Journal of Archaeological Science 113 (2020) 105044

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

How old are the towns and villages in Central Europe? Archaeological data reveal the size of bias in dating obtained from traditional historical sources

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ARTICLE INFO

Keywords:
Time lag
Dating
Archaeology
Written sources
Middle ages
Historical settlement
Central Europe

ABSTRACT

In various research fields, from archaeology to landscape history and ecology, it is important to know the date of the origin of historical settlements (i.e. towns, villages, hamlets, isolated farms) as precisely as possible. In Central Europe, there are two primary ways to obtain the date when a settlement was founded: “historical dating” (based on historical written sources) and “archaeological dating” (based on archaeological findings). Historical dating usually does not reflect the real time of origin, since the first reference to a settlement in written sources can be recorded many years after the real origin of the settlement. However, the time lag is unknown. Until now, no study has attempted to show exactly how the time lag differs in different centuries, or whether the time lag has been affected by any geographical factors.

This paper compares the dates of origin from archaeological data and from written sources of medieval and early modern settlements ($n = 527$, AD 850–1600) in the present-day Czech Republic. We also tested the influence of local environmental conditions on the time lag. Our comparison shows that the time lag has been decreasing with the passing of calendar years (from a time lag of 250 years for AD 1000 to approx. 80 years for AD 1400). Towns and places close to major towns also have a shorter time lag in their historical dating (the difference is almost 100 years).

These results make an interpretation of the historical dating of medieval towns and villages more complicated. The length of the time lag and its dispersion means that, for the purposes of settlement dating, historical dating needs to be combined with other dating methods (especially in the medieval period). Our results also identify a possible bias in the chronology of landscape transformation.

1. Introduction

In various fields, from archaeology to landscape ecology (e.g. Beneš and Brůna, 1994; Lehr and McGregor, 2008; Pokorný, 2011; Szabó et al., 2017; van Doesburg and Groenewoudt, 2014), it is important to know the date of the origin of historical settlements (i.e. towns, villages, hamlets, isolated farms) with sufficient precision. In this paper, we make a comparison between dates of origin derived from archaeological records and from written sources of medieval and early modern settlements in Central Europe (to the north of the ancient *Limes romanus*). The medieval settlements in our study region of Bohemia (Czech Republic), with their land division and field systems, are one of the oldest visible layers in the cultural landscape of Central Europe to the north of the historical frontiers of the Roman Empire (Beneš and Zvelebil, 1999; Löw and Míchal, 2003); most of the local towns and villages were founded during the medieval period (Klápště, 2012; Poschlod, 2015a; Semotanová, 2006). This topic impacts not just the historical and social sciences but also the environmental sciences, since historical settlements were significantly affected by the properties and the limitations of the surrounding environments (Fanta et al., 2019, 2018; Lukezic, 1990), and also because the people actively changed the landscape in their neighbourhood (by deforestation, agriculture, soil erosion etc.; Bork et al., 1998; Maděra et al., 2014; Pokorný, 2011). The formation of a cultural landscape makes the study of settlement history an important field of science (Poschlod, 2015b). Among other things, settlement history research uncovers the forces that formed the landscape we live in.

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https://doi.org/10.1016/j.jas.2019.105044
Received 7 March 2019; Received in revised form 14 October 2019; Accepted 4 November 2019
Available online 17 December 2019
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For systematic research on settlement history, a key question concerns the dates when the settlements were founded. There are two primary ways to obtain this date, “historical dating” and “archaeological dating”. In historical dating, a date has been recorded in a historical written document (a chronicle, correspondence, narrative sources or official papers). Every village or town in the Czech Republic has a recorded date of this kind (Růžková et al., 2006). However, the written sources had usually been recorded for different purposes (trade, financial transactions, legal issues, documentation etc.) – direct records documenting the foundation of a village are rare (Klápště, 2012). Therefore, it may be grossly misleading to use dates obtained from written sources for settlement dating: a settlement can be first recorded in written sources many decades or even centuries after its real origin – and the time lag is unknown (Žemlička, 2014). Historians have suggested that the length of the time lag was probably affected by the geographical position within the country (centres *vs.* marginal regions) (Žemlička, 2014).

Archaeological dating involves dating objects, features or layers found during archaeological excavations or during a survey. The methods of archaeological dating differ according to the nature of the data that are used. The most frequent method works with chrono-typological dating transformed into a time interval with a uniform probability distribution by assigning calendar dates to the beginning and end of the interval, on the basis of external evidence (Lyman and O'Brien, 2006). The second approach comprises exact methods (radiocarbon, dendrochronology etc.) where dates are represented with a certain level of probability (Aitken, 1990; Demján and Dreslerová, 2016). The widely-used archaeological chrono-typological method is very approximate, usually only assigning a date within a centennial interval for the medieval period. By contrast, chrono-typological models based on current multivariable approaches to medieval ceramics can offer more precise and more accurate chronology (Čapek, 2010; Macháček, 2010).

While an archaeological record offers high probability that the real date of origin of a settlement has been captured, not every settlement has been excavated. A further disadvantage of this method is its inaccuracy, which reflects the characteristics of the specific dating methods. E.g. when based on chrono-typological ceramics dating, archaeological dating anchors human activity and behaviour into a settlement space, but only within a centennial interval, and in lucky cases within a part of a century (Kuna et al., 2004). Other dating methods (e.g. radiocarbon dating or dendrochronology) provide much narrower probability intervals, but these methods became widely used only relatively recently. The differences between historical dating and archaeological dating are well known in the archaeological community (Blain et al., 2011; Černý, 1992; Klápště, 2012; Kuna et al., 2004; Sadravetzová, 2015; Szabó et al., 2017; van Beek et al., 2014).

However, an extensive literature search and discussions with relevant experts have pointed us toward only few studies that have investigated the exact relationship between these two types of dating. Two exceptions are a paper by van Beek et al. (2014), which however has a sample consisting of just 10 villages/farms, and an unpublished master thesis about the early medieval settlement development in Northwest Bohemia (Kraus, 2017). There is a lack of studies dealing with the high medieval transformation. Other studies have dealt with this topic as a secondary objective, but mostly on the basis of either local data, or pure speculation only (Černý, 1992; Sadravetzová, 2015). Černý (1992) performed a local study of 61 deserted medieval villages in the eastern part of the present-day Czech Republic, and claims that the time lag in historical dating is usually 50 years, and in exceptional cases 100 years. Other studies have shown that the time lag for a medieval village or building can be almost 150 years (Houfková et al., 2015) or even two centuries (Blain et al., 2011; Parkman et al., 2015). Examples from the Netherlands suggest that the time lag may vary between 50 and 300 years (van Beek et al., 2014).

Žemlička (2014) associates a long lag in historical dating with villages located outside monasterial territories or far away from the intersections of major communications, and also with small hamlets or villages owned by indigent lesser nobility. He also claims that most of the settlements were captured in written sources as late as at the end of the 14th century. This is in accord with Boháč (1987), who identifies the 13th and 14th centuries as a period with a rapid increase in the number of written documents in the Czech lands. The time lag may have been influenced by the fact that it was not usual to make written records about the organization of ordinary communities and communications in the 12th and 13th centuries (Bartlett, 1994). Klápště and Smetánka (1998) underline that the “need to register transfers of landed property” did not emerge until the mid-14th century. Cases when the written sources pinpoint the real foundation date of a settlement are quite rare (Měřínský, 2014; Profous and Svoboda, 1957). Since Klápště (2012) described the colonization process as very complex and very complicated with many exceptions and many regional variances, we expect that similar differences (spatial, temporal, regional etc.) can also be observed in the time lag pattern.

The existence of the time lag is generally known in the archaeological community, but studies have only focused on small samples or micro-regions so far. A broader overview with generally valid results is missing. In our paper, we want to fill this gap and find general patterns (if there are any). Based on the previous observations on the settlement history of the study area, we hypothesize that the time lag was mainly determined by the age of establishment of a settlement, and is also affected by environmental conditions (e.g. altitude, topography, landscape typology), previous settlements as well as by distance to centres/main roads. As a secondary objective, a comparison between historical and archaeological dating of historical settlements could also help us to answer the following questions: To what extent is historical dating accurate/reliable (or: What is the typical time lag of a settlement's historical dating)? How much has this time lag varied through the centuries? Is it possible to specify a time point at which historical dating becomes a reliable measure? Has the time lag been affected by any geographical factors (e.g. altitude, or distance from the capital city or from a monastery) or by settlement status (towns vs. villages)? Based on the known time lag for different centuries, will it be possible to derive a relation which could be used for estimating the real date of origin for places with no archaeological data? To answer these questions, we use an extensive dataset on historical and archaeological dating of hundreds of settlements spread over the whole Bohemian region (part of the Czech Republic).

2. Materials and methods

2.1. Data collection

The area selected for an analysis of this type should fulfil the following stratification requirements: (1) historical and archaeological dating must be available in sufficient quality, (2) the settlement structure in the analysed area should be strongly affected by medieval transformation and also by (early) modern transformation, and (3) there should be various environmental or geographical gradients to indicate the expected effect of environmental conditions. Within Central Europe, the region of Bohemia in the Czech Republic provided a suitable setting for a case study.

Archaeological data were obtained from *The Archaeological Database of Bohemia* (Institute of Archaeology of the Czech Academy of Sciences Prague, 2013), which provided us with 53 953 records from archaeological researches carried out in the Czech Republic with findings from the medieval age and the modern age. The archaeological dating is not expressed in exact years, but in centuries or other intervals. We selected only settlements dated to a specific century or more precisely (more extensive information about the archaeological data – including the type of human activity, the type of archaeological research and links to original records in the database – is available in Supplementary

Information). We excluded settlements dated by inaccurate research methods (e.g. building archaeology and undocumented research). Only data supported by accurate and trustworthy research methods (e.g. excavation, profile, trench, field survey) were used for further analysis. The selection resulted in 527 settlements with archaeological dating between AD 850–1600 (there are very few archaeological data after AD 1600). In the statistical analyses, we refer to the archaeological dating interval simply as the *archaeological date*.

Although the careful restriction of the dataset has greatly improved its reliability, it is worth noting that some systemic errors may have remained, resulting from different authors, different types of research, absence of context, etc.

At this point, it is necessary to consider the ability of archaeological data to capture the time of the real origin of a medieval settlement. In the Czech Republic, in a region lying to the north of the *Limes romanus*, we can distinguish two "settlement zones": an "ancient settlement zone", almost continuously inhabited since the Neolithic period, and "colonization areas", which were (mostly) settled in the medieval and post-medieval period. In the ancient settlement zone, the true date of settlement areas could theoretically lie in the Neolithic period, in some cases in the Mesolithic period (Beneš and Zvelebil, 1999). However, this zone is characterized by a high level of building activity in recent decades, which dramatically increases the probability that the task of detecting medieval components will be complex. In the colonization areas, medieval villages were established in an almost virgin landscape. To conclude: we cannot exclude the possibility that a medieval village is older than its archaeological dating, but the probability of this can be considered to be very low.

Since archaeological dating is expressed in dating intervals, we sometimes use the midpoint of the archaeological dating interval (*archaeological dating midpoint*) as a proxy for the real foundation date in our statistical analyses.

The *historical date* for all 527 settlements was largely obtained from *The Historical Lexicon of Municipalities* (Růžková et al., 2006); in a few cases, we used data from other historical lexicons and encyclopaedias (Kuča, 2011, 2008, 2004, 2002, 2000, 1998, 1997; Profous, 1951, 1949, 1947; Profous and Svoboda, 1957). (These lexicons and encyclopaedias are editions of historical sources; the primary sources are original historical documents, usually from the medieval age or the early modern age.)

To test the role of local conditions, we examined several environmental/geographical predictors. The *altitude* and *terrain undulation* (the average slope in a circle with a radius of 4 km) were extracted from the SRTM digital elevation model (GISAT, 2007). The *landscape typology* was adapted from a classification by Chuman and Romportl (2010), coarsened to five landscape types (Table 1). The extent of the *"ancient settlement area"* (i.e. the area inhabited almost continuously since the Neolithic) was taken from (Löw and Novák, 2008). We measured *distance from the capital* (Prague), *distance from the nearest major town* and *distance from the nearest monastery* at the time of the settlement foundation (proxied by *archaeological date midpoint*). The major towns in different periods were obtained from Hoffman (2009), Hrnčiarová et al. (2009), Müller (1720) and Purš (1965). The data about monasteries were compiled from Hrnčiarová et al. (2009) and Purš (1965). We also measured the *distance from the nearest major road*; for this purpose, we used the map of historical roads by Žemlička (2007). Similarly, we measured the *distance to the nearest major river*; the following rivers are classified as "major": the Vltava, Labe, Ohře, Berounka, Sázava, Dyje, Morava and Svratka. River data were obtained from the T. G. T. G. Masaryk Water Research Institute (2012). For distinguishing the *settlement status* (towns versus villages), we used the encyclopaedia of Czech towns (Kuča, 2011; 2008, 2004, 2002, 2000, 1998, 1997, 1996); settlements promoted to towns after the start of the industrial revolution (roughly 1800 AD) have been marked as "villages" in our database (because they really were villages during the period under study). The data were processed in *QGIS 2.18.15* and *ArcGIS 10.5.1* Geographical information system softwares (ESRI, 2017; QGIS Development Team, 2017).

Table 1
Landscape types used in the analysis. Classification by Chuman and Romportl (2010).

Categories of landscape type	Category	N	Landscape description
Moderately warm to warm downs predominantly up to 500 m a. s. l.	8	202	Elevation: 450–500 m, mean annual temperature: 7–8 °C, current land use/cover: mixed forest
Moderately warm downs and hilly lands extending between 250 and 750 m a. s. l.	6 and 7	194	Elevation: 450–500 m, slope: 0–2°, mean annual temperature: 7–8 °C, reconstructed natural vegetation: acidophilous oak forest, current land use/cover: non-irrigated arable land
Warm to very warm flat to gently sloping lowlands and downs up to 500 m a. s. l.	9, 10 and 11	121	Elevation: less than 450 m, mean annual temperature: 9–10 °C, soil type: chernozems
Cold to moderately warm uplands, hills and mountains	4 and 5	7	Elevation: 500–1000 m, mean annual temperature: 4–6 °C, soil type: cambisols or entic podzols, reconstructed natural vegetation: herb-rich beech forest or mountain acidophilous beech forest

2.2. Data analysis

The focal point of our analyses is the degree of concordance between the *historical date* and the *archaeological date* of the settlements. Two different aspects of this relationship are addressed. Firstly, we study the probability that the *historical date* is contained within the archaeological interval. If this is the case, we have no evidence of a time lag in the historical dating; we define a dichotomous *overlap* variable to identify these cases in our data. Secondly, we analyse the typical length of the time lag in the historical dating, proxied by the difference between the historical date and the archaeological date of the settlements: *time lag* = max(*historical date* – *archaeological date*, 0). Since the *archaeological date* is an interval variable, time lag is also an interval variable; in the event of an overlap between the historical date and the archaeological date, the lower bound of the *time date* is set to zero, i.e. the *time lag* intervals are all nonnegative.

A preliminary analysis confirmed the intuitive expectation that both the occurrence and the length of the time lag evolved rapidly over time. Therefore, the first part of our quantitative analysis is devoted to a detailed inspection of how the time lag varies with the foundation date of the settlements (proxied by the *archaeological date midpoint*). The nature of the relationship between these variables is assessed using a series of scatterplots with smoothed trend lines.

In the next stage, we use regression analysis to identify the settlement characteristics that can help predict the occurrence and the size of the time lag. First, we study the determinants of the *overlap* indicator using multiple logistic regression. Next, we analyse factors influencing the *time lag*; due to the interval nature of this variable, we use a modification of multiple linear regression designed for interval dependent variables, see (StataCorp, 2017: 1128–1140) for details on the implementation.

Several variables exhibited considerable positive skewness (*distance from the nearest major town*, *distance from the nearest major road*, *terrain undulation*); these variables were logarithmically transformed before all statistical analyses. The variable *distance from the nearest monastery* was the only one that contained missing values, in approx. 13 per cent of the observations. In regressions that contained this variable, we applied the multiple imputation procedure in order to both (i) increase the efficiency of the estimates and (ii) avoid the potential adverse effect of non-random assignment of missingness. One hundred regression-based imputations were used for this purpose, with all other variables included in the conditional distribution of *distance from the nearest monastery*.

The regression analyses were performed in *Stata 15.1*. All scatterplots with smoothed trends were created in *R 3.5.2,* using the *ggplot2* package, version 3.1.1 (Wickham, 2016).

3. Results

Table 2 summarizes the statistics of all variables except the categorical predictor *landscape type*. Pairwise correlations (Table 2 and Table S1) confirmed the importance of the *archaeological date midpoint* as a strong predictor of both *overlap* and *time lag*, and identified as other potential predictors the variables *settlement status* and *distance from the nearest major town*. These preliminary results were confirmed by the regression analyses presented in Table 3. Due to excessive multicollinearity, we dropped the variable *altitude* from the list of predictors, as it scored the highest variance inflation factor (VIF) among all numeric predictors (max. VIF = 5.77, mean VIF = 2.06 in an analogue to Model 1 from Table 3 which also contained *altitude*), mainly because of its correlation with *terrain undulation* ($r = 0.56$, the slopes were usually large in the highlands) and *old settlement area* ($r = -0.67$, older settlements were typically found in the lowlands). Dropping *altitude* reduced the VIFs to tolerable values (Table 3). Moreover, due to the issue of missing values in *distance from the nearest monastery*, we ran all regressions both with and without this variable.

Apart from *archaeological date midpoint*, the only significant predictors of time lag occurrence and length (Table 3) were: (i) the *distance from the nearest major town* (positive effect, i.e. greater distance makes the lag more likely and longer on an average) and (ii) *settlement status* (villages have a longer and a more probable lag than towns). No other predictors affected *time lag* significantly.

While the effect size for *settlement status* is substantial, the effect of *distance from the nearest major town* is much less pronounced. The coefficient estimates reported in Table 3 imply that the odds of an overlap between historical and archaeological dating for towns are nearly 4 times as great as the odds for villages ($e^{\beta} = 3.86$ in both Model 1 and 2), and the predicted time lag is more than 66 years shorter for towns ($\beta = -66.85$ in Model 3, $\beta = -66.48$ in Model 4), with other explanatory variables being held constant. If the distance from the nearest major town doubles, the odds of an overlap decrease by 16 percent ($2^{\beta} = 0.84$ in Models 1 and 2) and the expected time lag increases by only slightly over 3 years ($\ln(2)\beta = 3.27$ in Model 3, $\ln(2)\beta = 3.53$ in Model 4).

The typical time lag decreases with increasing *archaeological date midpoint*, a relationship dealt with in detail in Figs. 1–3. Settlements archaeologically recorded in early medieval times (10th to 12th centuries) have an estimated time lag of 112–338 years (Fig. 1B), depending on the actual archaeological date; the range is 63–229 years in the subsample of towns, and 130–392 years in villages (Fig. 2B). In the high medieval and modern ages (13th to 16th centuries), the predicted time lag varies between 54 and 112 years (13–63 years for towns, 83–130 years for villages). It should be noted, however, that the data exhibit considerable unexplained variance throughout the study period.

The predicted probability of an overlap between historical and archaeological dating grows steadily throughout the study period (Fig. 1A). It reaches 50% around AD 1350 (AD 1190 for towns, and AD 1420 for villages). Towards the end of our study period (AD 1600), the probability of an overlap increases to approx. 70% (97% for towns and 25% for villages, though the confidence interval for villages is very wide, due to the sparseness of the observations).

The 13th century is, generally speaking, characterized by a boom in first mentions of settlements in written records. However, the real situation was different, as Fig. 4 shows. Many places are dated back to the 13th century by written sources, indicating that a proportion of them had in fact been established in earlier centuries than that. Later, in the 14th century to 16th century, written sources became increasingly reliable for settlement dating.

Fig. 5 shows the spatial pattern of the historical dating (map A), the *archaeological date midpoint* (map B) and of the lag in historical dating, approximated by the midpoint of the *time lag* interval (map C); the interpolation was calculated by the *Simple Kriging* interpolation tool in SAGA software 2.1.4 (Conrad et al., 2015). Large continuous regions in either red or blue color document a degree of spatial correlation. The comparison of such regions in maps B and C points towards the relationship between the age of a settlement and the time lag in its historical dating. Relatedly, map D indicates areas where a *time lag* cannot be explained solely by the age of the settlement: it shows the residuals from a regression of the midpoint of the *time lag* on a natural cubic spline of the *archaeological date midpoint* with a knot in 1250.

4. Discussion

The growth of historically dated settlements in the 13th and 14th centuries corresponds well with the increase in manuscript production in Bohemia (Fig. 4). The increased manuscript production could also be responsible for the decrease in the time lag in the 12th to 14th centuries (Fig. 4B), as has been suggested by Boháč (1987). Szabó et al. (2017) wrote that the growth in the number of written documents throughout the middle ages reflects a rise in literacy.

Our results correspond with Bartlett's (1994) findings about "fewer

Table 2
Descriptive statistics and selected pairwise correlations.

	N	Mean	SD	Min	Max	Pairwise correlation 1.	2.	3.
1. *Time lag*, lower bound [years]	521	75.53	102.6	0	575	1.00		
2. *Time lag*, upper bound [years]	521	148.4	118.2	0	675	0.97*	1.00	
3. *Overlap* [1 = yes, 0 = no]	521	0.367	0.482	0	1	−0.56*	−0.64*	1.00
4. *Archaeological date midpoint* [years]	521	1242.5	132.0	850	1600	−0.51*	−0.52*	0.29*
5. *Settlement status* [1 = town, 0 = village]	521	0.250	0.433	0	1	−0.21*	−0.23*	0.24*
6. *Distance to nearest major town* [m, logged]	521	8.988	1.529	0.785	11.31	0.17*	0.19*	−0.22*
7. *Terrain undulation* [°, logged]	521	1.124	0.548	−0.661	2.471	−0.10*	−0.12*	0.10*
8. *Ancient settlement area* [1 = yes, 0 = no]	521	0.332	0.471	0	1	0.09*	0.08	−0.08
9. *Distance from the nearest monastery* [100 km]	454	0.178	0.105	0.0002	0.571	0.09	0.05	0.01
10. *Distance from the capital* [100 km]	521	0.826	0.375	0.0210	1.723	−0.07	−0.06	0.04
11. *Distance to nearest major river* [100 km]	521	0.153	0.123	0.0017	0.565	0.07	0.05	−0.02
12. *Altitude* [m]	521	369.3	126.6	133	1068	−0.07	−0.07	0.05
13. *Latitude* [100 km in Křovák projection]	521	−10.63	0.539	−12.06	−9.484	0.06	0.03	−0.04
14. *Longitude* [100 km in Křovák projection]	521	−7.268	0.683	−8.970	−5.854	−0.03	−0.04	−0.00
15. *Distance to nearest major road* [m, logged]	521	8.653	1.241	2.943	10.63	−0.02	−0.05	−0.01

Notes: (i) Explanatory variables are sorted by their correlation with *time lag*, lower bound (descending order). (ii) *$p < 0.05$.

Table 3
The effects of environmental and geographical predictors on the occurrence of and the length of the time lag in historical dating (regression results).

Dependent variable:	*Overlap* [1 = yes, 0 = no]		*Time lag* [years, interval]	
Regression model:	Logistic regression		Interval regression	
	Model 1	Model 2	Model 3	Model 4
Settlement status [1 = town, 0 = village]	3.856*** (0.960)	3.855*** (0.961)	−66.85*** (7.509)	−66.48*** (7.518)
Distance from the nearest major town [m, logged]	0.776*** (0.0518)	0.776*** (0.0517)	4.715* (2.242)	5.090* (2.257)
Terrain undulation [°, logged]	1.259 (0.353)	1.250 (0.354)	−2.417 (9.185)	0.491 (9.475)
Ancient settlement area [1 = yes, 0 = no]	0.832 (0.311)	0.820 (0.317)	−14.33 (12.98)	−8.610 (13.20)
Distance from the nearest monastery [100 km]		0.785 (0.917)		93.07 (49.77)
Distance from the capital [100 km]	0.609 (0.231)	0.614 (0.233)	13.49 (12.76)	10.23 (13.04)
Distance from the nearest major river [100 km]	0.522 (0.502)	0.529 (0.514)	57.04 (38.89)	52.24 (39.05)
Latitude [100 km in Křovák's projection]	0.848 (0.213)	0.861 (0.225)	6.590 (8.152)	0.506 (8.664)
Longitude [100 km in Křovák's projection]	0.902 (0.185)	0.899 (0.185)	2.514 (6.294)	4.199 (6.431)
Distance from the nearest major road [m, logged]	0.938 (0.0887)	0.940 (0.0897)	2.956 (3.208)	1.865 (3.260)
Landscape type				
• Moderately warm to warm downs predominantly up to 500 m a. s. l.	ref.	ref.	ref.	ref.
• Moderately warm downs and hilly lands extending between 250 and 750 m a. s. l.	0.778 (0.225)	0.777 (0.225)	−3.610 (10.32)	−3.618 (10.31)
• Warm to very warm flat to gently sloping lowlands and downs up to 500 m a. s. l.	1.019 (0.403)	1.012 (0.399)	2.899 (13.23)	5.677 (13.27)
• Cold to moderately warm uplands, hills and mountains	1.733 (1.499)	1.771 (1.533)	34.08 (44.76)	26.77 (42.92)
N	521	521	521	521
No. of imputations (no. of imputed values)		100 (67)		100 (67)
p(*archaeological date midpoint*)	<0.0001	<0.0001	<0.0001	<0.0001
p(*landscape type*)	0.641	0.628	0.826	0.845
Max. VIF	3.042		3.042	
Mean VIF	1.648		1.648	

Notes: (i) For logistic regression (Model 1 and 2), exponentiated coefficients (odds ratios) are reported. (ii) Heteroskedasticity-robust standard errors (based on the Huber-White sandwich variance estimates) are shown in parentheses. (iii) All regressions contained among the explanatory variables a natural cubic spline of *archaeological date midpoint* with a knot in 1250; only a *p*-value indicating a joint significance of all related terms is reported, in row *p*(*archaeological date midpoint*). (iv) Similarly, *p*(*landscape type*) indicates joint significance of all landscape dummies. (v) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

written records being made" in the 12th and 13th centuries. The growth in the time lag in the 15th and 16th centuries apparently reflects lower availability of archaeological data for that period. The length of the time lag observed in our data is similar to the results of van Beek et al. (2014). However, the time lag is much longer than that predicted by Černý (1992). In contrast with Žemlička's (2014) findings, the time lag did not disappear at the end of the 14th century. Towns and villages of early-medieval origin that are also close to major towns have a slightly shorter time lag than villages and settlements in remote areas (Fig. 3, Table 3). Similarly, settlements in marginal areas (*landscape type* "cold uplands and mountains") have a significantly longer time lag than settlements in central areas (Table 3). In the high medieval period (11th to 13th century), the mean time lag was approximately 40–125 years for towns, and 100–250 years for villages (Fig. 2). This is in accord with Žemlička (2014), who expected small settlements and settlements in distant or marginal areas to have a greater time lag. This could be due to the lower importance of such places for the ruling class, or for other people who were responsible for the written records, or due to a lower intensity of written communication in more remote and less important areas.

For more recent historical periods, historical dating is definitely more reliable than for the early medieval period, but there is still a considerable risk of a time lag. When working with historical dating from the middle ages, researchers should take its inaccuracy into account. Historical dating is an important historical source of knowledge about the date of settlement origins, but due to its unreliability each case should be considered individually. It should be compared with other geographical factors (as was suggested by van Beek et al., 2014) and above all with direct archaeological dating (Bellanger and Husi, 2012). We cannot recommend the use of historical dating alone as a sufficiently reliable source for "big data" computations, at least for the middle ages. However, the more recent the centuries that we look at, the more precise and the more reliable data is available, and the greater the opportunities are to use this data in various fields of science.

The dispersion of the prediction interval covers extremely long periods: from almost 400 years for the 16th century to 250 years for the 12th century (the horizontal distance in Fig. 4A). Unfortunately, this does not help us to date a settlement more precisely.

Historical dating is characterized by good availability but high irregularity. Even the growth in the quantity of written documents in early modern times (Buringh and van Zanden, 2009) does not guarantee the reliability of this source. There are examples of settlements from the 15th century that were not captured by written sources until 100 years later (Fig. 4A). Unfortunately, even if the time lag probability, e.g. for the 16th century, is "just" 30% (Fig. 1A), this does not give us the right to believe that a written source from the 16th century is reliable for dating a settlement. Conversely, many settlements captured in written sources in the 16th century were recorded by the archaeological dating between the 13th century and the 15th century, and only some of them were recorded by archaeological dating in the 16th century (Fig. 4). The situation is much worse for older times.

The problems with archaeological dating are substantially different. Archaeological dating can involve either exact dating or chrono-typology, nowadays in sophisticated forms using developments in statistics (Bellanger and Husi, 2012). In historical settlements, dendrochronology is mostly associated with younger historical buildings, which have limited applicability for entire historical settlements. Radiocarbon dating offers reliable data, but the intervals can be almost as long as in chrono-typology. Other methods are rarely used in archaeology. Despite the problems with archaeological dating, the results are usually reliable. The large bias in the quality of archaeological dating is probably caused by the uneven quality and quantity of the results from region to region (Klápště, 1989). In regions with a long tradition of archaeological research, archaeological dating is likely to be statistically more reliable than in regions without this tradition. This concerns especially mountainous/upland regions that were colonized in the high medieval period, some of them also in the early modern period, e.g. upper parts of the Šumava mountains (Beneš, 1996). Other problems with archaeological dating can arise when scientists want to identify the archaeological findings to historical settlements mentioned in written sources (this especially concerns towns).

Some authors (Sadravetzová, 2015; Szabó et al., 2017) admit the existence of a time lag, but in their work they treat historical dating as if it were a reliable source that can be used for drawing graphs and for statistical computation. That is to say, they attempt to carry out

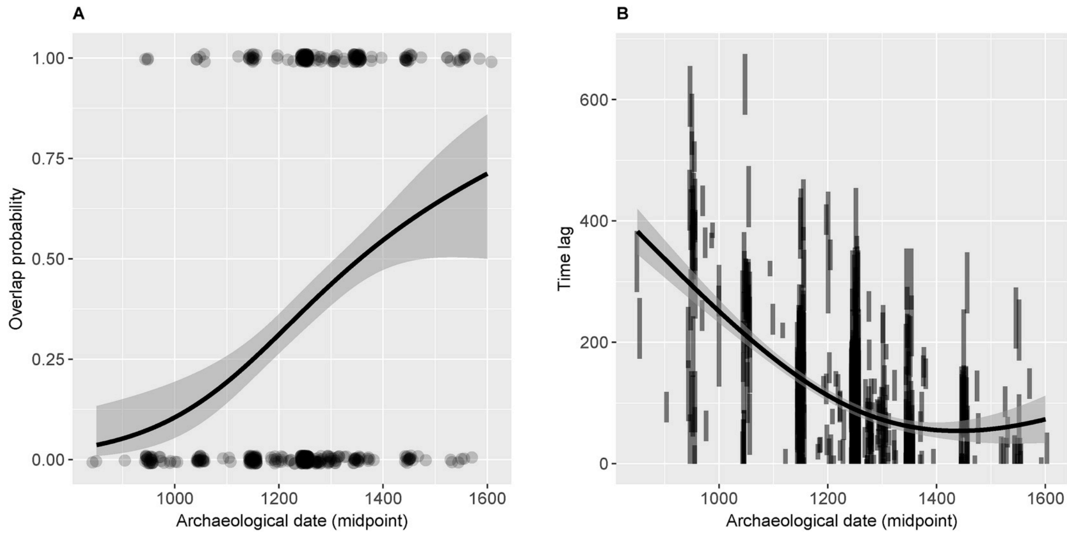

Fig. 1. (**A**) Scatterplot of the *overlap* indicator (1 = overlap between historical and archaeological dating, 0 = no overlap) against the *archaeological date midpoint*; the points are jittered to enhance readability. The curve shows the overlap probability, predicted by logistic regression of *overlap* on a natural cubic spline of the *archaeological date midpoint*, with a knot in year 1250, the sample median of *archaeological date midpoint*. The shaded area shows the 95% confidence interval for the predicted probability. (**B**) Scatterplot of *time lag* against *archaeological date midpoint*. The curve (and the shaded area) shows a least-squares fit of the relationship (and its 95% confidence region), again using a natural cubic spline of *archaeological date midpoint* with a knot in year 1250.

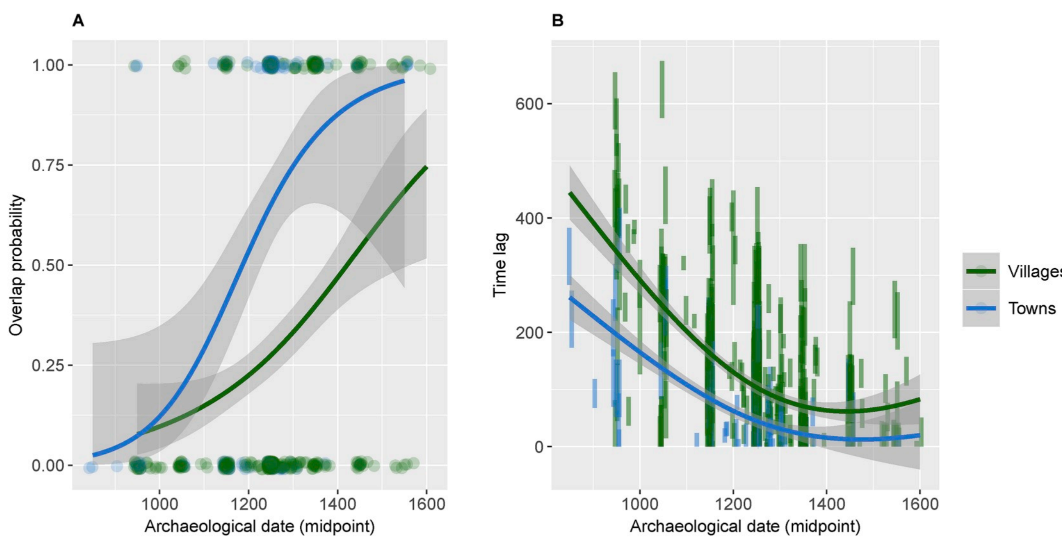

Fig. 2. The effect of *settlement status* (towns versus villages) on the relationship between *time lag* and *archaeological date midpoint*. The two plots are analogous to those in Fig. 1, only that villages and towns are now separated, and are shown in different colours (see the caption of Fig. 1 for more details). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

extremely precise work with data that is extremely imprecise (as we show in this paper). It is necessary to take all the irregularities and disadvantages of historical dating into account when analysing and interpreting such data – it really does not make sense to use historical dating for precise computations. It is also important to note that our conclusions were derived from the settlement history of Central Europe, specifically in an area in the western part of the present-day Czech Republic. Outside of this region, the relationship between historical dating and archaeological dating may different from what we present in this paper. E.g. Adams (2003) stated in his paper dealing with North America in the 19th century that historical dating is often the most precise way of dating settlements, and should be used in preference to archaeological dating. This example suggests that the validity of our results is spatially and temporally limited.

Fig. 5 indicates that in some areas (e.g. in the Labe valley in NW Bohemia and part of SW Bohemia), the time lag can be explained by the early origin of the settlements: the sites in these regions were established in the early medieval period, and it took a long time to log the towns and villages into the written records. However, in many other areas, the time lag (or the absence of a time lag) cannot be explained just by the date when a settlement was established – it must have been caused by other factors. For example, in the Bohemian-Moravian Uplands and in Eastern Bohemia, settlements were founded in early medieval times, but the time lag is (counterintuitively) very short. In such situations, the (low) availability of data, and also historical reasons, may have played a role: zones close to major communications, regions owned by the German Empire, mining areas, monastery activities or the colonization of "virgin" regions in periods when written sources were expanding may have attracted a greater density of written records. We suggest that it may be an interesting task for historians to look at these regions and to try to find out why the deviation from the "age of a settlement – time lag" pattern is so great there.

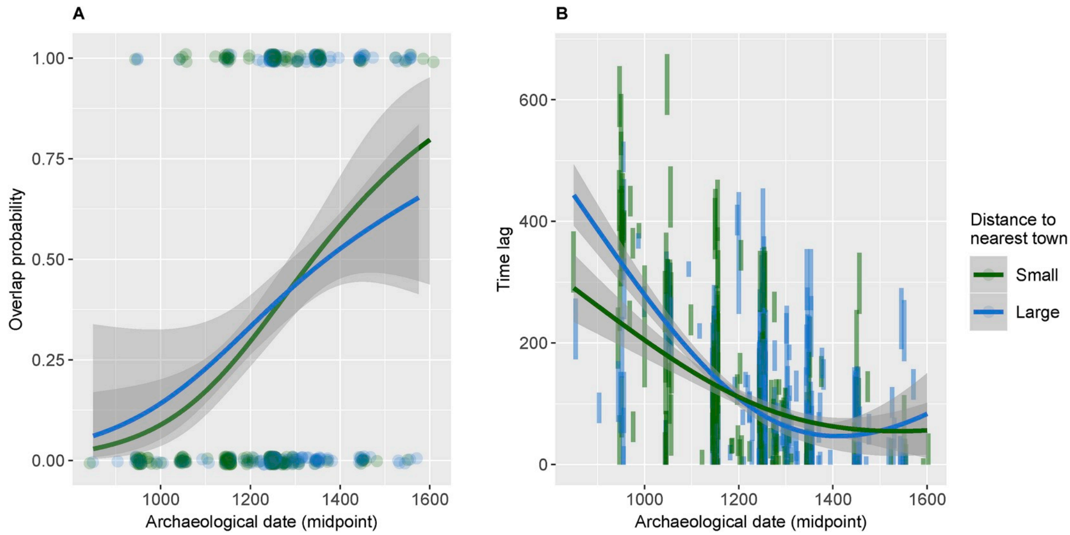

Fig. 3. The effect of *distance from the nearest major town* on the relationship between *time lag* and *archaeological date midpoint*. The two plots are analogous to those in Fig. 1, only that settlements that are a short distance away from a town (1st and 2nd quartile) and settlements that are a long distance away from a town (3rd and 4th quartile) are now separated, and are shown in different colours (see the caption of Fig. 1 for more details). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

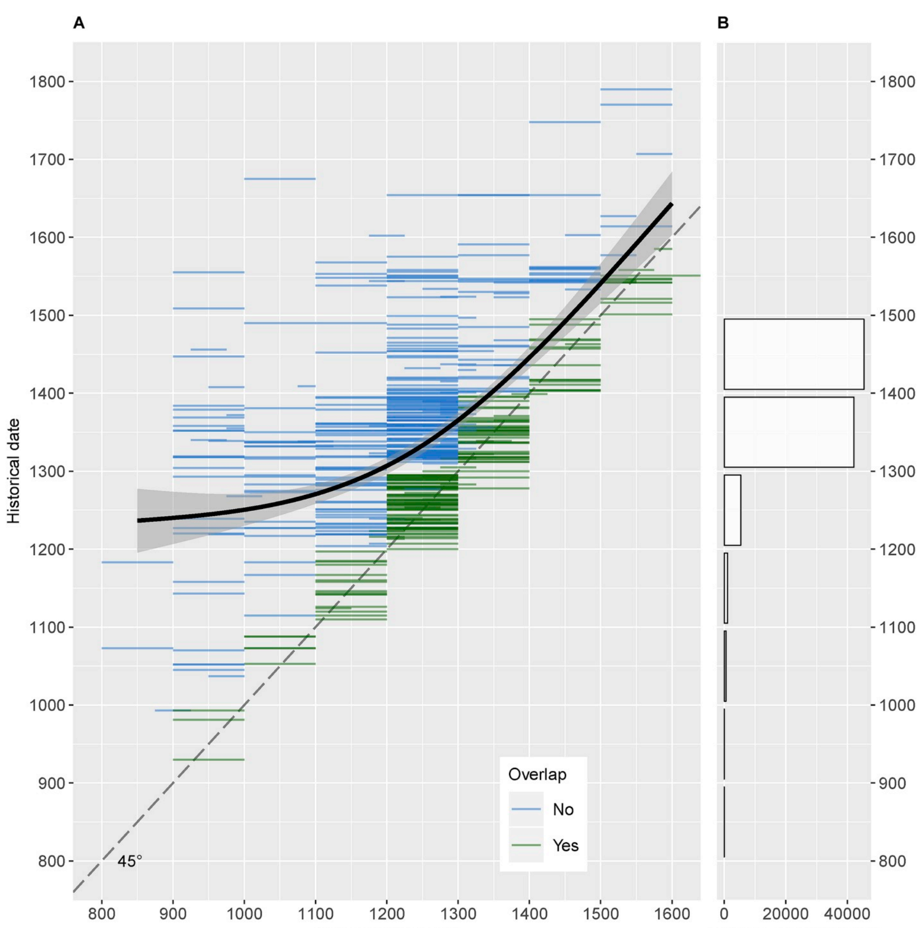

Fig. 4. (**A**) A plot of the *historical date* against the *archaeological date* of all settlements in the sample (the horizontal line segments indicate the span of the archaeological dating intervals). Whenever the line segment intersects the 45° line, *overlap* = 1; such cases are distinguished by green colour. *Time lag* is equal to the nonnegative horizontal from the 45° line. The black curve shows a least-squares fit of the historical-versus-archaeological dating relationship, using a natural cubic spline of the *archaeological date midpoint* with a knot in year 1250 (the sample median); the shaded area shows the 95% confidence region. (**B**) Manuscript production in Bohemia, 9th–15th century AD. Source: Buringh and van Zanden (2009). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Our results may have also implications for the study of historical landscape development, as archaeological dating of settlements shifts the perceived timing of landscape transformations (e.g. medieval colonization) to earlier centuries.

5. Conclusion

The historical dating of towns and villages includes important and unique information about settlement and landscape history. However,

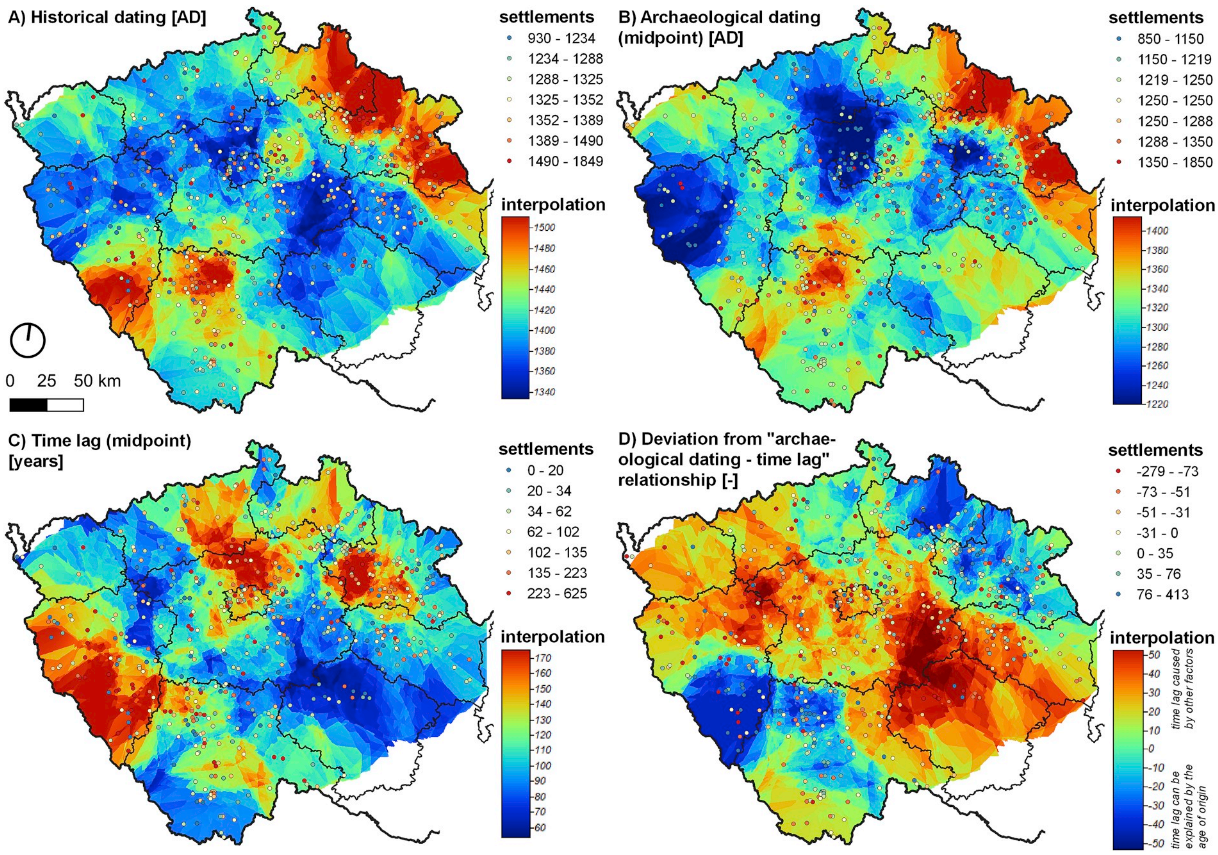

Fig. 5. Maps showing the spatial pattern of (A) historical dating, (B) the *archaeological date midpoint*, (C) the midpoint of the *time lag* interval and (D) the deviation from the "*archaeological date midpoint – time lag midpoint*" relationship. In map (D), blue colour indicates that the time lag can be explained by the age of origin (early medieval period → longer time lag, modern ages → shorter time lag), while red colour indicates that there was some other cause of the length of the time lag. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

historical dating of medieval towns and villages is characterized by high dispersion of the data, including a time lag of as much as 100 or even 200 years. Our study has provided the first statistical comparison between historical dating and archaeological dating on a solid sample of 527 historical settlements in the Czech Republic, which has allowed us to confirm the expectations of previous studies and to broaden their validity. Our results demonstrate the limits of historical dating or the first mention of the site in a written record: in central Europe, historical dating is surely useful for a rough estimate of the origin of individual settlements, but having in mind the time lag, and perhaps for micro-regional studies. However, historical dating is hardy useful for statistical and other precise work with "big data", since it carries overwhelmingly huge errors (especially in the pre-modern period, Figs. 1–5). We do not want to say that written sources are generally useless, but when deriving the date of origin of a settlement from written sources, the existence of the time lag should be kept in mind.

The probability of a time lag in historical dating has decreased with increasing calendar year (this corresponds with the increasing production of manuscripts/written sources in the course of history; Fig. 4), but the probability remained nonzero even at end of the 16th century. Towns and settlements located close to major towns had a shorter time lag, as these places were probably more important for the central and regional lords (the monarch/nobility/clergy) and/or there was greater intensity of written communication. The historical dating of medieval settlements may therefore reflect not so much the colonization of the landscape, but an increase in manuscript production (and indirectly the level of literacy, together with the intensity of communication).

We want to stress that our results may have a regional limitation. Our study also reveals the possibilities of an extensive data approach: we have shown how the data from regional studies fit into the broader pattern of the whole country; and we have also pointed to several deviations (Fig. 5D), which may become a topic for future research.

Data availability

All data are available in the electronic supplementary material, Dataset S1.

Authors' contributions statement

V. F., J. Z. and P. S. designed the research, V. F. collected the data, J. Bumerl and J. Beneš checked the data quality, J. Z. performed the data analyses, and V. F., J. Z., P. S., J. Bumerl and J. Beneš wrote the paper. All authors reviewed the manuscript.

Declaration of competing interest

The authors have no competing interests.

Acknowledgements

We would like to thank Milena Hauserová for suggesting this topic, Dagmar Dreslerová for her critical comments, Stephanie Krueger for language assistance, and Martin Kuna for providing the archaeological data for us. We also thank Robin Healey for his critical comments and for language editing the text of the manuscript.

This paper was supported by the Internal Grant Agency of the Faculty of Environmental Sciences, CULS Prague, Grant No. 4219013123114

"Use of the Archaeological database of Bohemia in a study of the influence of environmental conditions on cultural landscape evolution in the past". The research also received funding from Czech Science Foundation project GA17-07544S.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2019.105044.

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