | BBP                   |                      | 3.3| 16.0| 40.2     | -21.0          | 9.5           |
| Haunstetten, Unterer Talweg 85| I/3            | Kociumaka      | BBP                   |                      | 2.7| 15.0| 38.3     | -20.5          | 9.3           |
| Haunstetten, Unterer Talweg 85| II/1           | Kociumaka      | BBP                   |                      | 2.6| 16.8| 46.0     | -20.3          | 9.4           |
| Haunstetten, Unterer Talweg 85| II/2           | Kociumaka      | BBP                   |                      | 1.4| 13.3| 36.5     | -20.5          | 9.8           |
| Königsbrunn, Ampack           | 1              | Kociumaka      | none                  | BBP                 | 1.6| 16.7| 45.2     | -20.1          | 9.5           |
| Wehringen, Hochfeld           | 14             | Ind. A Massy   | 1192 BBP              | Rudernadel w/ small head | 1.5| 15.6| 39.7     | -20.8          | 9.1           |
| Haunstetten, Postillionstraße| 14             | Massy          | 50 EBA                | Rudernadel w/ small head | 2.3| 16.4| 43.6     | -20.8          | 9.3           |
| Haunstetten, Postillionstraße| 19             | Massy          | 131 EBA               | Rudernadel w/ small head | 2.7| 15.4| 39.2     | -20.8          | 9.1           |
| Haunstetten, Unterer Talweg 58–62| 39            | Massy          | 21 EBA                | Rudernadel w/ small head | 2.5| 13.7| 37.7     | -20.9          | 8.9           |
| Königsbrunn, Obere Kreuzstraße| 15             | Massy          | 6 EBA                 | Rudernadel w/ small head | 2.2| 15.6| 39.5     | -20.4          | 10.1          |
| Königsbrunn, Obere Kreuzstraße| 23             | Massy          | 80 EBA                | Rudernadel w/ small head | 3.9| 16.8| 45.3     | -20.0          | 10.3          |
| Königsbrunn, Obere Kreuzstraße| 40             | Massy          | 81 EBA                | Rudernadel w/ small head | 4.3| 16.7| 45.3     | -20.0          | 10.2          |
| Singen, Nordstadtterrasse, Lessingstrasse| 19            | Krause         | 55/13 EBA             | Rudernadel w/ small head | 2.7| 15.5| 41.4     | -20.5          | 9.3           |

(Continued)
is beyond any doubt. Taking together the dating of the Horkheimer Nadel, shows a surprisingly long use of this particular type of pin, which spans a large part of the EBA.

Due to the lack of Bz A2 type objects at Singen, the cemetery does not allow further insights into the chronological sequence beyond Bz A1. However, Singen reconfirms the parallel existence of Bz A1a and Bz A1b.

The radiocarbon dates for the Neckar region around the city of Stuttgart (Fig 1) also match our results from Augsburg and Singen (Fig 10) [20]. Our new data show that the dates from

| Name of site                                      | GraveNo. after | GraveNo. | Feat. No. | Archaeological dating | Diagnostic artifact | % oll | N% | C% | C/N atom | δ13C (% VPBD) | δ15N (% AIR) |
|---------------------------------------------------|----------------|----------|-----------|-----------------------|---------------------|-------|----|----|---------|---------------|---------------|
| Singen, Nordstadtterrasse, Widerholltstrasse       | 74             | Krause   | 52/6      | EBA                   | Rudernadel w/ small head | 8.6  | 13.6 | 37.4 | 3.2 | -20.2 | 9.1 |
| Haustetten, Postillionstrasse                      | 12             | Massy    | 35        | EBA                   | Rudernadel w/ large head | 3.1  | 14.6 | 37.2 | 3.0 | -20.7 | 9.0 |
| Haustetten, Postillionstrasse                      | 30             | Massy    | 111       | EBA                   | Rudernadel w/ large head | 1.2  | 16.4 | 43.8 | 3.1 | -21.1 | 9.6 |
| Haustetten, Postillionstrasse                      | 41             | Massy    | 2         | EBA                   | Rudernadel w/ large head | 2.1  | 17.1 | 43.0 | 2.9 | -20.7 | 9.0 |
| Königsbrunn, Obere Kreuzstraße                     | 14             | Massy    | 5         | EBA                   | Rudernadel w/ large head | 2.7  | 14.3 | 37.5 | 3.1 | -20.2 | 10.0 |
| Singen, Nordstadtterrasse, Lessingstrasse         | 7              | Krause   | 55/24     | EBA                   | Rudernadel w/ large head | 2.2  | 12.4 | 40.3 | 3.8 | -20.9 | 9.7 |
| Singen, Nordstadtterrasse, Widerholltstrasse       | 65             | Krause   | 53/4      | EBA                   | Rudernadel w/ large head | 5.5  | 14.6 | 42.8 | 3.4 | -20.6 | 9.9 |
| Haustetten, Postillionstrasse                      | 8              | Massy    | 140       | EBA                   | Bone pin/boar tusk pin | 1.5  | 14.6 | 39.0 | 3.1 | -20.5 | 9.1 |
| Haustetten, Postillionstrasse                      | 16             | Massy    | 84        | EBA                   | Bone pin/boar tusk pin | 2.6  | 15.9 | 42.6 | 3.1 | -21.0 | 10.1 |
| Haustetten, Postillionstrasse                      | 36             | Massy    | 6         | EBA                   | Bone pin/boar tusk pin | 0.8  | 15.9 | 40.1 | 2.9 | -20.7 | 9.1 |
| Haustetten, Unterer Talweg 58–62                   | 4              | Massy    | 152       | EBA                   | Bone pin/boar tusk pin | 2.4  | 16.6 | 45.8 | 3.2 | -21.3 | 8.8 |
| Königsbrunn, Obere Kreuzstraße                     | 17             | Massy    | 50        | EBA                   | Bone pin/boar tusk pin | 1.4  | 16.6 | 45.0 | 3.2 | -20.4 | 9.3 |
| Königsbrunn, Obere Kreuzstraße                     | 25             | Massy    | 67        | EBA                   | Bone pin/boar tusk pin | 2.2  | 16.7 | 45.3 | 3.1 | -19.8 | 10.6 |
| Königsbrunn, Obere Kreuzstraße                     | 29             | Massy    | 93        | EBA                   | Bone pin/boar tusk pin | 5.7  | 17.0 | 45.3 | 3.1 | -20.6 | 9.8 |
| Königsbrunn, Obere Kreuzstraße                     | 39             | Massy    | 82        | EBA                   | Bone pin/boar tusk pin | 2.1  | 16.8 | 45.0 | 3.2 | -20.0 | 10.6 |
| Königsbrunn, Obere Kreuzstraße                     | 43             | Massy    | 86        | EBA                   | Scheibenkopfnadel     | 2.3  | 15.1 | 41.0 | 3.2 | -20.3 | 9.7 |
| Königsbrunn, Obere Kreuzstraße                     | 46             | Massy    | 85        | EBA                   | Scheibenkopfnadel     | 5.6  | 16.2 | 46.1 | 3.1 | -20.4 | 10.4 |
| Wehringen, Hochfeld                                | 6              | Massy    | 1380      | EBA                   | Schleifenkopfnadel    | 1.6  | 11.7 | 32.2 | 3.2 | -20.78 | 9.98 |
| Wehringen, Hochfeld                                | 8              | Massy    | 1586      | EBA                   | Schleifenkopfnadel    | 4.1  | 16.4 | 44.9 | 3.2 | -20.16 | 10.66 |
| Wehringen, Hochfeld                                | 3              | Massy    | 1564      | EBA                   | Horkheimer Nadel      | 6.5  | 17.2 | 45.7 | 3.1 | -20.78 | 10.49 |
| Wehringen, Hochfeld                                | 7              | Massy    | 1474      | EBA                   | Horkheimer Nadel      | 5.5  | 17.1 | 46.8 | 3.2 | -20.95 | 10.65 |

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the Neckar region do not contradict the chronological development as has long been assumed but fit very well into the overall picture.

There are only three graves with Bz A pins which were dated by the radiometric technique. In the Neckar region, two ^14C dated graves contain Bz A1 type objects, i.e. a Scheibenkopfnadel or Ruderkopfnadel (Gäufelden, grave 1, individual 2; Remseck-Aldingen, Halden II, gr. 15); however, in both cases the state of preservation does not allow a further taxonomic identification of the pins which can, therefore, be attributed either to Bz A1a or Bz A1b following the Ruckdeschel system. The related 2σ calibrated ranges (Gäufelden, grave 1, individual 2: 1882–1747 BC with 95.4% probability; Remseck-Aldingen, Halden II, gr. 15: 1936–1746 BC with 95.4% probability) fit into the long time span for Bz A1 type objects between 2150 BC and 1700 BC.

The third burial, Rottenburg, Herderstraße, grave 1, contained a singular type of pin which does not appear in the Ruckdeschel system, but which Rüdiger Krause proposes to relate to Bz A2 shapes [25]. Due to the significant standard deviation, this old date (2137–1768 BC with 95.4% probability) does not contribute to a better understanding of the EBA chronology as it spans almost the complete EBA.

To conclude: the few radiocarbon dated burials with Bz A type objects are consistent with the late Bz A1 dates from Augsburg.

Discussion

Given our results from Augsburg, we can contribute to the long-standing discussion on the transition from the LN to the EBA in Central Europe. For eastern Germany, Johannes Müller [55] postulated a co-existence of LN and EBA groups for at least 150 years. Regarding southern Germany, Volker Heyd [56] already postulated a transition from the LN to EBA without any overlap around 2150/2100 BC, however, on the basis of only a small number of radiocarbon dates from Late Neolithic burials. Our data confirm that there is neither a significant gap nor long overlap between both periods. The radiocarbon dates from the cemeteries of Augsburg, Hugo-Eckener-Straße, and Haunstetten, Postillonstraße clearly show a succession from latest LN to earliest EBA burials shortly after 2150 BC. This fits very well to recent radiocarbon dates for the Bell Beaker settlement of Engen-Welschingen, Guhhaslen, and its relation to our new dates for nearby Singen: the 2σ calibrated ranges of the three dates from Welschingen fall between 2490 BC and 2110 BC [57] and the EBA at Singen probably does not start before 2150 BC.

In summary: a very short overlap or gap between the LN and the EBA in southern Germany is possible, but a smooth transition seems more plausible.

Our results fundamentally question the absolute and relative chronology of the EBA and its inherent notion of a linear and gradual development for southern Germany. Since Paul Reincke [3] the subdivision of the EBA into the phases Bz A1 and Bz A2 was explained with the growing ability to manage the new bronze technology. Almost all further chronological discussion has kept the view of a gradual development of the technology from bone and boar tusk pins to the first hammered metal objects–consisting mostly of copper with hardly any tin–in Bz A1 up to perfectly alloyed bronze with 90% of copper and 10% of tin and refined casting techniques in Bz A2 [14], [15]. With this in mind, a sequence of pin types was proposed which
Fig 9. Plot of old (grey) and new (black) radiocarbon dates from the cemetery of Singen. The sum calibration is shown on top.

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again was taken as a basis for socio- and cultural-historical interpretation. It was taken for granted that the duration of use and deposition of each type was rather restricted to a short period of time. Simultaneously, it was assumed that the similarity of particular types of pins also indicates contemporaneity.

The results from the Augsburg region and Singen both refute a any linear and gradual development and rather indicate very different dynamics in the late 3rd and early 2nd millennium. The sequence of pins is far more complex than proposed. Bone and boar tusk pins are not amongst the earliest EBA pin types and probably continue into the early 19th century BC in the Augsburg region. Pin types defined as Bz A1a by Ruckdeschel [15] indeed start with the beginning of the EBA—but so do also the pins of his sub-phase Bz A1b, which he supposed to succeed Bz A1a. Whereas the Bz A1a pin types indeed end around 1900 BC, Bz A1b pin types continue until the end of the EBA around 1700 BC (Fig 6), (Fig 7). In contrast to the dominant notion of research, Bz A2 pins do not replace the simple hammered pins of Bz A1. This is most obvious in Kleinaitingen, where Bz A1b and Bz A2a pins were deposited in contemporaneous burials. Bz A2a type objects start around 1900 BC and are used and deposited parallel to Bz A1b pin

Table 4. Burials from Singen with old and new radiocarbon dates (na = not analyzed).

| Name of site                          | GraveNo. after | GraveNo. Feat. No. | LaborNo. | C14 Age ± | Cal 1 sigma | Cal 2 sigma | C: N % | LaborNo. (from year 1988) | C14 Age (from year 1988) ± |
|---------------------------------------|----------------|--------------------|----------|------------|-------------|-------------|--------|--------------------------|---------------------------|
| Singen, Nordstadtterrasse, Goethestrasse | 63             | Krause 52/5 MAMS 21968 | 3712 29  | cal BC 2188–2039 | cal BC 2199–2028 | 3.1 36.6 HD—10692 | 3655 35 |
| Singen, Nordstadtterrasse, Lessingstrasse | 7              | Krause 55/24 MAMS 21974 | 3662 21  | cal BC 2123–1980 | cal BC 2133–1959 | 3.1 6.6 HD 8972–9116 | 3679 42 |
| Singen, Nordstadtterrasse, Lessingstrasse | 19             | Krause 55/13 MAMS 21967 | 3700 30  | cal BC 2136–2036 | cal BC 2197–1981 | 3.0 30.0 HD 8973–9117 | 3756 60 |
| Singen, Nordstadtterrasse, Widerholtstrasse | 65             | Krause 53/4 MAMS 21975 | 3620 22  | cal BC 2022–1947 | cal BC 2035–1910 | na na HD 8974–9155 | 3847 43 |
| Singen, Nordstadtterrasse, Widerholtstrasse | 68             | Krause 52/19 MAMS 21973 | 3537 22  | cal BC 1920–1783 | cal BC 1941–1774 | 3.3 4.7 HD 8975–9145 | 3651 43 |
| Singen, Nordstadtterrasse, Widerholtstrasse | 69             | Krause 52/17 MAMS 21976 | 3686 21  | cal BC 2131–2033 | cal BC 2139–1982 | 3.3 24.0 na na na | |
| Singen, Nordstadtterrasse, Widerholtstrasse | 70             | Krause 52/14 MAMS 21969 | 3604 29  | cal BC 2016–1922 | cal BC 2029–1892 | 2.9 25.3 HD 8978–9157 | 3766 37 |
| Singen, Nordstadtterrasse, Widerholtstrasse | 74             | Krause 52/6 MAMS 21972 | 3632 21  | cal BC 2025–1963 | cal BC 2116–1926 | 3.1 17.7 HD 8976–9129 | 3638 44 |
| Singen, Nordstadtterrasse, Widerholtstrasse | 79             | Krause 50/14 MAMS 21970 | 3688 29  | cal BC 2134–2032 | cal BC 2194–1977 | 3.0 25.4 HD 8971–9115 | 3677 44 |
| Singen, Nordstadtterrasse, Widerholtstrasse | 80             | Krause 50/16 MAMS 21971 | 3641 29  | cal BC 2106–1952 | cal BC 2132–1922 | 3.0 31.8 HD 8970–9147 | 3690 46 |
| Singen, Nordstadtterrasse, Widerholtstrasse | 82             | Krause 50/21 na na na na na na | | | | | |

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Fig 10. Sum calibrations of cemeteries from south Germany. Dates made in our project are marked in black.

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types until 1700 BC. However, it has to be kept in mind that we were not able to date type objects of Bz A2b and Bz A2c, which might indicate a continuation of the EBA after 1700 BC. Therefore, the traditional notion of the sequence of Bz A1 and Bz A2 and the associated idea of the development from simple hammered pins ("Blechkreis") to complex cast pins have to be revised.

Our data also shed new light on the transition from the EBA to the MBA. Up to now, a start of the MBA in Southern Germany around 1550 BC has been taken for granted (i.a. [21], [24]). So far, we have only five radiocarbon dated graves with MBA type objects from the Augsburg region, two of which can securely be attributed to the earliest MBA (Bz B) on the basis of particular types of pins. It seems that the MBA at least in the Augsburg region started significantly earlier than it has been proposed so far as the 2σ calibrated range of the Bz B inventory from Oberottmarshausen, grave 5, mostly falls into the 17th century BC. If such an early start of the MBA could be demonstrated on a larger basis of analyses, this would have a major impact on historical narratives in Central Europe. Such a re-dating would solve the problem that at this point the Central European MBA seems to be a rather short period regarding the fundamental social changes which took place. Moreover, the deposition of the Nebra hoard (1639–1401 BC with 95.4% probability) [58] and the related dating of the Apa horizon (with two swords of Apa type in the Nebra hoard) would then be contemporaneous with the MBA. However, only more radiocarbon dated Bz B graves will allow us to better determine the chronological position of this phase.

The contemporaneity of Bz A1 and Bz A2a as well as the small number of Bz A2 pins in the Augsburg region and in southern Germany as a whole raise the question, how to explain the appearance of these bronzes in this larger region. It seems that Bz A2a objects, most of which are related to the Únětice culture, should be interpreted as the appropriation of foreign influences and objects in southern Germany, which basically "stayed Bz A1" during the complete EBA. The Bz A2a Únětice bronzes could rather be seen as supplement to the local inventory of the material culture.

Moreover, it is most likely that Bz A2 in the area of the Únětice culture started considerably earlier than in the Augsburg region. An early start for Bz A2a already in the late 3rd millennium or at least around 2000 BC is indicated by Quenstedt, grave 34, a grave from Feuersbrunn and possibly also hoard II of Melz (cf. also the princely grave of Leubingen with a dendrodate of 1942±10 BC [23]). However, the rarity of metal objects as grave goods in the Únětice region poses a serious problem to a better understanding of the chronological development of the Únětice culture. Bz A1 bronzes are extremely rare in this area. Bz A2a type objects continue at least until the late 18th century BC (cf. [59]: Prag-Miškovice, grave 32: Ösenkopfnadel, 1950–1740 BC with 95.4% probability), where they sometimes appear contemporaneously with Bz A1 pin types in the same cemetery (cf. [59]: Prag-Miškovice, grave 18: Schleifenkopfnadel, 1970–1740 BC with 95.4% probability). This could indicate a very similar situation to what we are able to document in the Augsburg region.

Conclusions
For almost a hundred years, Early Bronze Age chronology has been dominated by an evolutionist paradigm that assumed a linear development from simple to elaborate bronze objects, whose chronological placement was based on a small number of radiocarbon dated burials since the 1980s. With a large corpus of new radiocarbon dated Late Neolithic, Early and Middle Bronze Age graves from the Augsburg region, we were able to shed new light on the cultural dynamics in the late 3rd and first half of the 2nd millennium BC.
We have demonstrated that the transition from the LN to the EBA happened without a significant gap or overlap in southern Germany around 2150 BC. Our results suggest that the time span of the EBA has to be shortened from conventionally postulated around 750/700 years to only about 450 years—starting from 2150 BC to at least 1700 BC. During the complete span of time, so-called Bz A1 pin types were used and deposited. More complex objects dated to Bz A2 appear around 1900 BC for the first time. Therefore, we do not see any transition from Bz A1 to Bz A2 in the way it has been proposed for the last 100 years. Our data show a complex coexistence of different types as well as simple and sophisticated shapes of bronze objects. We propose that Bz A1 and Bz A2 should not be understood as a chronological sequence even beyond southern Germany. In our view, Bz A1 and Bz A2 are nothing more than the consequence of different rates of appropriation of bronze technologies in southern Germany (= Bz A1) and the region of the Únětice culture in eastern Germany, Bohemia, Moravia, western Poland and parts of Slovakia and Austria (= Bz A2).

In summary, Bz A1 and Bz A2 seem to appear as different levels of ability and willingness to appropriate the new bronze technology and the non-technological knowledge transferred together with the technological knowledge. Bz A1 and Bz A2 do not represent chronological but rather regional phenomena. Bz A2 finds in southern Germany and Bz A1 finds in the area of the Únětice culture should be explained as the local appropriation of foreign objects rather than autonomous chronological phases.

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Author Contributions
Performed the experiments: BK SL CK RF. Analyzed the data: PWS KM FW CK. Wrote the paper: PWS KM BK CK JK RF. Designed the figures: JR.

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