Journal of Archaeological Science: Reports 43 (2022) 103466

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Popularity of the cult of Asclepius in the times of the Antonine Plague: Temporal modeling of epigraphic evidence

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ARTICLE INFO

Keywords:
Asclepius
Roman Empire
Temporal modeling
Monte Carlo algorithm
Epigraphy
Antonine Plague

ABSTRACT

The research presented in the article tests quantitatively the existing hypothesis from the academic debate that the Greco-Roman cult of Asclepius was more popular in the times of the Antonine Plague which spread in the Roman Empire approximately in the years 165–180 CE. This hypothesis is based on the rationale that the god of medicine, Asclepius, could have been more appealing to the Roman population in times of health crisis. However, there are also voices in the debate arguing that there is no indication of an increase in popularity of the cult of Asclepius during the Antonine Plague. The article explores this question quantitatively by means of temporal modeling of epigraphic evidence from the Roman Empire, i.e., the primary material source for arguments in the academic debate on the topic. By employing Monte Carlo algorithms to simulate the temporal distributions of Latin inscriptions from epigraphic databases, the article demonstrates that there is no observable increase in the number of inscriptions dedicated to Asclepius in the times of the Antonine Plague that would deviate significantly from the temporal distribution of a) general epigraphic trend as represented by epigraphic databases Epigraphic Database Heidelberg and Clauss-Slaby Epigraphic Database, and b) inscriptions dedicated to other deities such as Apollo or Jupiter Optimus Maximus. The hypothesized increased popularity of the cult of Asclepius during the Antonine Plague is thus not supported by the results on the level of epigraphic trends. These findings have a significant potential to push forward the discussion which is divided by mutually opposing hypotheses that were constructed mainly by traditional historiographical approaches. The article also reveals the applicability of quantitative approaches in overcoming temporal uncertainties in archaeological data.

1. Introduction

Recently, research exploring the role that natural forces such as the climate or spread of infectious diseases have played in shaping ancient Mediterranean cultures has increased significantly (Seland 2020; Romanowska et al., 2021; Harper 2017; 2021; Harper and McCormick 2018; Glomb et al., 2018; Scheidel 2019; Erdkamp et al., 2021). In regard to the reasons for this trend, Eivind Heldaas Seland, for example, notes that the increased interest in the natural environment in archaeology is to a certain degree parallel to the currently increasing awareness of climate change in the world (Seland 2020). Another important factor enabling this trend – as demonstrated by Walter Scheidel's volume *The science of Roman history: biology, climate, and the future of the past* (Scheidel 2019) – is that the methodological portfolio and amount of available data in digital form for historiography and archaeology has grown significantly in recent years, and the gap between these fields and the natural sciences has, in turn, become narrower. Methods such as agent-based modeling, network science, GIS, or quantitative textual analysis are now often employed to deal with research problems related to the past (see e.g., Brughmans et al., 2019; Brughmans and Poblome 2016; Collar 2013; Munson et al., 2014; Fousek et al., 2018; Glomb 2021; Graham and Weingart 2015; Woolf 2016; Czachesz 2016).

The academic study of the Greco-Roman cult of Asclepius, the god of medicine, is no exception to this development. The spread and popularity of the cult in Roman times is increasingly seen in the context of the natural environment of the ancient Mediterranean. Specifically, there is a debate on whether the cult of Asclepius was more popular in the times of the Antonine Plague (for the debate on the identification of the pathogen, see e.g., Harper 2021; Flemming 2018) that was spreading throughout the Roman Empire between ca 165–180 CE and caused high

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https://doi.org/10.1016/j.jasrep.2022.103466
Received 15 February 2022; Received in revised form 8 April 2022; Accepted 28 April 2022
Available online 10 May 2022
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mortality rates among the population, which are estimated up to app. 10% on average (Romanowska et al., 2021). As was already stated, the cult of Asclepius was focused on healing, and in 293 BCE, the god was invited to Rome from the Greek city of Epidauros, the home of one of the most renowned temples of Asclepius, to ward off a plague (Livy *Periochae* 11, van der Ploeg, 2018). It is therefore plausible to hypothesize that the cult was more popular in the times of the Antonine Plague, as the demand for good health could have been more intense in such a crisis. However, the debate has not reached a consensus, and there are hypotheses, on one hand, claiming that there was an increase in the popularity of the cult during the plague, while others claim there is no sign of such interest in the deity in the context of the Antonine Plague.

Proponents of the possible impact of the Antonine Plague on the popularity of the cult of Asclepius include Ghislaine van der Ploeg, who, on several occasions, hints at this potential relationship. In *The Impact of the Roman Empire on the Cult of Asclepius* (van der Ploeg, 2018, 189), she argues that "[D]ue to the timing of when these inscriptions were erected and when the provincial expansion took place, it is possible that the increased interest in the cult coincided with the Antonine Plague" – the increased interest in this context means a rise in the number of inscriptions dedicated to Asclepius. Georgi Mihailov, the editor of *Inscriptiones Graecae in Bulgaria Repertae*, proposes a connection in dedications to Asclepius in Thracia to the Marcomannic Wars and the Antonine Plague and mentions the increased recruitment of the local population into the weakened Roman army (Mihailov 1961, 123). Van der Ploeg acknowledges this proposition and mentions that this could have led to a "boost" in inscriptions dedicated to Asclepius (van der Ploeg, 2018, 202). Later in the book, van der Ploeg ties this claim to the Roman army: "it is possible that Asclepius was especially worshipped at times of crisis by the military, such as during the Antonine Plague and also the Marcomannic Wars." (van der Ploeg, 2018, 213). Next to Mihailov and van der Ploeg, Nacéra Benseddik also finds a possible connection and hypothesizes that the temple of Asclepius built by legionaries in African Lambaesis could be tied to the positive relationship of the emperor Marcus Aurelius, who was mentioned on an inscription in the temple, towards Asclepius, but also that it could be related to the context of the Antonine Plague (Benseddik, 2010). Finally, Maria Elena Gorrini is an explicit proponent of this hypothesis and writes that "we should remember that the greatest revivals of healing cults are marked by the plagues which tormented the reigns of Marcus Aurelius and Gallienus. These times coincide with restoration works and peaks in the dedications at the Amphiaraium of Oropus, and at the sanctuary of Asclepius." (Gorrini 2005, 146–47).

On the other hand, Gil Renberg is sceptical towards the hypothesis that Asclepius was more popular in the times of the Antonine Plague and points out that "After 180 BC there are no recorded instances of the Roman government calling upon Asclepius to ward off a plague. Even during the great epidemic of Marcus Aurelius' reign there is no evidence that Asclepius' aid was officially sought by the senate, though admittedly the contemporary sources for this period are relatively sparse." (Renberg 2006, 90). Based on the exploration of epigraphic evidence from Rome, Christer Bruun claims that "[…] nothing seems to indicate a particular interest for [Asclepius] during the years of the Antonine Plague." (Bruun 2012, 138). Leonardo Ambasciano acknowledges both Renberg's and Bruun's claims and adds that "when most needed, a few centuries later [i.e., during the Antonine Plague], Asclepius seems to have lost any significant appeal." Ambasciano also remarks that this failure of the cult of Asclepius to bring a cure in the times of the plague is referred to by Christian authors Augustine and Arnobius (Ambasciano 2016).

The debate on the popularity of Asclepius during the Antonine Plague has relied on more traditional historiographical approaches without significant support from quantitatively oriented methods, and it remains outside the methodological developments in historiography and archaeology described above. Ultimately, the inability of traditional scholarship to test the assumptions produced by the debate is probably one of the key underlying reasons for the divisive arguments and fragmented discussion described here. Therefore, we present a quantitative analysis that tests and validates existing hypotheses in this debate and thus provides a path allowing the debate to move forward. The tested hypothesis produced by the discussion is that the cult of Asclepius was worshipped more in the time of the Antonine Plague. Using quantitative modeling of the temporal distribution of inscriptions, we explore the available epigraphic evidence to reveal any changes over time in the popularity of Asclepius. More specifically, this method allows us to observe whether there was a statistically significant increase in the number of Roman inscriptions mentioning the god Asclepius in times of the plague when compared to other periods. The examined trend for Asclepius is then compared to the temporal trends of surviving Latin inscriptions in the Roman Empire, as represented by selected epigraphic databases, namely the *Epigraphic Database Heidelberg* (EDH) and *Epigraphic Database Clauss-Slaby* (EDCS), as well as inscriptions dedicated to other deities such as Jupiter and Apollo. Using this method, the results overcome the limits of the current debate in revealing patterns, as this debate has been focused either on using only selected pieces of evidence or analyzing only the cult of Asclepius without exploring the broader cultural context to support or challenge the hypothesis.

2. Materials and methods

2.1. Materials

In this study as well as in the debate, Latin inscriptions mentioning the god Asclepius from the time and space of the Roman Empire are conceptualized as proxies for the worship of the god. Epigraphic evidence is a rich source for the study of Roman culture. Making inscriptions in stone was a widespread form of social communication in the Roman world, and was particularly intensive in the first three centuries CE (Beltrán Lloris 2015; MacMullen 1982). The fact that we can speak of an "epigraphic habit" in the times of the Roman Empire is immediately tangible in the amount of surviving inscriptions. There are only a few thousand inscriptions from the Roman Republic and hundreds of thousands from the Empire (Beltrán Lloris 2015). By the time of the Roman Empire, this habit was no longer tied only to the elite members of the population, and it spread to many layers of society. Another crucial attribute of the Roman epigraphic habit that makes it suitable for learning about Roman culture is the diversity of the type of information the inscriptions convey. Epitaphs commemorate the dead; legal inscriptions or military diplomas help us understand Roman law, administration and institutions; boundary and building inscriptions provide us information on the division of Roman space, and the list continues. In other words, epigraphy accompanied a very wide spectrum of life activities, and the religious sphere was no exception. Roman epigraphy, predominantly written in Latin, informs us about the various methods of interaction between the author of the inscription and the cultic sphere, such as fulfilment of a vow to a deity or dedicating a temple or an altar, and provides large amounts of data for exploring geographical and temporal trends in worship. Because inscriptions are frequently the key part of the arguments produced by the debate, the quantitative exploration of this particular type of evidence then increases the chances that the presented results will have a significant impact on the debate.

In order to explore any potential temporal patterns in the worship of Asclepius in the context of the Antonine Plague, the inscriptions mentioning the god needed to be collected in representative numbers in digital form. For a significant portion of provinces in the Roman Empire, the *Epigraphic Database Heidelberg* (EDH) (Alföldy et al., 1997) offers representative or complete numbers of Latin provincial inscriptions in a digital form (app. 81,000 inscriptions in total) providing detailed attributes such as dates of origin, geographical provenance, transcription of the text, names of persons mentioned, social status if derivable from the text (e.g., military personnel, slaves), type of inscription (e.g., votive

inscription, epitaph), type of monument (e.g., altar, statue base), etc. However, there are certain regions such as Italy and particularly Rome where EDH is not sufficiently representative for the inscriptions found there. On the other hand, the *Epigraphik Datenbank Clauss-Slaby* (EDCS) (Clauss et al., 2007) offers the most extensive epigraphic database of Latin inscriptions from the Roman Empire (over 500,000 inscriptions in total), with significant temporal and spatial coverage, including the city of Rome. When compared to EDH, however, EDCS includes fewer categories and is not as suitable for very specific searches (for an overview and further comparison of these projects, see Orlandi 2021). Together, EDH and EDCS provide adequate coverage of epigraphic evidence for this type of research. Due to different database structures and attributes of both databases, it is not straightforward to access and collect inscriptions from EDCS using the criteria from EDH. Fortunately, the Social Dynamics in the Ancient Mediterranean project (SDAM) team has developed a machine-learning model which, after being trained on inscriptions covered by both datasets, is able to categorize and label EDCS inscriptions according to the EDH classification system. The resulting database combining EDH and EDCS into one is called the Latin Inscriptions from the Roman Empire dataset (LIRE), available through Zenodo (Kaše et al., 2021a; Kaše et al., 2021b).

The LIRE dataset contains data for 136,190 inscriptions. The dataset is a merger of all deduplicated inscriptions from EDH and EDCS filtered by certain criteria. Namely, the dataset contains only inscriptions (1) with valid geospatial coordinates, (2) with these coordinates falling within the boundaries of the Roman Empire at its largest extent in 117 CE, (3) with metadata containing some sort of information concerning the date of creation (typically in the form of a temporal interval), and (4) whose date of creation intersects with the timespan of the Roman Empire (arbitrarily set to 50 BCE through 350 CE).

Using LIRE, it was possible to extract all inscriptions mentioning the god Asclepius in different noun-cases and alternative spelling forms excluding personal names in the transcribed text of the inscription. Following the same procedure, we also collected inscriptions naming Apollo and Jupiter (in the form of Iup(p)iter Optimus Maximus). Apollo was the mythical father of Asclepius and, despite being a universalistic deity, Apollo is related to healing aspects (Rüpke 2011; Graf 2009). Furthermore, the cult of Apollo was invoked in protection against plagues in some contexts. Specifically, the oracle of Apollo in Claros issued prescriptions to ward off plagues that were endangering cities in Asia Minor in the second century CE (Graf 2007; Duncan-Jones 2018). Jupiter was the main deity of the Roman pantheon and was one of the most widespread cults in Roman times (Rüpke 2011; Scheid 2016, 75-76, 103). Comparing the temporal distribution between the inscriptions for Asclepius, Apollo and Jupiter makes it possible to determine whether there was any change in the epigraphic trend in the times of the Antonine Plague specific only to the cult of Asclepius, or to cults related to healing.

It is important to note that Greek inscriptions are not incorporated in this study, and thus the results are not representative of the Eastern Mediterranean and Greece, i.e., parts of the Roman Empire where Greek epigraphy was dominant. As LIRE consists of Latin inscriptions, it has a higher relevance for the Western part of the Roman Empire, where Latin was the main language of publication (Beltrán Lloris, 2015). Databases collecting Greek inscriptions are yet not up to par with their Latin counterparts and the computer-operational datasets are either distributed to tens of databases with different structure or do not comply with FAIR data principles (e.g., *Searchable Greek Inscriptions* by the Packard Humanities Institute contains over 200,000 inscriptions that can be only viewed and searched via the website (https://epigraphy.packhum.org/), but the data is not further reusable; Iversen, 2007; Elliott, 2015). The results presented here can thus be compared with trends in Greek inscriptions in a future study.

2.2. Temporal modeling of epigraphic evidence

The analysis presented in this study tests the premise that if the cult of Asclepius was worshipped more during the Antonine Plague than in other periods, there should be an increase in the number of inscriptions mentioning the god dated to that particular period of time, and this increase should be specific to the cult of Asclepius, i.e., not observable in the body of all inscriptions as represented by LIRE. However, a simplistic analytical scenario of projecting the amounts of inscriptions for Asclepius on a timeline and observing the peaks and dips is not possible for several reasons. The first problem is that a significant portion of the collected data contains a highly variable level of uncertainty in attributed dates of origins. Although some inscriptions might contain a reference to a known period, dating system, or known historical event or figure and thus can be dated with precision to a single year, the date of most inscriptions is determined by epigraphers based on their assessment of available contextual information, such as provenance and archaeological context, and characteristic traits typical for certain times and types of inscriptions. The date, represented by an interval between the *terminus post quem* and *terminus ante quem*, indicates the most probable time when the inscription was created (or repurposed in case of reused inscriptions) and its precision is solely based on the context of the discovery, the rate of preservation, availability of comparanda and most of all, the experience of the epigrapher in charge (Cooley 2012; Bruun and Edmondson 2015). When all these factors are combined, inscriptions are sometimes dated with precision spanning over one or two centuries and thus present a serious obstacle for placing them on a definite spot on the timeline of the Roman Empire. A second aspect obstructing any straightforward analytical solutions is the relative disproportionality in the number of inscriptions for individual deities when compared with the entire LIRE dataset. While the comparison of the temporal distribution of several hundred (or thousand in the case of Jupiter) inscriptions for individual deities with tens of thousands of inscriptions from LIRE can reveal relevant initial patterns, it can also lead to misleading readings of the data on the timeline. Particularly, the inscriptions naming deities have a specific mixture of types of inscriptions – usually, the largest number of these consist of votive and building/dedicatory inscriptions, and the overall epigraphic trend as represented by LIRE can include diverse temporal biases and changes tied to particular inscription types such as milestones, epitaphs, or military diplomas, which renders the comparison untenable. In the following paragraphs, we provide analytical procedures that overcome these two limitations.

In order to quantitatively explore the temporal distribution of LIRE while considering the temporal uncertainties inherent to the epigraphic data, it was necessary to determine the possible dates of origins by estimation. In order to mitigate the temporal uncertainty but at the same time avoid forcing only one date onto each inscription – for example by averaging the date of origins based on the *terminus post* and *ante quem*, where an inscription dated between 100 and 300 CE would be dated to 200 CE (thus excluding the other 200 options) – we employed the so-called Monte Carlo approach to model probabilities in the temporal distributions of the inscriptions (Crema, 2012; Crema and Kobayashi, 2020). Monte Carlo is an umbrella term for computational algorithm-based methods focusing on repeatedly generating random numbers, usually following specific distributions and/or based on specific probability rules. In this respect, we relied on a custom Python package (Kaše, 2021) offering functions for the generation, plotting and analysis of random dates following certain parameters. Using this tool for each inscription in the dataset, we generated 1,000 possible random dates of origins between the *terminus post* and *ante quem* (in LIRE coded as not_before and not_after). Subsequently, we simulated the possible temporal distribution of the inscriptions for Asclepius, Apollo and Jupiter by projecting the possible dating of these inscriptions one thousand times on the timeline, with each simulation using a different randomly generated date of origin for each inscription. The result then

reveals one thousand possible scenarios of how many inscriptions could originate from a specific period of time. We then applied a kernel density estimation (KDE), i.e., a tool for estimating probability density function, to this simulation result to better observe the probability distribution and thus temporal trends within the data (Fig. 1).

The next step was to compare temporal trends for inscriptions mentioning Asclepius, Apollo and Jupiter with the rest of the epigraphic dataset, as represented by LIRE. The main aim was to analyze whether the cult of Asclepius appeared in inscriptions more frequently compared to general trends of all inscriptions during the Antonine Plague. To avoid potential temporal biases related to different types of LIRE inscriptions that would potentially blur the outcome of such a comparison, we implemented two levels of proportionality to the comparison. Specifically, random control samples of inscriptions from the LIRE dataset had two attributes representing the two levels: a) they were of corresponding size to the number of inscriptions naming Asclepius, and b) had the corresponding proportion of types of inscriptions as those for Asclepius. These data were once again subjected to the Monte Carlo method, i.e., simulating one thousand times the temporal distribution of the inscriptions from the sample using their random possible dates of origin. The probable temporal trends of the random sample of LIRE inscriptions were then revealed again by KDE. This procedure allowed us to observe and statistically test whether the inscriptions naming Asclepius followed the temporal trend of a structurally proportionate sample of the body of all inscriptions as represented by LIRE or whether they were deviating from the general trend in the time of the Antonine Plague (Fig. 1). This comparison was then repeated for the cult of Apollo and Jupiter in the same fashion.

To statistically compare the temporal distributions of different subsets of inscriptions against control samples, we used a two-sample Kolmogorov-Smirnov (2sKS) test (Hodges 1958). In a null-hypothesis testing framework, the 2sKS serves to determine whether we can reject the null hypothesis that the two samples come from the same distribution regardless of the shape of this distribution. In our case, the first sample (target sample) is the subset of inscriptions referring to a deity; the second sample is a control sample obtained as a random sample of inscriptions from the LIRE dataset and is of the same size and with the same proportion of individual inscription types as the first (target) sample. Here we combine this approach with the Monte Carlo approach described above, reporting the average *KS statistic* and *p values* over 1,000 pairs of samples of inscriptions. In each pair, the sample of inscriptions referring to the deity is the same; the dates (i.e., years) assigned to each individual inscription change and the control sample is always different. The initial form of this analysis was pre-registered in the Open Science Framework (Glomb et al., 2021) and was further elaborated during research into the form that is presented here (the data and scripts used in this research are accessible as Glomb et al., 2022).

3. Results

In the LIRE dataset, we identified 210 inscriptions referring to the god Asclepius, 474 to the god Apollo, and 2,855 to the god Jupiter (for their spatial distribution, see Fig. 2). In the case of Asclepius and Apollo, the numbers were originally slightly higher (238 and 479 respectively), as our script also captured inscriptions referring to people named after Asclepius or Apollo. However, we removed these false-positive instances upon a manual check.

When we look at the distribution of different types of inscriptions in the three subsets of inscriptions referring to the deities, we see that votive inscription is by far the most common category (Table 1). In the case of Asclepius and Apollo, we can also observe a noteworthy proportion of building/dedicatory inscriptions and epitaphs. By contrast,

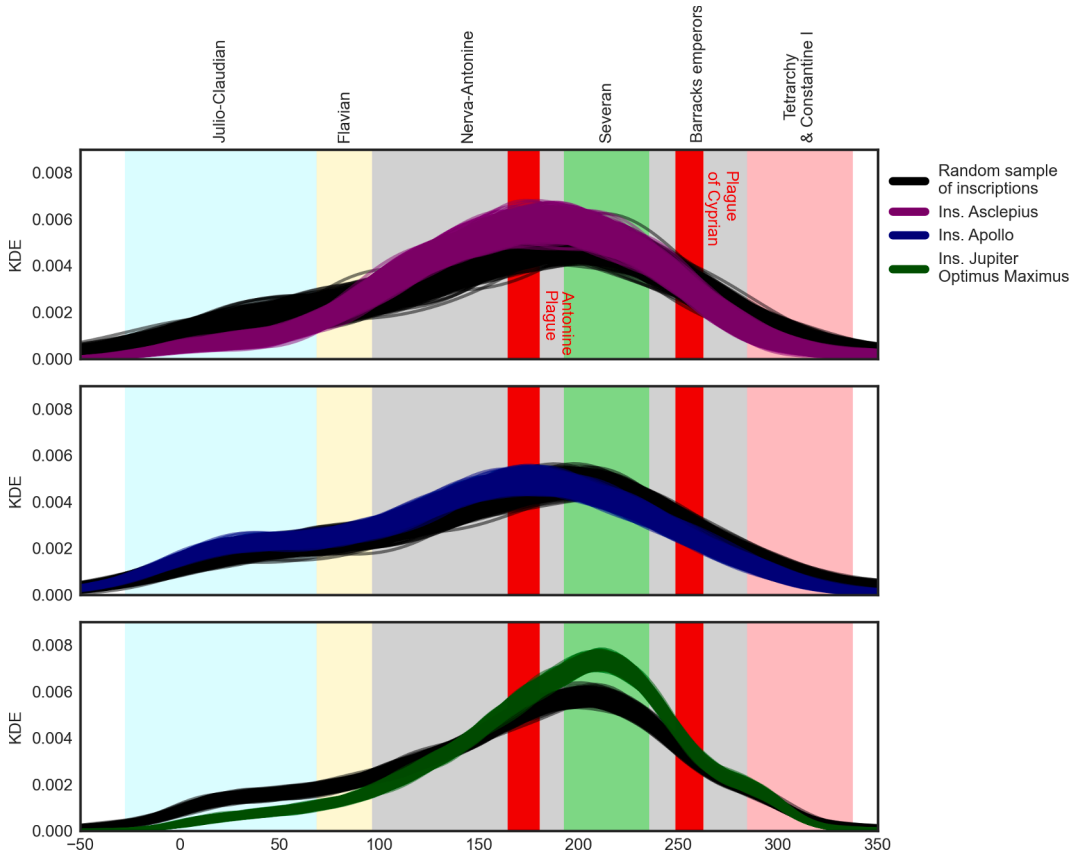

Fig. 1. Temporal distribution of the number of inscriptions naming the selected deities compared with the temporal distribution of random selection of inscriptions from the LIRE dataset of corresponding sizes as modeled by the Monte Carlo and KDE approaches.

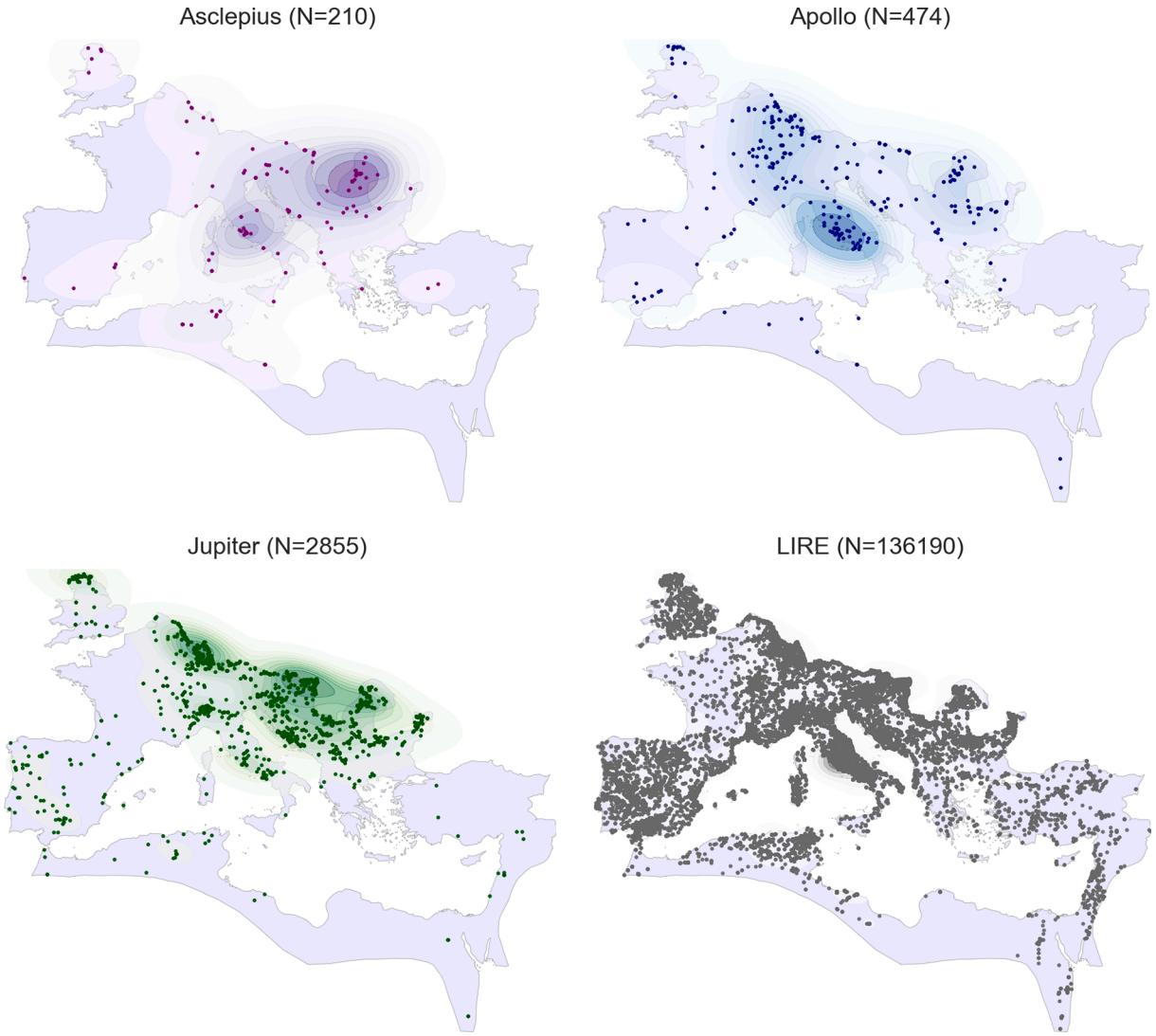

Fig. 2. Spatial distribution of inscriptions referring to Asclepius (upper left), Apollo (upper right) and Jupiter (lower left), compared with the spatial distribution of the LIRE dataset as a whole.

Table 1
Percentage distribution of types of inscriptions across three subsets of the LIRE dataset and the LIRE dataset as a whole. The overview includes only inscription types represented within the Asclepius subset; all remaining types are collapsed here as "rest".

	asclepius_pct (N = 210)	apollo_pct (N = 474)	jupiter_pct (N = 2855)	LIRE_all_pct (N = 136190)
votive inscription	89.34	81.28	97.75	13.45
building/ dedicatory inscription	5.08	2.61	1.67	2.78
epitaph	4.06	10.43	0.11	63.88
honorific inscription	1.02	2.84	0.21	4.77
defixio	0.51	0	0.04	0.25
rest	0	2.84	0.24	14.87

when we look at the LIRE dataset as a whole, we see that it is strongly dominated by epitaphs (63.88%), with votive inscriptions representing only 13.45% of its content. The difference in typological composition of these data reminds us that we have to be careful when comparing the temporal distribution of the subset with the temporal distribution of inscriptions in the dataset as a whole.

To obtain an overview of the precision with which the different groups of inscriptions are dated, we generated Fig. 3, which compares

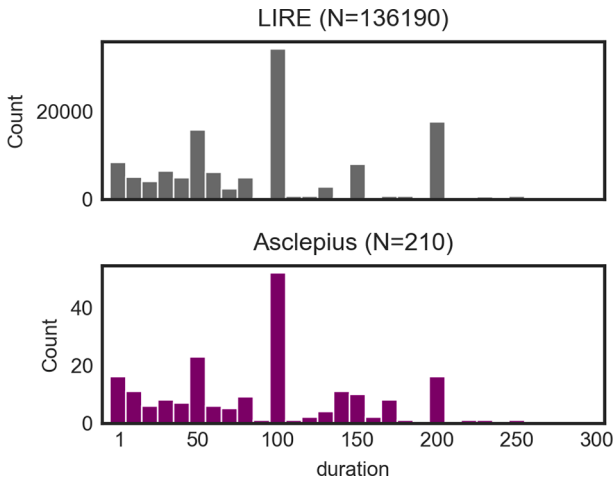

Fig. 3. Distributions of durations (years) of the dating intervals.

the distribution of durations of dating intervals for the LIRE dataset as a whole with the distribution of durations within the subset of inscriptions referring to Asclepius. On the two histograms, we see that the distributions are similar to some extent: In both cases, approximately one fourth of inscriptions is dated by reference to a century. But it also reveals that among the inscriptions referring to Asclepius there is a slightly higher proportion of those dated more precisely. In particular, among the subset of inscriptions referring to Asclepius, 10.95% (N = 23) are dated by means of an interval not longer than 10 years, while in the LIRE dataset as a whole there are 8.52% of inscriptions dated by the same precision. Also, the mean duration is lower in the case of inscriptions referring to Asclepius than in the general dataset (x = 93.79 and x = 103.45 respectively). Thus, it appears that the dating precision of the subset of inscriptions referring to Asclepius is even slightly higher than in the LIRE dataset as a whole.

The Monte Carlo approach together with the application of KDE as employed in Fig. 1, followed by statistical testing, yielded several relevant observations of the temporal distribution of the LIRE inscriptions. Firstly, the temporal distribution of inscriptions naming Asclepius is not significantly different from the distribution of its control sample (*KS statistic* = 0.11, $p = 0.2$). In the case of Apollo, the probability that the target sample and the control sample come from the same distribution is 0.062, i.e., slightly above the conventional significance value. Only in the case of Jupiter did the distribution of the target sample differ significantly from the distribution of the control sample (*KS statistic* = 0.11, $p < 0.001$).

We should not overlook the fact that the Apollo subset is more than twice as large as the Asclepius subset, and that the Jupiter subset is about twelve times larger than the Asclepius subset. This is important, as the ability of the Kolmogorov-Smirnov test to determine whether two samples come from the same distribution is inversely proportional to the size of the tested samples, as larger samples amplify differences. Thus, to explore the impact of different sample sizes on the results, we reran the test on subsamples from the Apollo subset and Jupiter subset of an equal size to the Asclepius subset ($N = 210$). Under these conditions, the probability that the Apollo subset and its control sample come from the same distribution increased to a value of 0.27, which is even higher than the one we encountered for Asclepius. In the case of Jupiter, the reduced sample of 210 inscriptions caused the difference between the two samples to be less certain to some extent, as the probability that they come from the same distribution increased from the original value of $p < 0.001$ to $p = 0.01$. However, even under such conditions, the difference between the target and control distributions is still much more obvious than in the case of the Asclepius and Apollo subset of equal size ($N = 210$). We also tested the difference between the Asclepius and Apollo subset distributions of equal size. The previous tests revealed that they cannot be differentiated from the general trend represented by the control samples. Here we confirmed that they can neither be differentiated from each other, with $p = 0.5$ suggesting that they are even closer to each other than to the general trend. The closeness in distribution between the subsets for Asclepius and Apollo in contrast with the significant difference with the subset for Jupiter (even when the N of inscriptions in the Jupiter subset is lowered to 210) indicates that we can still observe significant mutual differences in the epigraphic traces of the worship of these deities despite a lower N of inscriptions.

Fig. 4 depicts the proportional difference between the number of inscriptions within the Asclepius subset and the number of inscriptions within corresponding control samples per 25-year-long time-blocks. Each time-block is represented by a boxplot. The boxplots depict differences over 1,000 pairs of samples of inscriptions. The control samples serve here as a baseline for the overall temporal trend in the target data. The dashed green lines and the orange lines represent the mean and median values respectively. The mean and median higher than 1 within a time-block imply that there is on average a higher number of inscriptions dedicated to Asclepius dated to this time-block than within corresponding control samples. The boxes represent inner quartiles; the whiskers correspond to 95% confidence intervals; the dots depict outliers. The high extent of the dispersion of data within the box plots reflects a high extent of temporal uncertainty combined with a limited sample size. For instance, in the case of the 1–25 CE time-block, we observe that the highest value is 4.5. It means that among the 1,000 pairs of data, there is a pair in which there are 4.5 times more inscriptions referring to Asclepius than in the corresponding randomly generated control sample. However, as the dashed green line and orange line within this time-block indicate, the mean value of the ratio is 0.74 and the median 0.67 (std = 0.49), which implies that in that time-block there are typically fewer inscriptions referring to Asclepius than in the baseline data.

We see that during the second century CE, the number of datable inscriptions referring to Asclepius is slightly higher than the number of inscriptions within the baseline data of the control samples. It is remarkable that this difference is relatively stable over the course of the entire century: upon visual inspection, we are unable to differentiate between the median values of the ratio for the 126–150 CE, 151–175 CE, and 176–200 CE time-blocks. When we look at the third century, we see that the number of inscriptions referring to Asclepius from the 251–275

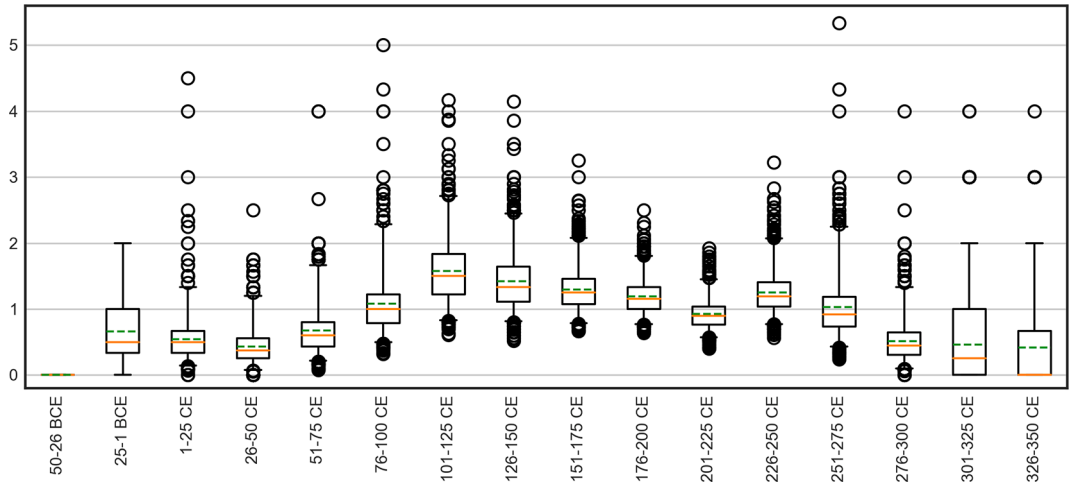

Fig. 4. Proportional difference between the number of inscriptions naming Asclepius and the number of inscriptions from randomized control samples of the corresponding size in 25-year-long time-blocks. The baseline for the random samples of LIRE inscriptions is at a value of 1 on the vertical axis; The dashed green lines and the orange lines represent the mean and median values respectively; The boxes represent inner quartiles; the whiskers correspond to 95% confidence intervals; the dots depict outliers. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

CE time-block is on average lower than the number of inscriptions in the baseline data (the median of the ratio is below one) and that the ratio is also lower than in the previous time-block. Overall, we can conclude that there is no statistically significant rise in the number of inscriptions simulated for the cult of Asclepius either in the time of the Antonine Plague (ca 165–180 CE) or in the short time horizon after, nor was there later in the time of the Cyprian Plague that raged between ca 249–262 CE.

The same applies to the cult of Apollo. The cult of Jupiter, represented by the biggest number of inscriptions from the selected cults, follows a different trajectory than the general epigraphic trend of LIRE inscriptions with a significant peak in the number of datable inscriptions in the Severan period (193–235 CE, Fig. 1). The epigraphic trend for inscriptions naming Jupiter reveals a rise in the time of the Antonine Plague; however, as is the case for Asclepius, this increase is gradual, beginning at the end of the Flavian period and extending to the time of the Severans. Overall, the temporal analysis suggests that there was no increase in the number of inscriptions in the time of the Antonine Plague for all the observed cults that would significantly deviate from A) the general epigraphic trend as represented by LIRE, and B) long-term temporal trends for inscriptions related to the individual cults.

In the context of the research question, the greater number of inscriptions dedicated to Asclepius from the second half of the second century CE reported and discussed in the academic debate is not a trend specific only to the cult of Asclepius in the presented analysis. It is rather a trend that also occurs in the cults of Apollo, Jupiter and, more importantly, in the general epigraphic trend as captured by random samples from LIRE. Together with the revealed absence of any steep increase in the number of inscriptions mentioning Asclepius, particularly in the time of the Antonine Plague or shortly after, the results challenge the validity of the hypothesis that Asclepius, as a healing deity, was more intensively worshipped in reaction to the plague. This study thus provides new arguments in line with the sceptical voices of the debate represented by Renberg, Bruun or Ambasciano, who claim there is no indication that the cult of Asclepius had a stronger appeal to people because of the Antonine Plague. Nor is there any observed pattern that would support Gorrini's thesis that there was a revival of healing cults in the times of the plague as A) there is no increase in the number of inscriptions relatable to either Asclepius or Apollo specifically in the period of the Antonine Plague, and B) there is a rather long-term gradual increase in the number of inscriptions for the tested healing cults between the first and second century CE, i.e., not a sudden short-term peak in the time of crisis. It is important to point out that epigraphic evidence is only one material for approximating the worship of Asclepius; another possible approach would be, for example, to conduct a numismatic analysis of the symbolism and deities incorporated on Roman coins representing cultural preferences of the Roman emperors in the times of the Antonine Plague. However, it is equally important to note that the tested hypothesis from the debate that Asclepius was more popular in the times of the Antonine Plague is originally constructed by researchers' interpretation of Latin dedications and, in this context, the results are highly relevant.

Although we observed the inscriptions mentioning Asclepius and Apollo as being part of the general epigraphic trend, this is only partially the case for the cult of Jupiter, which peaked in the number of inscriptions surpassing the general epigraphic trend during the rule of the Severan dynasty. The temporal distribution of the inscriptions in the Jupiter subset is significantly different statistically from the random samples from LIRE. One possible interpretation of the unique trend related to the cult of Jupiter, which is already widely accepted in the debate, is that the cult of Jupiter Dolichenus received special attention from the Severans. This patronage could have further opened crucial social channels for the spread of the cult (Collar, 2013; Najdenova, 1989; Petrović, 2015). The cult of Jupiter Dolichenus, most frequently mentioned in the form of Iup(p)iter Optimus Maximus Dolichenus in the LIRE inscriptions, refers to a cult originally from Northern Syria. Although it was present in the Roman Empire before the rule of the Severan dynasty, it significantly benefited from the cultural preferences and ties with the Severans. For example, Iulia Domna and Iulia Mammea, both Roman empresses of the Severan dynasty, were born in Syria, and Septimius Severus himself visited Syria in 198 CE (Petrović, 2015). The fact that there was an increase in the number of people with eastern Mediterranean origins in the military personnel and administration of the Roman Empire was another factor that was beneficial for the spread of the cult of Jupiter Dolichenus and is related to the aforementioned ties with the Severans (Najdenova, 1989; Petrović, 2015). For example, Commagenian cohorts have been attested in the Roman province of Dacia (Collar 2013, 79-145), and Doliche was a Commagenian town in Syria.

4. Discussion

The modeling of temporal distribution trends in Latin inscriptions from the Roman Empire revealed a highly relevant pattern: although the number of inscriptions mentioning the healing cult of Asclepius in the second half of the second century CE was high, it was most probably not the result of a sudden reaction to the Antonine Plague as argued by some scholars, but rather a natural peak of a long-term rising epigraphic trend. Moreover, this trend was aligned with the general trends of all surviving inscriptions as represented by random samples from LIRE. In addition to providing a specific argument challenging the validity of the hypothesis that Asclepius was more popular because of the Antonine Plague, the results revealed a conceptual flaw in the academic debate on this topic: if the epigraphic evidence for the cult of Asclepius is studied in isolation, the interpretative bias to relate the high number of inscriptions to the danger posed by the Antonine Plague is unchecked. Only after a comparison does a very similar picture appear in the epigraphy for other cults and in the general epigraphic trend in the Roman Empire approximated by LIRE. Thus, the research presented here also brings to the debate a reminder that absolute numbers often tell a different story than relative ones.

A potential counterargument to the results and methods employed in this study might be that there is a slight chance that many of the inscriptions dedicated to Asclepius with uncertain dating could have originated in times of the Antonine Plague. In fact, some of the aforementioned voices of the academic debate argue that Asclepius was more popular during the plague based on this assumption. However, this precisely is the fallacy of such hypotheses since they work with only one specific temporal distribution in a situation where the data with temporal uncertainties do not allow for such operation. The Monte Carlo approach, on the other hand, is able to provide large numbers of possible scenarios and reveal the most probable distributions. Combined with the comparisons with simulated temporal distributions of the other subsets and the whole LIRE dataset, we can conclude with confidence that there is no significant indication that Asclepius was worshipped more in Latin inscriptions because of the Antonine Plague.

A question that might arise along with the presentation of our results is whether there is a section or genre in the epigraphic habit or related material culture that did react to the crisis of the Antonine Plague. The plague is explicitly mentioned very rarely in Roman Latin epigraphy. In the whole EDH dataset containing around 81,000 inscriptions, only one epitaph from Noricum (HD042335) mentions deaths within a family "per luem", i.e., by a plague, and it is dated precisely to 182 CE. However, there are significant and sudden dips in certain genres that were interpreted by researchers as indicators of a plague crisis. Such materials are military diplomas of honorable discharges from the Roman army, in which, as Richard Duncan-Jones (2018) demonstrated, there is an abrupt decrease from tens of attested diplomas to single digits nearing zero after 167 CE. Considering the fact that the army was severely hindered by the outbreak (Duncan-Jones 2018), the sudden reduction of the institute of honorable discharges is a highly plausible outcome, i.e., discharging soldiers is not desirable in times of significant personnel

losses. Another relevant observation in this context was presented by Romanowska et al. (2021), who identified a clear dip in the number of funerary portraits from Palmyra in the period of 160–175 CE after a long-term rise in these data in the first century and the first half of the second century CE. These scholars see the cause in societal disruptions caused by the Antonine Plague and Romano-Parthian War. As we also identified in the case of the cult of Jupiter, these observations suggest that the epigraphic habit and related materials such as funerary portraits are indicative of sudden changes in history. Yet, the specific nature of these changes has to be confirmed by further research. Recent studies exploring the nature of the epigraphic habit agree on its strong regionalism that may to a certain degree reflect the distributed nature of epigraphic datasets (Nawotka 2020; Heřmánková et al., 2021). It is also important to note that the results presented in this study address the popularity of Asclepius in times of the Antonine Plague but they do not touch on the topic of the significance of the Antonine Plague as a whole.

This study also confirms the proposal put forward by Enrico Crema (2012) that the modeling of temporal uncertainties via probabilistic methods is a viable tool to conduct an analysis and reach conclusive results with material that poses significant problems to the traditional methods of historiography due to imprecise dating. Although the data have significant gaps in their dates of origin, the *terminus post* and *ante quem* of the LIRE inscriptions are still sufficient to determine the most probable temporal trends in the epigraphic habit when approached by Monte Carlo methods. This is particularly the case for the academic discussion on the topic of the popularity of Asclepius during the Antonine Plague, where consensus has not been reached and the proposed hypotheses are diverse and often in mutual opposition. This application of temporal modeling thus has the potential to push the discussion forward. Finally, the research presented here is aligned with the Findability, Accessibility, Interoperability, and Reuse of digital assets principles of Open Science, so anyone can either verify the results, improve the methods or reuse the data (see principles in Wilkinson et al., 2016; scripts and data used Glomb et al., 2022).

CRediT authorship contribution statement

Tomáš Glomb: Conceptualization, Methodology, Investigation, Supervision, Project administration, Funding acquisition, Writing – original draft, Writing – review & editing. **Vojtěch Kaše:** Methodology, Software, Validation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Petra Heřmánková:** Resources, Data curation, Formal analysis, Writing – original draft, Writing – review & editing.

Acknowledgments

Tomáš Glomb has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 892604. Vojtěch Kaše and Petra Heřmánková have received funding by the Aarhus University Forskningsfond Starting grant no. AUFF-E-2018-7-22 awarded to the "Social Complexity in the Ancient Mediterranean" (SDAM) project. The authors have no competing interests to declare.

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