Abhandlung

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Digging up the plague: A diachronic comparison of aDNA confirmed plague burials and associated burial customs in Germany

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Zusammenfassung: Vergangene Pestepidemien wurden vor allem in schriftlichen Quellen überliefert; insbesondere die Justinianische Pest des frühen Mittelalters und der Schwarze Tod des späten Mittelalters wurden dort in lebendigen Farben beschrieben. Vor der Einführung der aDNA-Analyse war es aber oftmals schwierig, archäologische nachgewiesene Bestattungen eindeutig der Pest zuzuweisen – vor allem in Gegenden, wo schriftliche Überlieferungen, die die Pest erwähnen, fehlen. Die Analyse alter DNA erlaubt es nun, die Opfer der Pest eindeutig im archäologischen Befund zu identifizieren. In diesem Artikel sollen daher die ersten bekannten Beispiele von durch aDNA-Analyse bestätigten Pestgräbern aus Deutschland aus dem frühen Mittelalter, dem späten Mittelalter und dem 30-jährigen Krieg präsentiert und mit einander verglichen werden.

Dieser Beitrag soll zudem ein Plädoyer für eine differenzierte Sicht auf die mit der Pest assoziierten Grab- und Bestattungssitten sein, insbesondere, wenn mehr als ein Pestopfer zusammen in einem Grab bestattet wurden. Zudem soll aufgezeigt werden, welche möglichen Rückschlüsse von durch aDNA-Analyse bestätigte Pestgräber auf die unterschiedlichen Strategien gezogen werden können, die die vergangenen Gesellschaften verfolgten, um mit Katastrophen wie einer Epidemie umzugehen.

Schlüsselworte: aDNA, Yersinia pestis; Justinianische Pest; Schwarzer Tod; 30-jähriger Krieg; Massengräber; Mehrfachbestattungen; Deutschland

Résumé: Les épidémies de peste d'autrefois furent surtout transmises à travers les écrits. Ce sont particulièrement la peste de Justinien du haut Moyen Age et la Peste noire du bas Moyen Age qui firent l'objet de récits hauts en couleur. Cependant, l'attribution à la peste de sépultures identifiées par l'archéologie était souvent difficile avant l'introduction de l'analyse de l'ADNa – surtout dans les régions dépourvues de sources écrites mentionnant la peste. L'analyse d'ADN ancien permet maintenant d'identifier avec certitude les victimes de la peste dans un contexte archéologique. Cet article voudrait donc présenter les premiers exemples connus en Allemagne de tombes de pestiférés du haut Moyen Age, du bas Moyen Age et de la guerre de Trente Ans vérifiées par l'analyse de l'ADNa, et qui seront comparées les unes aux autres. Cette contribution voudrait plaider pour une approche différenciée des rites funéraires, particulièrement lorsque plusieurs pestiférés furent ensevelis dans la même tombe. On veut en outre montrer les conclusions possibles, qui peuvent être tirées à partir des tombes de pestiférés identifiées par l'analyse de l'ADNa, pour les différentes stratégies suivies autrefois par les sociétés en vue de gérer des catastrophes comme les épidémies.

Mots-clés: ADNa; Yersinia pestis; peste de Justinien; Peste noire; guerre de Trente Ans; fosses communes; sépultures collectives; Allemagne

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Abstract: Plague outbreaks in the past are mainly known from written sources; in particular, the Justinianic Plague of the Early Middle Ages and the Black Death of the Late Middle Ages have been described in vivid detail. Yet prior to the introduction of aDNA analysis, it was often quite difficult to associate burials with plague beyond doubt – especially in areas where written evidence of the plague is scarce. As analysis of ancient DNA now allows the detection of plague victims in the archaeological record, new ways are being developed for combining archaeological, historical and ancient DNA research. In this paper we would like to present and compare known examples of plague graves from the Early Middle Ages, the Late Middle Ages and the Thirty Years' War in Germany that have also been confirmed by ancient DNA analyses. We would like to argue for a differentiated view of the burial customs, especially when more than one plague victim shared a grave, and would like to show possible conclusions, drawn from the aDNA-confirmed plague burials, that can indicate the different strategies adopted by ancient societies to deal with catastrophic events like a pandemic disease.

Keywords: aDNA analysis; Yersinia pestis; Justinianic Plague; Black Death; Thirty Years' War; mass graves; multiple burials; Germany

Introduction: Plague in history

"Plague, as any disease, has both a biological as well as a social dimension. To address its social component, we need to examine such aspects as popular perception and response as well as the effects that the pandemic had" as plague historian Dimitrios Stathakopoulos has remarked[1]. This is true of all historically known plague outbreaks, from the initial irruption of the Justinianic Plague in 541 AD to the epidemic that killed roughly 70 people in Madagascar in December 2016. In case of the Early Medieval outbreak, the plague spread according to the written sources within a few years through the world as it was known at that time, and reappeared in at least 18 waves until 750 AD[2]. Classically, the Justinianic Plague is considered as the first of three plague pandemics: The second one, the so called "Black Death", rose in Central Asia in the 1330s, reached Crimea in 1346 AD and spread from there over vast parts of Europe, where it reappeared regularly until 1815[3], inter alia during the Thirty Years' War[4]. The third pandemic ("Hong Kong Plague") broke out in China in the 1850ies and arrived in Hong Kong in 1894. From there, it spread out to other regions of Asia, Africa, the Americas and Australia[5] and lasted until 1914[6]. Even nowadays plague remains endemic in several natural foci around the world[7]. However, recent anthropological and microbiological research revealed that the plague bacterium affected humans also long before this historically known pandemics, and can be detected in Bronze Age burials as well[8]. Plague is more than a disease: it also stands for the frightening terror people associate with epidemic disease outbreaks. Even today the rumours of plague infections can lead people leaving their homes and fleeing the region, as happened 1994 in India – although the plague is today curable by antibiotics[9].

Besides historical sources, plague can be tracked by archaeological as well as by palaeogenetical approaches. In this article, we will focus on burial sites of a limited geographic area located in present-day Germany where the plague has been detected by the use of aDNA analysis (tab. 1; fig. 1). By combining the data from aDNA and the archaeological record it is possible to gain insight into the varying mortuary practices during the historic pandemics, the "Justinianic Plague" and the "Black Death", and their following epidemic outbreaks[10].

Epidemic events can lead to different ways of treating the sick and the dead. In this article, we will argue for a

1 Stathakopoulos 2007, 105.

2 Little 2007a, 3–7; Stathakopoulos 2007, 100. In this article, we can only introduce the first two pandemics shortly, for an overview over research to the Justinianic plague see for example Little 2007b. A maps that shows the known outbreaks of the Justinianic plague according to written evidence can be found for example in Rosen 2006, 220.

3 According to Samuel K. Cohn, the last attack of the second pandemic in Europe occurred in 1815 in Noja (Noicattaro), near Bari, Italy: Cohn 2008, 74.

4 Keil 1989, 117. For an overview over the research on the Black Death and the second pandemic, see for example Bergdolt 1994, Benedictow 2004, Nutton 2008a and b, Green 2015. In general, it seems that more research was conducted on the second pandemic than on the first one: Cf. Schamiglou 2016, 295.

5 Seifert 2014, 16–17.

6 Little 2007a, 5–6.

7 Tikhomirov 1999.

8 Rasmussen *et al.* 2015 detected *Y. pestis* DNA in burials from Bronze Age Eurasia. However, this old version of the bacterium might only have been able to transmit between humans, and might have been missing the ability of transmission trough fleas: Cf. Spyrou *et al.* 2016; Zimbler *et al.* 2015.

9 Meier 2009, 178–180.

10 Interdisciplinary research, however, does not only promise interesting results, but needs also a theoretical framework how to combine different categories of sources. We are aware of this, but exploring and discussing such a framework was not the purpose of this article. For general discussions, see e. g. Andrén 1998 or Meier/Tillessen 2011.

Fig. 1: The archaeological sites presented in this study. Drawing: Sabine Peisker, Ludwig-Maximilian's-University Munich, Institute of Pre- and Protohistoric Archaeology and Archaeology of the Roman Provinces

careful and close investigation of graves of aDNA-proven plague victims, and to give a closer definition of this kinds of graves. We would like to argue for a distinction of graves with two or more burials between *multiple graves* and *mass burials* by the way the death were handled and placed in the grave, and to argue for the way of handling the death being a reflection of how a society reacted to a cathastrophic event like a plague outbreak.

Plague detection via ancient DNA

The way people are infected by the plague bacterium *Yersinia pestis* (henceforth *Y. pestis*) was only understood during the third pandemic. In 1894, Alexandre Yersin successfully isolated the bacterium that caused this disease, and in 1898 Paul-Louis Simond revealed the connection between *Y. pestis*, fleas and rats[11]. The plague is a zoonotic disease that circulates mainly in fleas on small, wild living rodents. If a rodent population that lives near or in human settlements gets infected by the plague and many of the rodents die, the fleas start searching for new hosts and move on to humans. More recent research, however, also discusses the possibility of direct human to human infections during the first two pandemics by an insect ectoparasite vector like the human flea or the human louse[12].

When the bacterium enters the human body by way of flea bites, *Y. pestis* attacks the lymphatic system, undergoes mass reproduction and spreads through the lymphatic system until it reaches a lymph node, where it stimulates an infection expanding the lymph nodes and thus produces the characteristic "bubo". This bubonic plague often leads to septicemic plague, in which the bacteria enter the bloodstream and thus infect the whole body. Pneumonic plague can develop if the pathogen spreads to the lungs. In this form, the pathogen can also be transmitted from person to person by droplet infection, resulting in so-called primary pneumonic plague, where only the respiratory system is affected[13].

Plague kills rapidly, normally within two weeks. Bones on the other hand react slowly on environmental impulses. Therefore, plague does not appear to affect bone, and thus cannot be identified morphologically on skeletal remains. However, the causing bacterium *Y. pestis*, like all other living organisms, carries DNA as genetic material. That is why an approach to diagnose plague is offered by DNA analysis on putative plague victims in question. Pathogen DNA can possibly be detected in the relicts of the victim, just like the individual's DNA itself.

When the infected individual dies of septicemic plague, the bacterium dies with them. The DNA of *Y. pestis* is released during the decomposition process and can be preserved alongside the DNA of the human host in their bones and teeth since skeletal material is known for its ability to bind DNA molecules[14]. However, most plague detection attempts using ancient DNA are carried out on teeth because of their protection against external contamination and durability. As it is crucial for every single research on ancient DNA, the detection of ancient plague DNA has to be carried out in a specialized aDNA laboratory using precautions avoiding cross-contamination and false positive results.

The main DNA of *Y. pestis* is preserved in one big molecule – the chromosome. Furthermore, *Y. pestis* contains three plasmids, small circular DNA molecules, which do

11 Little 2007a, 5–6.

12 Hufthammer/Walløe 2013.

13 Poland/Dennis 1999.

14 Grunenwald *et al.* 2014

not exist just in one but in a large number of copies. Two of them (pPCP1 and pMT1) are not carried by other *Yersinia* species and are therefore specific particularly for *Y. pestis*. One of these plasmids, the pPCP1-molecule, is normally the primary target when searching for *Y. pestis* DNA because of both its specificity for *Y. pestis* and its high copy number, which makes it statistically more likely to survive decomposition[15]. If a part of its unique DNA sequence is found in human skeletal remains, it can be considered as a strong evidence of a *Y. pestis* infection of the individual – and as the bacteria and therefore the infection were still massive when the individual died, the plague was most likely also the reason for the death.

Due to the characteristics of aDNA, it is to be expected that plague DNA cannot be found in every sample of the same plague positive individual as it has been observed earlier[16]. This phenomenon might be explained by low DNA-template numbers, which do not allow for catching the respective molecules in every attempt of detection.

Moreover, one should keep in mind that a negative test result does not exclude an infection with *Y. pestis* but can also be explained by insufficient DNA preservation. It is also conceivable that *Y. pestis* DNA is only detectable in victims who suffered from forms of plague which include bacterial mass invasion into the blood stream. It is e. g. rather unlikely that victims of primary pneumonic plague, which is only affecting the respiratory system and not the whole body, are detectable by DNA tests. This might also be the explanation for the observation that normally just a few of several individuals buried together in one grave give positive results of plague DNA. One has to assume that the other individuals which have been laid down simultaneously with the plague positive individuals most probably died of the same cause, which is, however, not detectable anymore. Additionally, if an individual is tested positive, it has to be assumed that plague should have been the cause of death because it is rather unlikely (but admittedly not impossible) that a person carrying the highly lethal plague bacterium dies of another reason. An individual who survived the disease and dies at a later point in time does not carry the bacterium or traces thereof any longer.

The biomolecular testing for infectious pathogens in human remains cannot only contribute to the determination of the individual's cause of death, thereby documenting the occurrence of an epidemic in a population, but the DNA molecule contains information itself. For example, it has been proven by its DNA sequence that the Justinianic Plague bacterium had its genuine origin in Asia and not in Africa as previously assumed[17].

Archaeological sites from Germany with molecular proofs of plague infections

It might be difficult to identify plague graves in the archaeological record, especially when complementary written sources, inscriptions or similar evidence are missing. Mass graves or multiple burials, on the one hand, can be caused by many reasons; only one of them might be a disease with high mortality as the plague[18]. On the other hand, especially in the beginning and the end of a disease, the number of deaths is not that high that necessarily mass graves had been created[19]. Therefore, in most cases only the analysis of ancient DNA can identify the cause of death, and proof the deceased as victims of the plague.

With this study, we discuss and compare diachronically four archaeological sites from Germany where the DNA of *Y. pestis* and therefore the plague was detected palaeogenetically (tab. 1). These are on the one hand graves from two cemeteries of the Early Medieval period from the Munich Gravel Plain, Aschheim-Bajuwarenring and Altenerding/Klettham, where victims of the Justinianic Plague had been buried. On the other hand, these are the Late Medieval mass grave from Manching-Pichl, Upper Bavaria, and an Early modern period multiple burial from the cathedral area from Brandenburg city, Brandenburg, in the northeast of Germany, which can most likely both be associated with the Black Death. Whereas the biological results for the cases had been published elsewhere[20], the focus of this paper will be on the discussion of the burial customs, and the different ways the contemporary society chose to deal with the late victims of the plague.

15 e. g. Raoult *et al.* 2000.

16 e. g. Hänsch *et al.* 2010; Harbeck *et al.* 2013.

17 Harbeck *et al.* 2013; Wagner *et al.* 2014. See also Haensch *et al.* 2010 or Bos *et al.* 2011 for molecular information about the Black Death. However, in historical research, e. g. Peter Sarris still assumed an African origin of the Justinianic Plague, while George Sussmann recently argued against it: Sarris 2002; Sussmann 2016.

18 e. g. Schneider 2008; Castex 2008, 23–24. Especially mass graves or multiple burials caused by war or massacre could be identified by violent traumata at the skeletons, while mass graves or multiple burials without indicate more an epidemic disease as reason for the simultaneous burials: Cf. Castex/Kacki 2016.

19 Castex 2008, 29–30. See also Castex/Kacki 2016.

20 Garrelt/Wiechmann 2003; Wiechmann/Grupe 2005; Harbeck *et al.* 2013; Wagner *et al.* 2014; Wiechmann *et al.* 2013; Seifert *et al.* 2013; Seifert *et al.* 2016.; Feldman *et al.* 2016.

Tab. 1: Summary of the presented archaeological sites with aDNA of *Y. pestis*

Period	Archaeological Site	aDNA Data published by	Tested individuals (positive results)
Early Medieval	Aschheim-Bajuwarenring (Bavaria)	Garrelt/Wiechmann 2003 Wiechmann/Grupe 2005 Harbeck *et al.* 2013 Wagner *et al.* 2014	19 (9)
Early Medieval	Altenerding/Klettham (Bavaria)	Feldman *et al.* 2016	20 (2)
Late Medieval	Manching-Pichl (Bavaria)	Garrelt/Wiechmann 2003 Wiechmann *et al.* 2013 Seifert *et al.* 2016	43 (12)
Thirty Years' War	Brandenburg City (Brandenburg)	Seifert *et al.* 2016	3 (3)

Example 1: Justinianic Plague

Until recently, the "Justinianic Plague" was only known from written sources. Most of these are literary texts; antique medical texts are remarkably silent[21]. To understand the effects of this pandemic, historical research used the contemporary literary texts, mostly originating in Mediterranean urban contexts, which draw a quite dramatic picture of it. According to Peter Sarris they "speak with one voice in describing the plague as having had a major demographic impact on communities urban and rural alike"[22]. For example, Procopius writes: "[...] And at first the deaths were a little more than the normal, then the mortality rose still higher, and afterwards the tale of dead reached five thousand each day, and again it even came to ten thousand and still more than that [...]"[23].

Within historical research, there were only some critical remarks on this widely accepted view on the Justinianic Plague that was provided through the contemporary narrative sources[24], even though they are characterized as "hysterical in tone"[25]. Scholarly interest for the Justinianic Plague first arose in the middle of the 19th century, together with a general interest in epidemics in the past, which came under the impression of the cholera outbreaks in Europe in the 1830s and 1840s[26]. This historical research was carried out before the plague bacterium *Y. pestis* was isolated and described for the first time in 1894 and also before the disease's propagation mechanism was discovered and understood. It is remarkable though that the view on and the perception of the Byzantine written sources didn't change much with this progress of medical research[27].

It is also remarkable that the ideological and historical background on which the Byzantine authors wrote their texts was usually not taken into account. As Jo N. Hays states, diseases are both biological entities and social constructs[28]. The Byzantine written sources on the Justinianic Plague were written in a background of early Christianity, where the *Parousia*, the return of Christ, was expected. Natural catastrophes as well as diseases were believed to be the first signs of this expected end of the world – what explains the drastic pictures the authors drew of the Justinianic Plague[29]. Written sources mentioning the plague from other parts of the Early Medieval World were much less taken into account, even though they come from a more rural environment, also more comparable to the circumstances of the below discussed Early Medieval Plague graves[30].

So far, only few *non*-written sources had taken the effects of the Justinianic Plague on the societies into

21 Meier 2009, 180.
22 Sarris 2002, 172. An overview over the written sources can be found in Little 2007a, 7–15
23 Procopius, De Bello Persico II 23, 2–3.
24 E. g. Stathakopoulos 2000; Sarris 2002; Meier 2009.
25 Sarris 2002, 173.
26 Besides historical interest on the topic, the authors of the first publications on the plague also needed to argue for an improved interest of officials and politicians in epidemic research. Especially Justus Friedrich Carl Heckers work was "[...]a plea for the importance of the new epidemiology in modern medicine" (Nutton 2008, 3; Hecker 1832).
27 Stathakopoulos 2000, 257–259.
28 Hays 2007, 33.
29 Hays 2007; Meier 2004.
30 See for example Maddicott 1997.

account[31]. For example, Jean Durliat used a wide range of sources – inscriptions, papyri, coins, archaeological finds, legislation – in addition to the historical Byzantine writings, and tried to de-emphasise the catastrophic role that the disease allegedly played in the demographic and economic field[32]. According to Stathakopoulos, Durliats work is "an attempt to show the discrepancy between the information provided by some Byzantine authors and that gained through the modern quantitative analysis of other sources"[33]. In addition, it should be taken into account that the written sources often came out of an urban context, and we know few about the distribution of the plague in rural areas where historical tradition starts in later times. Therefore, Durliat describes the Justinianic Plague mainly as an urban phenomenon[34]. This was substantiated by Clive Foss, who pointed out for Late Antique Syria that the archaeological evidence and a combined re-evaluation of the literary sources "[...] suggest that it [the plague] was not such a widespread disaster as it has been portrayed, and especially that it was not the agent of fundamental change"[35]. From an archaeological point of view, this has been supported by a compilation of mass graves from the Mediterranean, which can be dated to the later 6th and 7th century[36].

Furthermore, since the Justinianic Plague was mostly identified through written sources, it was not known if or how far the disease was spread to the countryside, from where we have little or no written evidence. Here, aDNA analysis of archaeologically known burials provide another source for research on the Justinianic Plague, which was so far surprisingly little used.

Plague graves in Early Medieval Cemeteries

Even though we do not know mass graves as usually associated with plague outbreaks from the Early Medieval countryside in today's Germany, double and multiple burials are widely known from Merovingian cemeteries[37]. They are now and then occurring on regular cemeteries, but are also part of separate cemeteries and farmyard burials. The reasons, why two or more persons had been buried at once had also been widely discussed, and different reasons had been taken into account. Among those are personal connections, like relationship, friendship or allegiance, simultaneous death in war or in another violent event, the need to wait for the burial until the freezing season is over, shortage of space at the cemeteries, and, last but not least, diseases[38].

The slightly higher rate of double and multiple burial in the cemetery of Aschheim-Bajuwarenring[39], and the absence of lethal injuries in these burials[40] leads to the question, if disease might have been the reason for this higher mortality rate, and if so, which. In 2005, *Y. pestis* was detected first in this cemetery's grave 166/167, a richly equipped double burial of a juvenile and a middle-aged woman, who were according to DNA-analysis relatives, most likely mother and daughter[41]. In the following years, some more double and multiple burials from Aschheim-Bajuwarenring were palaeogenetically analysed. So far, 19 late individuals out of 12 graves had been analysed, and 9 victims of the plague are by detection of *Y. pestis* DNA confirmed (tab. 2). There are no archaeological indications that these people died of the plague. The burials were laid out in traditional Merovingian fashion, with the deceased laid out on the back, carefully dressed and equipped with personal equipment and other grave goods. In fact, some of the richest of the 444 known burials from Aschheim-Bajuwarenring were found among the plague graves.

But Aschheim-Bajuwarenring was not the only early medieval cemetery of the Munich Gravel Plain where victims of the plague were buried. Two more had been detected by aDNA analysis in the cemetery of Altenerding/Klettham, approx. 25 km northeast of Aschheim (tab. 3). Also here, the confirmed victims of the Justinianic Plague were buried in the same way than other deceased of this time: The preserved grave goods indicate that they were dressed up in their best clothes, and equipped with tools and jewellery in case of women, and with tools and weapons in case of men.

Unfortunately, the archaeological and radiocarbon dating of the graves is not accurate enough to connect the graves with one particular wave of the Justinianic plague. For those graves that are equipped with meaningful grave goods, however, it might be possible to reduce the number of most probable plague events to two or three[42].

31 Durliat 1989; Sarris 2002.
32 Durliat 1989.
33 Stathakopoulos 2000, 270.
34 Durliat 1989, 118.
35 Foss 1997, 260; contra Kennedy 2007, 95.
36 See McCormik 2015, esp. Fig. 1; McCormick 2016.
37 Examples are e. g. discussed in Schneider 2008.
38 Schneider 2008, 18–20.
39 8 % of the 402 graves of the cemetery Aschheim-Bajuwarenring are double or multiple burials.
40 While they are detectable in some cases in single burials of the cemetery: Staskiewicz, 2007, 47–53.
41 Wiechmann/Grupe 2005.
42 As e. g. done by McCormick 2015, 345–346 and tab. 1.

Fig. 2: Two examples of plague graves from the cemetery Aschheim-Bajuwarenring: Above grave 166/167: Burial 167 (left), burial 166 (right), below grave 119/120/126: Burial 119 (left), burial 120 (right), burial 126 (in the middle), both displayed with some grave goods. After Gutsmiedl 2005 and Gutsmiedl-Schümann 2010

The dating of the confirmed plague graves from the cemeteries of Aschheim-Bajuwarenring and Altenerding/Klettham point to the first three waves of the Justinianic plague, which took place, according to the written sources, in 541–544[43], 558–562[44] and 571–574[45]. But as every wave of the Justinianic Plague according to the written sources also lasts for some years, and might be interrupted by the cold conditions of the winter at the Munich Gravel Plain[46], so it cannot be distinguished if those plague victims dated to the same archaeological period died in the same month or year, or in several years during one longer lasting plague wave. It might be possible that the plague victims did not pass away in one single event, but the plague returned to the Early Medieval settlement on a regular basis. However, the simultaneous death of two or more persons would nevertheless have been a dreadful event for the small societies.

The burials from the early medieval cemeteries of Aschheim-Bajuwarenring and Altenerding/Klettham show that plague victims have been dressed and prepared carefully for their funeral. Compared to other graves from these cemeteries on the one hand and to contemporary burials in general, nothing basically indicates that the *Y. pestis* infected individual had been treated different than other deceased. Among the buried who were infected with *Y. pestis* occurred some of the richest and most well-equipped graves of the cemeteries. Therefore, it cannot be proven on base of the Early Medieval plague graves of the Munich gravel plain that "[...]at that time all the customary rites of burial were overlooked. For the dead were not carried out escorted by a procession in the customary manner, nor were the usual chants sung over them [...]"[47]. On the contrary: The burial rites, as far as reconstructable, had been carefully conducted. The only difference is that the so far confirmed victims of the plague in the cemeteries of Aschheim and Altenerding/Klettham seem to have been more often buried in double or multiple burials. However, the screening of single burials is still in an initial stage, and other cemeteries in distant areas and other time periods revealed single graves of plague victims as well[48].

Therefore, we have to assume that the plague victims were treated as other dead bodies. They were even not only dressed up carefully, but most likely also washed and cleaned as they had been passed away. But according to the contemporary written sources we have from the Justinianic Plague, this behaviour would not be expected.

The Justinianic Plague was nevertheless a disease that affected Europe in the Early Middle Ages, but its occurrence appears not everywhere as drastic and with mass graves as the written sources make us believe. To get a more differentiated picture about the pandemic, its effects and the reactions of the contemporary societies, it is necessary to examine different regions with several sources, and use especially examinations of ancient DNA and archaeological sources as well.

Early Medieval multiple burials, like the ones found at the above discussed cemeteries, had also been subsumed under "mass graves"[49]. But, in our opinion, more than one person buried in a grave does not necessarily make it a "mass grave". Usually, the term "mass grave" includes the perception of a certain way to conduct burials, like to bury the dead hastily, and with very minimalistic or no burial rites. Therefore, we would like to distinguish between "mass graves" and "multiple burials". Both can be the physical or material expression of a plague outbreak and therefore a higher rate of mortality, but they show a very different way of handling the crisis by the contemporary society.

The medieval grave excavated at Manching-Pichl, however, meets the implications of a mass grave, as does the triple burial from the city of Brandenburg[50]. Both graves can be dated to the second pandemic, the so called "Black Death", and are presented and discussed below.

Example 2: Black Death

600 years after the last known waves of Justinian Plague, that were reported in written texts, the Plague definitely reappeared in Europe. In 1347 AD the first outbreaks were reported in Caffa, modern-day Feodossija, at the Crimea[51]. From there it spread to Italy, continued to France, Spain, Portugal and England in 1348 AD and further on to Germany and Scandinavia 1348–50 AD. It was introduced

43 Italiy, Illyricum (Marcellinus Comes), southern France (Gregor von Tours): cf. Stathakoupolos 2004.

44 Ravenna, Grado, Istrien (Paulus Diaconus, indirectly): cf. Stathakoupolos 2004.

45 Italy, Gallia (Marius von Avenches, Gregor von Tours), Italy, Ligurien (Paulus Diaconus): cf. Stathakoupolos 2004.

46 As observed in other cold climatic conditions: Cf. Benedictow 2010, 109–113.

47 Procopius, De Bello Persico II 23, 15.

48 e. g. Bolgar City, Russia: Spyrou *et al.* 2016; Les Fédons; France: Bianucci/Kacki 2012, 72–73; Bizot *et al.* 2005.

49 McCormick 2015.

50 The triple grave of Brandenburg City was also published announcing it as the smallest mass grave of Brandenburg: Dalitz *et al.* 2012.

51 Cf. e. g. Bergdolt 1994, 35–37.

to Northwestern Russia in 1351 AD[52]. Contemporary texts often write of the "Great Pestilence", nowadays the second pandemic is known as the "Black Death".

For the second pandemic, much more written evidence can be found than for the Justinianic Plague, and from much more different kinds of texts and inscriptions; therefore the Black Death seems to be understood in more detail. Some medieval authors also note dying rats on the eve of another outbreak of the plague, or that people working on food production got infected in a higher rate than other labourers, but the connection between rats and the plague was never understood clearly until P.-L. Simond's work in 1898. Instead bad air, *miasma*, etc. were held responsible for the outbreaks of the plague. Therefore, a quick burial of the dead was one of the actions taken to stem the plague in order to avoid the bad air that came from the deceased. Other actions taken by people and local authorities were the isolation or the expulsion of the infected. Contemporary people also tried to flee from the plague: Not only territorial by leaving the infected settlements, but also by searching for shelter and salvation in religion, miracle healers or flagellants[53]. The mass grave of Manching-Pichl can be seen as an example for those strategies to deal with a plague outbreak. It corresponds therefore also much better with the common public expectations of plague graves than the Merovingian plague graves presented above.

The mass grave from Manching-Pichl

The Late Medieval mass grave of Manching-Pichl consists of at least 75 individuals[54] who had been buried in a single event. The deceased have been buried hastily in a large pit that was found below the sacristy of a church, scrammed together tightly in four layers[55]. The individuals neither showed signs of coffins nor of individual clothing, so burial shrouds can be presumed (fig. 3a). The sacristy was built in the second half of the 15th century AD, therefore the mass grave must be older. According to ^{14}C-analysis the burials of the mass gave can be dated to the 14th century AD, however, it seems also that single bones from earlier burials had been relocated into this grave pit during or after the burial event. Surprisingly, two of the four positive individuals (59-I and S4-XX, see appendix) appeared to originate from the High Middle Ages on the first glance. However, detailed investigations made it most likely that already during rescue excavation some mixed bones of the earlier occupation of the churchyard have been assigned to skeletons of the mass grave. Due to the destructive aDNA method, the samples itself have not been available for ^{14}C analysis anymore.

The observation of intrusive remains of an earlier phase of the churchyard is supported by the only small find, a fibula with the depiction of a beast (fig. 3b). It was found in the pit's filling without a clear individual context and dates most probably to the 11th century AD[56].

Already in the early 2000s, Ingrid Wiechmann and Christina Garrelt succeeded in the detection of *Y. pestis* in some of the skeletons[57]. A recent study[58] included bones and teeth of 21 individuals. Meanwhile, 43 individuals have been screened of which 6 tested plague positive. The mass grave of Manching-Pichl can therefore be connected to the first or one of the first waves of the Black Death.

Interestingly, no contemporary reports of plague cases survive from the southern area around Ingolstadt. The sudden loss of more than two dozens fellow village inhabitants normally must have left a trauma in the social memory. However, it cannot be ruled out that today's sacristy was attached to St. Leonhard's church in the direct context of the mass grave, e. g. as a memorial place or separate chapel.

The mass grave of Manching-Pichl seems to be a typical plague grave for the second pandemic. A very similar mass grave found in Ellwangen, approx. 100 km east of Manching-Pichl, was analysed very recently by Spyrou *et al.*[59]. Here, 102 individuals were buried unstructurally in one pit, clearly reflecting an event of mass mortality. Detection of *Y. pestis* on these skeletons provided also positive results. However, also for the time of the "Black Death" plague victims were not exclusively buried in mass graves. Multiple burials and single graves with aDNA-confirmed burials of plague victims at regular cemeteries were observed e. g. by Spyrou *et al.*[60] for the Russian city of Bolgar or by Kacki *et al.*[61] for a rural cemetery in Southern France at Saint-Laurent-de-la-Cabrerisse. Here, the victims were

52 Cf. Keil 1989, 112–113.
53 Bergdolt 1994, 21–25; Keil 1989, 115–117.
54 Morphological analysis and further estimation of the number of individuals was carried out by O. Röhrer-Ertl, then Bavarian State Collection for Anthropology and Palaeoanatomy, Munich.
55 Garrelt/Wiechmann 2003.
56 Reich der Salier 1992, 134 fig. A16.
57 Garrelt 2002; Garrelt/Wiechmann 2003; Wiechmann *et al.* 2010.
58 Seifert *et al.* 2016.
59 Spyrou *et al.* 2016, esp. 875–876 and S2.
60 Spyrou *et al.* 2016.
61 Kacki 2011.

Fig. 3a: Medieval mass grave located below the vestry of the St. Leonhard parish church (Manching-Pichl, Bavaria, Germany). By courtesy of the Bavarian State Conservation Office

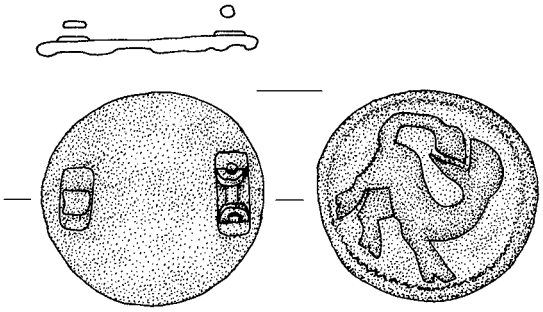

Fig. 3b: Fibula from the medieval mass grave of St. Leonhard's church (Manching-Pichl, Bavaria, Germany). Drawing: Johann Zyzik. By courtesy of the Muncipality Museum Ingolstadt

carefully deposited in dorsal decubitus showing the same orientation as the other deceased. The authors of that study suggested, that the way how the funeral was conducted depend on the number of corpses to be buried at the same time. Mass graves would be expected more often, but not exclusively in urban centres where a plague epidemic caused the demise of several dozens or hundreds of people daily. Following this attempt, in small villages the death rate would have been much lower and could have been more easily managed by gravediggers. So, one would suspect more single graves or graves with a smaller number of corpses at the countryside than in urban centres[62].

Other examples from urban contexts show that mass graves dated to the Black Death had not necessarily been laid out in one single event. As an example from the city of London, the East Smithfield cemetery, shows, there were burial trenches conducted during the time of the Black Death, where burials were carefully but very densely laid out over some time; some dead were even placed in the burial trench in a coffin[63]. The trenches stood open for some time, during which more and more burials were entombed there until it was filled up. From the same cemetery, single graves and smaller multiple burials are also known[64].

However, the example of Pichl – being by no means a 14th century urban centre and even today a small village – proves that this assumption cannot be adopted generally.

62 Bianucci/Kacki 2012.

63 Grainger *et al.* 1988, 429–431; Grainger *et al.* 2008. It must be noted, though, that the cemetery was identified as plague cemetery by 14th century manuscripts, not by aDNA analysis. Anthropological analyses of 121 teeth for aDNA of *Y. pestis* unfortunately didn't lead to one positive result.

64 Graigner *et al.* 2008, 12–16.

The mass grave of Manching-Pichl leave many open questions: Did the disease erase most of the villages' inhabitants? Have other people of the parish or neighbouring villages been buried together in one large grave in one event? The scarce written sources still lack plausible explanations.

Triple burial behind the house Domlinden 12 in Brandenburg City

The plague repeatedly returned in the following centuries, as it did in the time of the Thirty Years' War. The last example of an aDNA-confirmed plague burial we want to discuss comes from the Cathedral Island in Brandenburg City, on the shore of the Havel River[65]. This burial, which was interred shortly after 1630 AD behind a middle-class house on the yard or in the garden, avoiding the regular cemetery, can be linked to a historically documented outbreak of the plague during the Thirty Years' War documented in Brandenburg for the years 1625–1627 and 1631 AD[66]. In 1625 AD several armies could be located in Brandenburg City, which billeted their soldiers in private homes[67]; Swedish troops occupied Brandenburg in 1631 AD[68]. Therefore, it can be assumed the skeletons may have been quartered Swedish (?) mercenaries who died because of the plague. Perhaps they haven't been buried at a regular cemetery but in this highly unusual way due to their foreign origin or their military context.

Because no military equipment or parts of a uniform were found in the three men's grave, the theory that they have been mercenaries buried in a special way was tested further. To clarify the origin of the buried, isotopic analyses were carried out[69]. The $^{87}Sr/^{86}Sr$ from the apatite of the dental enamel was examined, as well as the $\delta^{13}C$ and $\delta^{18}O$ of the structural carbonate fraction of the same sample. The result showed a consensus of the skeletons 1 and 3, who could originate from the North German lowlands, but because of the $\delta^{18}O$ value probably not from the area around the burial site. By the use of the combined consideration of the $^{87}Sr/^{86}Sr$ values with the $\delta^{18}O$ value of the dental enamel, individuals from a mass grave of the Thirty Years' War in Wittstock have already been discussed and eventually identified as members of the Swedish army[70], as all three men could have originated from Sweden, Finland or the Baltic[71].

This was no normal sepulture for Swedish soldiers who died from the plague, but it was more likely a "clean-up" in which they were hastily buried in the backyard. The citizens of Brandenburg, who had been forced to accommodate Swedish soldiers, may have feard retributions for the death of these soldiers. To make matters worse, the mercenaries stood on a low social level and therefore didn't get a Christian burial, but could be hastily buried as a kind of dishonorable people[72].

Other samples from the Thirty Years' War show a different way of burying plague victims. Death caused by the plague was in some extent ignored by the aristocratic elite of the State of Brandenburg and Bayreuth. Several members of the aristocratic family von Reitzenstein who – as known by records – died from the Plague were buried in the ancestral graves of their family, following the usual burial rites of this time[73]. They were buried in their burial crypt in front of the altar of the Protestant St. Kilians' church in Bad Windsheim in their gorgeous clothes and with their personal jewellery in their tradition from their surviving family members in ecclesiastical rite, and also ordered renowned artists to keep the memoria of the family by erecting grave memorials. However, even though the written evidence on these burials speaks about the plague, it would be desirable to confirm this also by aDNA analysis.

Final Remarks

The starting point of our reflections were four sites with aDNA confirmed plague graves from Aschheim, Altenerding, Manching-Pichl and the City of Brandenburg, which were discussed together with other graves associated with plague outbreaks. These examples from different times and places show the complexities from detecting the plague. It was shown that there is a wide range of possibilities how the victims of the plague might have been treated and inhumed after their death and how the left-behind communities dealt with these traumatic incidents. Therefore, all discussed graves have in common that something in the burial custom, sometimes some detail, sometimes the whole grave, attracted the attention of the

65 Dalitz *et al.* 2012.
66 Geiseler 2008; Dalitz *et al.* 2012, 65.
67 Brekow 2008; Dalitz *et al.* 2012, 65.
68 Engel *et al.* 2000; Brekow 2008; Dalitz *et al.* 2012, 65.
69 Dalitz *et al.* 2012; for details of the applied method see Grupe *et al.* 2009; 2011.
70 Grupe *et al.* 2012.
71 Dalitz *et al.* 2012.
72 Förster 1984.
73 Ibid.

archaeologists, and gave some initial suspicion that this might be the grave of plague victims. In case of the mass grave of Manching Pichl the reasonable suspicion was quite obvious, whereas in case of the multiple burials of the Early Medieval cemeteries and the multiple grave of Brandenburg it was a more subtle suspicion.

The demographic aspect might be just one of the possible explanations for the observed contrasts of historical records, that report mass graves and high death toll, and archaeological finds, that show a wide variety of burial customs. Especially in Early Medieval rural Bavaria, which was, as revealed by aDNA detection of *Y. pestis*, also hit by the Justinianic Plague, no mass graves are known, but multiple burials appear at the cemeteries on a regular basis. Such perpetuation of the typical burial customs leads also to the question how the contemporary society had seen the plague. How much did they understand? Was it different to usual infections? The carefully conducted burial customs in the Early Medieval cemeteries indicate on the one hand, that it was much more important to follow the burial traditions than to protect the ones who handle the dead from the infection. On the other hand, it also indicates that the ones who were sick from the plague were as well nursed like any other sick person inside the families or inside society, and plague-sick persons were not separated, as it might have been expected from a modern point of view.

Another aspect might be the social status of the deceased, as shown by the examples of the Thirty Years' war: In case of aristocratic plague victims, the burials were nevertheless conducted according to the contemporary common and accepted burial rites, including the handling and the preparation of the dead body. On the contrary, the quartered soldiers who died in the outland were buried hastily in a grave that has the features of a mass burial, as defined above.

If the plague travels naturally within wild living rodent populations, it only bridges a distance of approx. 25 km per year[74]. So it must have had help from human travellers to spread so fast over Europe, like ships or wagons that carried rats with infected fleas or just the infected fleas or other insect ectoparasite vectors[75] with their load. And indeed, especially in the 14th century with its to some extent considerable number of written sources, sometimes the ships can be identified in the contemporary written evidence that brought the plague to a certain place. To give an example, according to written sources the Black Death was introduced to Bergen, Norway by a ship that came from England during shipping season (April to October) in 1349 AD[76].

With increasing possibilities to palaeogentically investigate skeletal remains of disease victims, more and more aDNA confirmed plague graves will be known. Together with archaeological evidence and written records, this will lead to more interdisciplinary investigations, and to a deeper understanding, how the plague travelled over Europe and beyond, and how local societies reacted to the resulting epidemic events. This might not only lead to a deeper understanding of the past, but might also give insights in human strategies that might be of value when contemporary societies are confronted with other epidemic events.

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74 Benedictow 2012.

75 Hufthammer/Walløe 2013 e. g. discuss the human flea and the human louse as possible insect vectors for human to human transmission of the plague.

76 Benedictow 1992, 74–78.

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Appendix

1 Aschheim-Bajuwarenring

The early medieval cemetery Aschheim-Bajuwarenring is located near Munich in southern Germany. It was excavated in 1997 and 1998 and dated to a timespan of 470/480–670/680 AD. The necropolis consisted of 444 burials, found in 402 grave pits[77].

Tab. 2: List and results of sampled individuals from the early medieval cemetery Aschheim-Bajuwarenring. * weak positive signal = either not reproducible at least three times or only very small fragments (of 70 nucleotides) were detectable

Tested individual	age	sex	plague detection – negative, + positive signal (+) weak positive signal*	grave goods	burial	dated archaeologically	14C dates cal 2σ
49	adult	f	–	S-shaped brooch (gilded silver with garnet inlay); necklace of glass, amber and nacre beads; belt with iron belt buckle; comb; knife	Total of 3 individuals in one burial pit	mid 6th century AD	
56	mature	f	–	no preserved grave goods	Total of 5 individuals in one burial pit	6th century AD	431–544 AD
58	mature-senile	m	(+)	fragmented iron and silver objects			
59	mature	m	–	belt with bronze belt buckle; knife			
60	adult-mature	m	–	sword with spatha belt; waist belt with iron belt buckle; belt bag with tools and other small objects			
66	adult	f	(+)	bronze needle (hair dress); necklace of glass beads; belt with bronze belt-buckle; knife	Total of 2 individuals in one burial pit	mid 6th century AD	
72	mature	m	–		Total of 2 individuals in one burial pit		
76	senile	f	(+)	belt with iron buckle	Total of 5 individuals in one burial pit	mid 6th century AD	443–566 AD (A76)
77	mature-senile	m	(+)	no preserved grave goods			
82	infans II	f	+	no preserved grave goods			
105	adult	f	(+)	no preserved grave goods	Total of 3 individuals in one burial pit	end 6th/ beginning 7th century AD	

77 Gutsmiedl-Schümann 2010.

Tested individual	age	sex	plague detection – negative, + positive signal (+) weak positive signal*	grave goods	burial	dated archaeologically	14C dates cal 2σ
119	adult	f	–	2 disc brooches (gilded silver with garnet inlay); necklace of glass- and amber beads; belt with bronze belt buckle	Total of 3 individuals in one burial pit, two of them holding hands, a child laid above them	mid 6th century AD	435–631 AD (A120)
120	adult	f	+	2 bow brooches (gilded silver with garnet inlay); belt with bronze belt buckle; small knife; fragment of La Téne glass arm ring (amulet?)			
166	mature	f	(+)	bow fibula (gilded silver); 2 disc brooches (gilded silver with garnet inlay); necklace of glass- and amber beads and golden pendants; belt with iron belt buckle; chatelaine with silver fittings and attached scissors, two golden pendants and the content of a belt bag	Total of 2 individuals in one burial pit	mid 6th century AD	
167	juvenile	f	+	bow fibula (gilded silver); 2 S-shaped brooches (gilded silver); necklace of glass- and amber beads belt with iron belt buckle; chatelaine with silver strap end, bronze ring, ivory ring, antler pendant and the contents of a belt bag			
197	mature	m	–	sword; belt with iron belt buckle; knife	Total of 2 individuals in one burial pit	end 6th/ beginning 7th century AD	
205	adult	m	–	sword; scales; belt with iron buckle and fittings; knife; iron ring	Total of 2 individuals in one burial pit	end 6th/ beginning 7th century AD	
278	senile	f	–	S-shaped brooch (gilded silver with garnet inlay); necklace of glass beads; belt with iron belt buckle and chatelaine with iron ring; knife	Total of 2 individuals in one burial pit	mid 6th century AD	
295	adult	f	–	2 ear rings (bronze); necklace of glass beads; knife	Total of 2 individuals in one burial pit	7th century AD	

2 Altenerding/Klettham

It is located approximately 25 km northeast of Aschheim. The large Merovingian graveyard Altenerding/Klettham was excavated in 1966–1969 and 1973[78]. The necropolis consisted of 1521 burials[79]. The graves from Altenerding/Klettham date to 450–670/680 AD[80].

Tab. 3: List and results of sampled individuals from the early medieval cemetery Altenerding/Klettham

Tested individual	age	sex	plague detection – negative, + positive signal	grave goods	burial	dated archaeologically[81]	14C dates cal 2σ
AE 96	mature	f	–	no preserved grave goods	joint coffin, buried arm in arm	–	
AE 97	juvenile	?	–	no preserved grave goods			
AE 127	infans II	?	–	2 S-shaped brooches (gilded silver); necklace of glass and amber beads with bronze bull-pendant; belt with iron belt buckle; antler ring; spindle whorl; scraper; iron tools and fragments	Two coffins in one burial pit	mid – end 6th century AD	
AE128	adult	f	–	2 disc brooches (gilded silver with garnet inlay); necklace of glass, amber, rock crystal and bronze beads; belt with bronze belt buckle; knife; comb; ivory ring;			
AE 349	adult	f	–	necklace of glass and amber beads	Two coffins in one burial pit		
AE 350	infans II	?	–	fragmented disc brooch; glass bead; belt with iron belt buckle			
AE 468	infans II	?	–	necklace of glass beads; fragments of Roman pottery	468 is secondary burial to 469	after 510 AD (as secondary burial to AE 469)	
AE 469	adult	m	–	Lance; 3 arrows; belt with white bronze buckle; 2 knives; bronze hook; firestone; iron fragments		before 510 AD	

78 Sage 1984, 10–11; Helmuth *et al.* 1973, 213–214.
79 Sage 1984, 14; see also Helmuth *et al.* 1996.
80 Losert 2003, 492–494.

81 The cemetery of Altenerding/Klettham had been the subject of various archaeological publications, however, a chronological overview over the whole cemetery and all its graves is still missing. As most of the graves used for *Y. pestis* detection were also part of the work of Susanne Hakenbeck, who created a chronology for the cemeteries of Altenerding/Klettham and Aubing, based on selectively chosen graves, this graves are dated according to her chronology. See Hakenbeck 2011, appendix A–C.

Tested individual	age	sex	plague detection – negative, + positive signal	grave goods	burial	dated archaeologically[81]	14C dates cal 2σ
AE 887	adult	m	–	2 arrows; belt with iron belt buckle and fittings	joint coffin	after mid 7th century AD	
AE 888	adult	m	–	sax; belt with iron belt buckle and fittings; iron ring; chicken			
AE 1004	infans II	?	–	necklace of glass beads with lead pendant; belt with iron belt buckle; chatelaine with bronze and iron rings	joint coffin		
AE 1005	infans I	?	–	no preserved grave goods			
AE 1154	senile	m	–	belt with iron fitting; knife	One burial pit, coffins not reconstructable, right arm of 1154 lays around the head of 1155		
AE 1155	infans I	?	–	belt with iron belt buckle			
AE 1175	adult	f	+	2 disc brooches (gilded silver with garnet inlay); iron arm ring; belt with bronze belt buckle; chatelaine with antler pendant, roman brooches, iron keys, chained links and scales; knife; fragment of La Tène glass arm ring (amulet?); necklace of glass and amber beads with pendants made of a fragment of a blue roman glass vessel and a so called Hercules or Donar club	Joint coffin or grave installation	mid – end 6th century AD	430–560 AD
AE 1176	adult	m	+	knife; lighter (iron band, firestone); belt with belt bag; iron nails			
AE 1184	infans I	?	–	no preserved grave goods	Joint coffin, buried arm in arm	–	
AE 1185	infans I	?	–	no preserved grave goods			
AE 1223	adult	f	–	necklace of glass, amber and nacre beads; bronze finger ring; chatelaine with iron rings and bronze and iron fragments; comb	Heavily disturbed, possibly one grave pit, could also be secondary burial	mid – end 6th century AD	
AE 1241	adult	f	–	Fragment of glass bead			

3 Manching-Pichl

The village of Pichl (municipality of Manching, district of Pfaffenhofen/Ilm, Upper Bavaria) is situated 10 km south of the city of Ingolstadt. In autumn 1984, the renovation of the succursal church of St. Leonhard, a late Gothic building of the 14th century AD with a distinctive bell tower above the choir ("Chorturmkirche"), caused a rescue excavation carried out by the Department of Archaeological Heritage Management Ingolstadt, Bavarian State Office for Cultural Heritage Management, within less than two weeks in September and October 1984. Right below the sacristy, a mass grave was discovered.

The sacristy, a square room of ca. 3.25 × 3.25 m internal space, was attached to the eastern wall of the church's tower most probably in the second half of the 15th century. It is accessible through an aperture behind the altar. During excavation, the remains of at least 75 individuals have been discovered below the building (Fig. 3a). Since not a single burial pit was visible and the bodies appeared to lie intertwined, the presence of a large grave shaft of ca. 1.80 m depth below today's floor level, of which the limits remained invisible below the sacristy's arched foundation walls is very likely. The individuals were laid to rest in loose light-brown humous sediment, clearly different from the graves outside of the church and seemingly above the medieval settlement layers of the vicinity. However, as the outer limits of the mass grave could not be reached and as it was dug into a much older burial site, initial suggestions of a ground-level or even shallow interment definitely have to be rejected. The context made clear that the individuals had been buried at one particular event. But single bones found within the grave pit have obviously been relocated from earlier burials during or after the burial event, as some of the Radiocarbon dates indicate. It should be noted, however, that for the aDNA analysis and the detection of *Y. pestis* tooth were used, while only in one case (S1-I) the attached mandibula could be used for radiocarbon dating.

Tab. 4: List and results of sampled individuals from the mass grave of Manching-Pichl. Radiocarbon dating was performed on bones of four individuals at the Klaus-Tschira-Laboratory for Radiometric Dating Methods (Curt-Engelhorn-Centre Archaeometry gGmbH Mannheim) by B. Kromer. * weak positive signal = either not reproducible at least three times or only very small fragments (of 70 nucleotides) were detectable

Tested Individuals	Age	Sex	Plague detection – negative, + positive signal (+) weak positive signal*	14C-dates cal 2σ
1-I	adult	f	–	
2	adult	m	–	
3-I	infans I	f	–	
5-I	25–30	m	–	
10-I	adult	f	–	
15-I	~ 8	m	–	
17-I	~ 11	m	+ (tooth)	1287–1391 AD (rib)
19-II	infans I	m	+	
22	20–22	f	(+)	
26-I	adult	m	(+)	
28-I	~ 8	m	–	
34-I	adult	f	+	
40	20–25	m	–	
44-III	~ 5	f	(+)	
49-I	mature	m	–	

Tested Individuals	Age	Sex	Plague detection – negative, + positive signal (+) weak positive signal*	14C-dates cal 2σ
50	adult	f	–	
59-I	mature	f	+ (tooth 16, probably fixed in mandibula)	1027–1154 AD (tarsal bone)
64-I	mature	f	–	
67-II	mature	m	–	
73-I	20–25	m	(+)	
74	adult	f	–	
S1-I	~ 8	m	+ (tooth 36, probably fixed in mandibula)	1298–1403 AD (mandibula)
S2-II	adult	m	–	
S3-IIX	12–14	m	(+)	
S3-IX	11–13	?	–	
S4-III	adult	w	–	
S4-IV	adult	w	–	
S4-VI	~ 10	m	(+)	
S4-XX	~ 15	w	+ (loose premolar)	985–1026 AD (temporal bone)[45]
S6-II	Not determinable?	Not determinable?	–	
S8-III	mature	w	–	
S8-VII	20–25	w	–	
S8-XXXI	juvenile	m	–	
S9-II	adult	m	–	
S9-VI	infans I	m	–	
S11-II	adult	w	–	
S11-IV	mature	m	–	
S12–1	juvenile	m	–	
S13-I	20–25	w	–	
S13-IX	mature	m	–	
S14-I	15–16	m	–	
S15-I	mature	m	–	
S15-VII	infans I	w	–	

4 Domlinden 12 in Brandenburg City

In fall 2011, an excavation was performed at the estate Domlinden 12 on the Cathedral Island in Brandenburg City, on the shore of the Havel River. Because of earlier observations, a younger Slavic cemetery was expected to be found behind a Late Baroque building, but instead three skeletons were found with an ornamented glazed pottery sherd of the 17th century in a larger pit of about 70 cm depth without any trace of a coffin or further grave construction. All three bodies were deposited on top of each other with skeleton 1 in the highest position, and skeleton 3 right at the bottom of the pit with its right side under skeleton 2 (fig. 4). The grave can be archaeologically dated because of a pipe bowl of white clay that was found beyond the left half of the pelvis of skeleton 2. It shows the label SC under a crown on the heel, which relates the pipe to the Dutch pipe producer Samuel Collier who was registered as a master in Amsterdam between 1630 and 1640 AD[82]. As clay pipes had a short lifespan, they are an extremely useful tool for precise dating when coming from a secure context.

Fig. 4: Drawing of the three skeletons found in one pit at the estate Domlinden 12, modified after Dalitz *et al.* 2012, by courtesy of B. Jungklaus

82 Dalitz *et al.* 2012, 64. On smoking in that time see also Binder 2008 and Palubeckaitė *et al.* 2006.

Tab. 5: List and results of sampled individuals from the 17th Century triple burial from Brandenburg City; age, sex and health status after Dalitz *et al.* 2012. * weak positive signal = either not reproducible at least three times or only very small fragments (of 70 nucleotides) were detectable

Tested individual	Age	Sex	Plague detection – negative, + positive signal (+) weak positive signal*	Health status	dated archaeologically
1	adult	m	(+)	dental calculus, periodontitis, caries, stomatitis, dental enamel hypoplasia, healed impression fracture right above the left eye	
2	adult	m	(+)	Brown covering on the inside of the teeth (results of smoking)	1630–1640 AD
3	juvenile-adult	m	+	Massive plaques on the inside of the maxillary antrum: chronic inflammation of the paranasal sinuses	