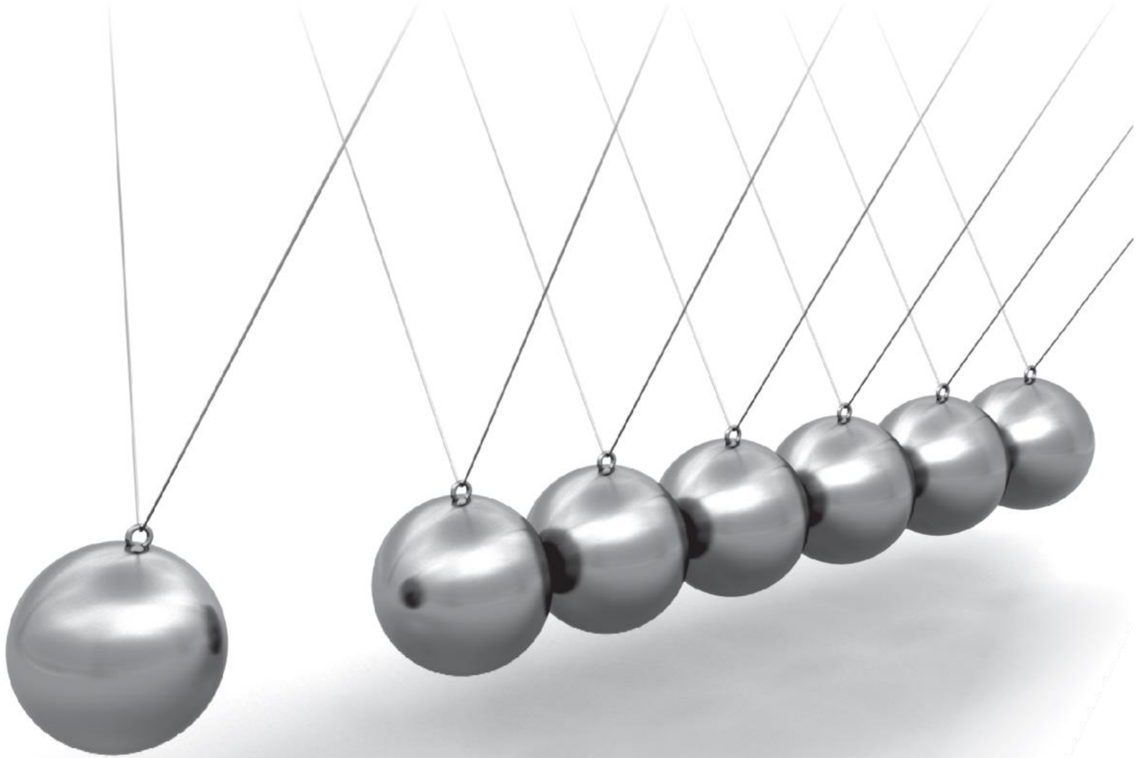
HUMANS AND SOCIETY IN TIMES OF CRISIS

Archaeology of Crisis

Edited by Staša Babić



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CONTENTS

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Senka Plavšić**

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THE IMPACT OF THE CAMPANIAN IGNIMBRITE (CI) ERUPTION ON PALAEOLITHIC SETTLEMENT PATTERNS IN THE CENTRAL BALKANS

Abstract: The Campanian Ignimbrite eruption happened 39 ka ago. The magnitude and volume of tephra affected not only the regional but also the global climate and ecosystems. The aim of this study was to investigate the impact this eruption had on the settlement pattern of central Balkan Palaeolithic communities in the period between 45 and 35 ka cal BP. Based on the published data, we have conducted bivariate (WABI) and multivariate (PCA) analyses of the variables frequently used to access settlement patterns of prehistoric human populations. The results confirm that there was a change in the settlement pattern of Balkan Palaeolithic communities in the post-CI times, observable in the clear lack of residential or logistical sites, and a probable practice of a forager-like settlement model.

Keywords: CI eruption, settlement patterns, Balkan Peninsula, Middle and Upper Palaeolithic

Introduction

The Campanian Ignimbrite (CI) eruption represents the largest volcanic eruption in the Mediterranean area in the last 200 ka, as well as one of the most explosive eruptions in the Late Pleistocene. This catastrophic

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explosion of the Phlegrean Fields Caldera (near Naples, Italy) occurred 39.85 ± 0.14 ka cal BP (Giaccio et al., 2017). According to the estimated amount of emitted SO_2, the CI volcanic event is comparable to other super-eruptions, such as the Toba and Bishop Tuff events (Costa et al., 2012; Silleni et al., 2020). Even though it lasted only for about 2–4 days (Costa et al., 2012), eruptions like this can have severe consequences for ecosystems and both regional and global climates, causing a temperature drop known as "volcanic winter" (Fedele et al., 2002; Costa et al., 2012; Smith et al., 2016).

Having in mind the changes of global temperatures and the fact that tephra reduced the area available for human settlement by up to 30% (Marti et al., 2016), the aim of this study was to investigate the possible impact of the CI eruption on the organization and settlement patterns of the Palaeolithic communities in the Balkan region.

Variability in the settlement patterns of hunter-gatherers was described by Binford (1980, 1982) with the concepts of foragers and collectors (Kelly, 2013, p. 78). Both of these concepts rely on models of residential and logistical mobility patterns. Foragers employ more residential mobility patterns where the whole community often moves, establishing short-term residential sites next to suitable resources; however, the number of residential moves is highly variable. Extremely mobile foragers have highly ephemeral residential sites resulting in small amounts of deposited archaeological material (Binford, 1980). Collectors, on the other hand, practice more of a logistical model, where a task unit would set a camp in order to complete a specific task and then return to the base camp (Binford, 1980). The hunter-gatherers' settlement model depends on a multitude of natural factors, most prominently the availability of resources (Binford, 1980; Kelly, 1983). In this regard, changes in the environment and climate caused by a mega-eruption could also result in changes in the settlement patterns of Palaeolithic communities.

In order to investigate this hypothesis, we have chosen the territory of the Balkan Peninsula, between the Drina River to the west, the Danube to the north, the Black Sea to the east, the Adriatic Sea and the Rhodopes to the south, as the research area for several reasons. Firstly, this territory was most definitely affected by the CI eruption, as evidenced in the deposits of tephra and cryotephra recorded at several archaeological sites (Fig. 1). Deposits are documented at archaeological sites in Northern Macedonia (Golema Dupka – Lowe et al., 2012), Montenegro (Crvena Stijena – Morley, 2017), Bulgaria (Temnata Dupka – Ferrier, 2000; Kozarnika – Lowe et al., 2012) and Serbia (Tabula Traiana Cave – Borić et al., 2012). An almost 1-meter-thick deposit of tephra has been recorded in the Urluia basin in the Lower Danube region (Fitzsimmons et al., 2013), testifying to the strong impact of the CI eruption on the territory bounded by the Carpathian and the Balkan Mountains. This territory also includes well-documented Mousterian sites, fossils of early anatomically modern *Homo sapiens* (Trinkaus et al., 2003; Hublin et al., 2020), and Aurignacian sites, making it relevant to the goals of the present study.

Materials and Methods

This study is based on published data for 31 layers from 10 archaeological sites situated in the defined territory of the Balkans, all dated within the ~45–35 ka cal BP interval, around 5000 years before and after eruption (Fig. 1, Tab. 2). Layers and sites were grouped according to their chronologies into: 1) MP = Middle Palaeolithic (n = 19); 2) pre-CI UP = Upper Palaeolithic prior to the CI eruption (n = 7); and 3) post-CI UP = Upper Palaeolithic after the CI eruption (n = 5). Although available, the data for layer VI–trench II of Temnata Dupka (Bulgaria) was not included in the present study, due to the confirmed stratigraphic disturbance of the layer (Tsanova, 2008).

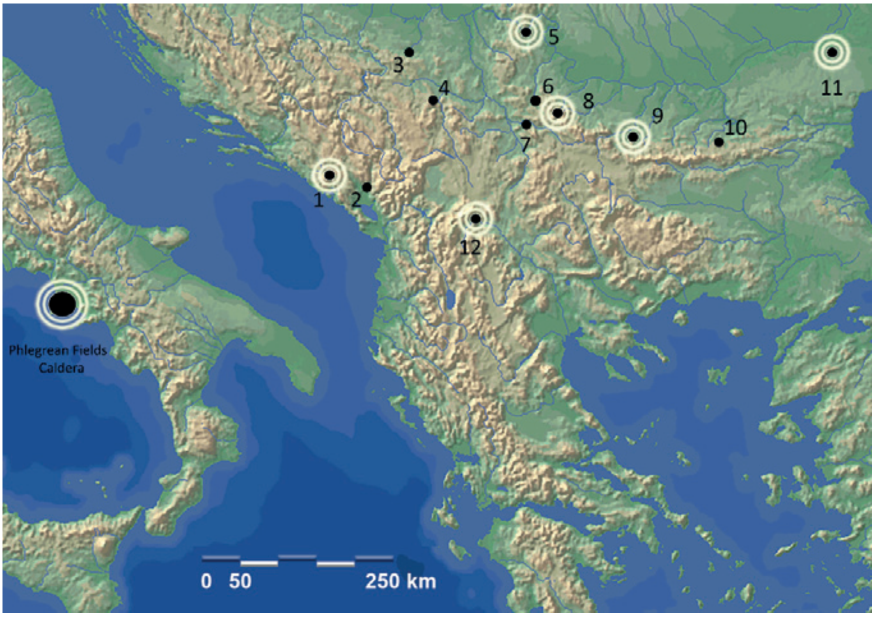

Figure 1. Geographic locations of the sites discussed in the text: 1. Crvena Stjena; 2. Bioče; 3. Šalitrena Cave; 4. Hadži Prodanova Cave; 5. Tabula Traiana Cave; 6. Baranica; 7. Pešturina; 8. Kozarnika; 9. Temnata Dupka; 10. Bacho Kiro; 11. Urluia basin; 12. Golema Dupka. Sites with white concentric circles have confirmed tephra deposits.

The collected data for each site/layer includes the following information: site area (excavated area of the site), the thickness of deposits, and the total number of artifacts, as well as the numbers of cores, blanks, chips, retouched tools and tool types, which are traditionally used for reconstruction of duration of occupation of Palaeolithic communities (Bicho & Cascalheira, 2020). Six variables were calculated based on the collected data (Tab. 1).

In order to assess the whole-assemblage behavioural index (WABI) of Clark & Barton (2017), we plotted the log-transformed lithic volumetric density (artifacts per m^3) against retouch frequency of our sample and conducted a linear regression to assess the correlation between the two variables (following Bicho & Cascalheira, 2020). We also conducted a principal components analysis (PCA) of the correlation (i.e., normalized variance-covariance) matrix based on the data set of 6 variables for the chosen localities/layers. The missing data (7 data points in total) were handled using the so-called iterative imputation approach (Ilin & Raiko, 2010). Statistical analyses were conducted using the PAST 4.05 (Hammer et al., 2001) and Minitab 18 (Minitab Inc., 2017) software packages.

Table 1. The list of archaeological variables used in the analysis. Definitions according to Bicho & Cascalheira (2020).

Variable	**Definition**
Lithic Density	Estimated number of artifacts per 1 m^3 of sediment (sensu Clark & Barton, 2017)
Core Frequency	Relative frequency of cores in the lithic sample
Blanks Frequency	Relative frequency of blanks in the lithic sample
Chip Frequency	Relative frequency of chips (i.e., artifacts smaller than 1.5 cm) in the lithic sample
Retouch Frequency	Relative frequency of retouched artifacts in the lithic sample (sensu Clark & Barton, 2017)
Tool Diversity	Diversity of tool types within each assemblage, calculated using the Menhinick's index (the number of tool types divided by the square root of the total number of retouched tools)

Table 2. The list of archaeological sites used in the analysis, with the sources of data.

Group	Site (abbreviation)	Dating (cal BP)	Data sources
MP	Bacho Kiro, layer 13 (Bacho-13)	>47 ka (Tsanova, 2008)	Drobniewicz et al., 1982
	Bioče, layer 5YR3/4 (Bio-5YR3/4)	39–48 ka (Pavlenok et al., 2017)	Dogandžić & Đuričić, 2017
	Bioče, layer 10YR3/2 (Bio-10YR3/2)	39–48 ka (Pavlenok et al., 2017)	Dogandžić & Đuričić, 2017
	Crvena Stijena, layer XII (CS-XII)	37.6–46.1 ka (Mercier et al., 2017)	Mihailović & Whallon, 2017
	Crvena Stijena, layer XIII (CS-XIII)	44.2–49.2 ka (Mercier et al., 2017)	Mihailović & Whallon, 2017
	Crvena Stijena, layer XIV (CS-XIV)	No dates available	Mihailović & Whallon, 2017
	Crvena Stijena, layer XV (CS-XV)	No dates available	Mihailović & Whallon, 2017
	Crvena Stijena, layer XVI (CS-XVI)	No dates available	Mihailović & Whallon, 2017
	Crvena Stijena, layer XVI (CS-XVII)	No dates available	Mihailović & Whallon, 2017
	Crvena Stijena, layer XVIII (CS-XVIII)	No dates available	Mihailović & Whallon, 2017
	Šalitrena Cave, layer 6a (Šal-6a)	42.8–41.3 ka (Marín-Arroyo & Mihailović, 2017)	Михаиловић, 2017
	Šalitrena Cave, layer 6b/c (Šal-6b/c)	No dates available	Михаиловић, 2017
	Šalitrena Cave, layer 6d (Šal-6d)	No dates available	Михаиловић, 2017
	Šalitrena Cave, layer 6e (Šal-6e)	No dates available	Михаиловић, 2017
	Hadži Prodanova Cave, layer 4 (HadžiP-4)	40.8–36.9 ka (Alex et al., 2019)	Mihailović et al., in prep.
	Hadži Prodanova Cave, layer 5 (HadžiP-5)	44.3–42.5 ka (Alex et al., 2019)	Mihailović et al., in prep.
	Pešturina, layer 3 (Pes-3)	47.6–39 ka (Alex & Boareto, 2014; Alex et al., 2019; Blackwell et al., 2014;)	Mihailović et al., in prep.
	Temnata Dupka, level MP I (TemDup-MP I)	46–45 ka (Ginter & Kozlowski, 2011)	Drobniewicz et al., 2011
	Tabula Traiana Cave, context 206 (TT-206)	>41 ka (Мандић & Борић, 2015)	Borić et al., 2012

Group	Site (abbreviation)	Dating (cal BP)	Data sources
Pre-CI UP	Bacho Kiro, layer 7/6b (Bacho-7/6b)	40.0–36.6 ka (Mihailović, 2020; Tsanova, 2008)	Kozlowski et al., 1982
	Bacho Kiro, layer 9 (Bacho-9)	No dates available	Kozlowski et al., 1982
	Bacho Kiro, layer 11 (Bacho-11)	44.1–38.3 ka (Mihailović, 2020; Tsanova, 2008)	Kozlowski et al., 1982
	Baranica Cave, layer 4b (Bara)	41.1–39.7 ka (Mihailović, 2020)	Mihailović et al., 2011
	Peshtera Kozarnika, layer VII (Kozarnika)	43.9–41.8 ka (Tsanova, 2008)	Tsanova, 2008
	Temnata Dupka, trench TD-I, layer 4 (TemDup-4)	44.5–36.3 ka (Ferier, 2000; Tsanova, 2008)	Drobniewicz et al., 2000
	Tabula Traiana Cave, context 207 (TT-207)	41.3–34.5 ka (Borić et al., 2012)	Borić et al., 2012
Post-CI UP	Bacho Kiro, layer 6a/7 (Bacho-6a/7)	33.6–29.4 ka (Tsanova, 2008)	Kozlowski et al., 1982
	Bacho Kiro, layer 7 (Bacho-7)	37.8–35.5 ka (Mihailović, 2020; Tsanova, 2008)	Kozlowski et al., 1982
	Šalitrena Cave, Excavated area 3, layer 2 (Šal-2)	34.5–33.6 (Marín-Arroyo & Mihailović, 2017)	Plavšić et al., 2020
	Šalitrena Cave, Excavated area 2, layer 2b (Šal-2b)	No dates available	Plavšić et al., 2020
	Šalitrena Cave, Excavated area 1, layer 5 (Šal-5)	36–33 ka (Marín-Arroyo & Mihailović, 2017)	Plavšić et al., 2020

Results

The WABI plot clearly demonstrates that the sites included in this study are very diverse in terms of the practiced settlement models (Fig. 2). However, the graph also reveals some patterns that can provide an insight into the settlement dynamics of the human populations that inhabited the central Balkans ~45–35 ka ago. The Middle Palaeolithic sites are the most widely dispersed in the graph, indicating a diverse group. A similar pattern can be observed for the pre-CI eruption Upper Palaeolithic sites, which are widely scattered across the WABI plot, indicating that various settlement patterns had been practiced in the Balkan Peninsula during this time as well. However, the distribution of the post-CI UP sites is clearly different from those of MP and pre-CI UP, as they all group in the middle part of the WABI plot. As expected, there is a negative correlation between the two variables (Bicho & Cascalheira, 2020), although not particularly strong (i.e., the value of Pearson correlation coefficient is equal to 0.39).

As WABI is not considered to represent a conclusive method in assessing the longevity of occupancy on the site (Bicho & Cascalheira, 2020), the dataset was further explored via principal component analysis. The PCA results confirm that the post-CI eruption sites differ from the pre-CI UP and MP sites. The first four principal components (PCs) account for 91.9% of the total variance (Tab. 3). Figures 3 and 4 show XY plots for the first and second, and the third and fourth PC, respectively, while Figure 5 presents the PCA loadings (coefficients) for the first four PCs. For PC1, eigenvector loadings for tool diversity, retouch frequency, and core frequency are strongly positive, while the spread of the data points is further influenced by the strong negative loadings for lithic density and blank frequency. For PC2, eigenvector loading for chip frequency is strongly negative, while retouch/blank frequencies show strong positive loadings. For PC3, which explains about 16% of the total variance, the core frequency and lithic density variables show strong positive loadings. PC4 explains only about 12% of the total variance and shows strong positive loadings for lithic density and retouch frequency. The plot of the first two principal components (which, when combined, explain 63.9% of the total variance; Figure 3 reveals that, in contrast to the MP and pre-CI UP sites which are scattered widely, post-CI UP sites are all closely grouped; a similar situation can be observed in the plot of PC3 and PC4 (Fig. 4).

Discussion and Concluding Remarks

The results clearly show differences between the pre- and post-CI eruption sites in central Balkans. These differences are visible in the WABI plot, as well as in the PCA results. Although there is no clear definition of how WABI plots should be interpreted, the sites which group in the far bottom right (i.e., those which show high lithic density but low retouch frequency values) can be considered to represent long-term occupations. The high frequencies of lithic debris found at these sites (which is reflected in the low relative retouch frequencies) indicate base camps (Nishiaki & Akazawa, 2015: 536; Clark et al., 2019). On the other hand, the sites located on the upper left of WABI plots are considered to represent short-term occupations, with low lithic density values but high retouch frequencies. This is probably due to the logistical occupancy, which was practiced in order to complete a specific task and then abandoned. Therefore, these sites yield tools but not lithic debris as the tools were produced elsewhere (Nishiaki & Akazawa, 2015, pp. 535–536; Clark et al., 2019). The sites located in the middle of WABI plots are not clearly defined and are thus rarely interpreted. These sites have lithic debris and retouched tools in similar frequencies, probably indicating a markedly short-term residential site (Malinsky-Buller et al., 2021). Therefore, the distribution of the MP sites (Fig. 2) in our study probably indicates the presence of the different settlement models, which comes as no surprise as the MP sites included in the study come from a larger data set that included various practices. The distribution of pre-CI eruption UP sites also indicates that a range of different settlement patterns had been practiced in the central Balkans during this time. However, the distribution of the post-CI sites is clearly different from the other two groups: the sites are all grouped in the middle of the WABI plot, without clearly defined long- or short-term sites. Bearing in mind that the Šalitrena Cave data were primarily collected with the goal of conducting a spatial analysis, and do not contain all of the material found on site (Plavšić et al., 2020), the results presented here should be taken with a grain of salt, our WABI plot does show a noticeably close grouping of the Šalitrena Cave and Bačo Kiro data points. This can be interpreted as a consequence of the forager settlement model being practiced in the post-CI central Balkans.

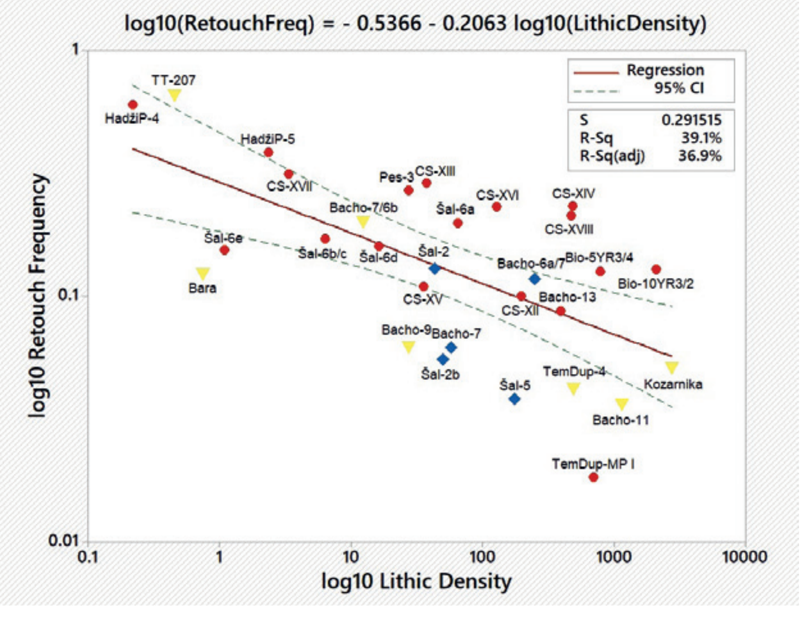

Figure 2. Whole-assemblage behavioral index (WABI) with the linear regression for the two variables. Groups: Middle Palaeolithic (red dots), Upper Palaeolithic prior to the CI eruption (yellow inverted triangles), and Upper Palaeolithic after the CI eruption (blue diamonds). Abbreviations as in Table 2.

Table 3. Eigenvalues and percentages of the total variance for each principal component

PC	Eigenvalue	% of total variance
1	2.2544	37.573
2	1.58123	26.354
3	0.951406	15.857
4	0.727388	12.123
5	0.348644	5.8107
6	0.136928	2.2821

According to the PCA results (Tab. 3, Fig. 3, 4), the positions of post-CI eruption sites along PC1 are influenced by highly positive loadings for tool diversity, retouch frequency and core frequency, and positions along PC2 by negative loadings for chip frequency. Positions of sites along PC3 are influenced by highly negative loadings for retouch frequency and along PC4 by positive loadings for lithic density and retouch frequency. Considering the eigenvalue loadings for these PCs (Fig. 5), all of the post-CI sites represent characteristics of short-term residential sites, representative of the forager settlement model (Shott, 1986; Kelly, 1992).

The results of our study have shown that the Middle Palaeolithic and pre-CI eruption Upper Palaeolithic hominin groups of the central Balkans probably practiced similar, highly variable settlement patterns. Moreover, this study confirms that drastic changes in the settlement pattern of the analyzed territory of the Balkan Upper Palaeolithic communities indeed took place after the CI eruption. The settlement pattern of the post-CI UP peoples became uniform, as demonstrated by the close clustering of these sites in our analyses. The complete lack of residential (base) camps represents the most striking aspect of the observed change. Although distinct settlement patterns (forager or collector) are known to be hard to distinguish in the archaeological record (Clark et al., 2019; Cortell-Nicolau et al., 2019), a clear lack of residential or logistical sites indicates that, in contrast to those of the previous periods, the post-CI UP communities did not practice a collector-like settlement model.

An abrupt change in the settlement dynamics is clearly visible in the central Balkans after the CI eruption. Palaeolithic communities living in this region changed from using various settlement models to almost exclusively forager settlement patterns. Although it is not evident why, consequences of the CI eruption may be the explanation. Our analysis shows that, prior to the CI eruption, most residential sites were located in the Adriatic coastal region or Danubian plain (i.e., Kozarnika, Bacho Kiro 11, Temnata Dupka 4, Temnata Dupka MP I, Bioče 10Y3/2). After the CI eruption, however, these sites were not inhabited (i.e., there are occupation hiatuses) and tephra deposits are recorded (Crvena Stijena and

Temnata Dupka; Fig. 1). Such conditions resulted in a limited inhabitable area, located mostly in the central Balkan inlands, where most of the post-CI sites are found (Karavanić et al., 2018: 164). As evident from the results of this analysis, sites in this area are characterized by forager settlement patterns even before the CI eruption. This suggests that terrain and resource availability of Balkan inlands imposed a forager model as the only efficient one. Furthermore, the CI eruption resulted in a “volcanic winter” which affected both primary biomass and effective temperature (Fedele et al., 2002, Costa et al., 2012, Smith et al., 2016). These two variables are closely related with settlement dynamics, as previously demonstrated by Kelly (1983; 2013). In addition, if the effects of the CI eruption caused changes in demographics (Fedele et al., 2008), they would have also caused changes in the settlement dynamics, as the cost of residential moves decreases and the frequency of the moves increases (Gallagher et al., 2019). However, it remains unclear how long the effects of the CI eruption lasted, and if the impact was strong enough to completely change the settlement dynamics of central Balkan populations. Short-term effects caused by the “volcanic winter” may not have affected communities for long (Marti et al., 2016), but was the initial impact strong enough to cause the change in settlement dynamics? Even if this was not the case, long-term effects such as population decrease (as hinted by the lack of information on the settlement of central Balkans in the times directly following the CI eruption) would have had a lasting impact on the communities.

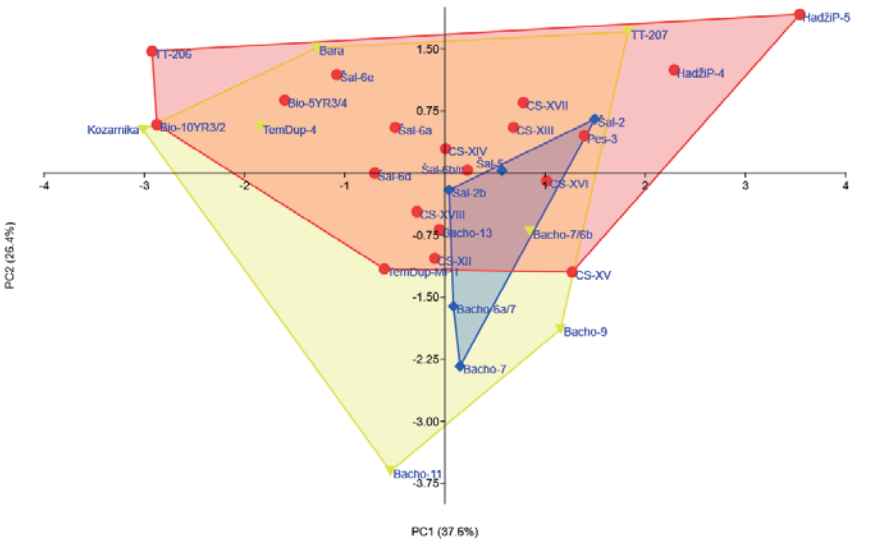

Figure 3. Bivariate plot of scores for the first two principal components. Groups as in Figure 2, abbreviations as in Table 2.

Settlement dynamics in hunter-gatherer societies are complex and represent one of the most important aspects of these societies, which shapes their way of life. Hunter-gatherer mobility influences the procurement of food and water, lithic resources, population size, social hierarchy, reproduction, sharing of knowledge, and exchange of goods. Therefore, changes in settlement dynamics are not frequent or without a cause. Our analysis shows that there is a clear change in the settlement dynamics, following the uniform settlement dynamic that lasted at least 10 ka. Although the change that we see in the central Balkan settlement dynamics after the CI eruption was probably not due to a single factor, the fact that this change occurred at this time indicates that the CI eruption was at least one of them.

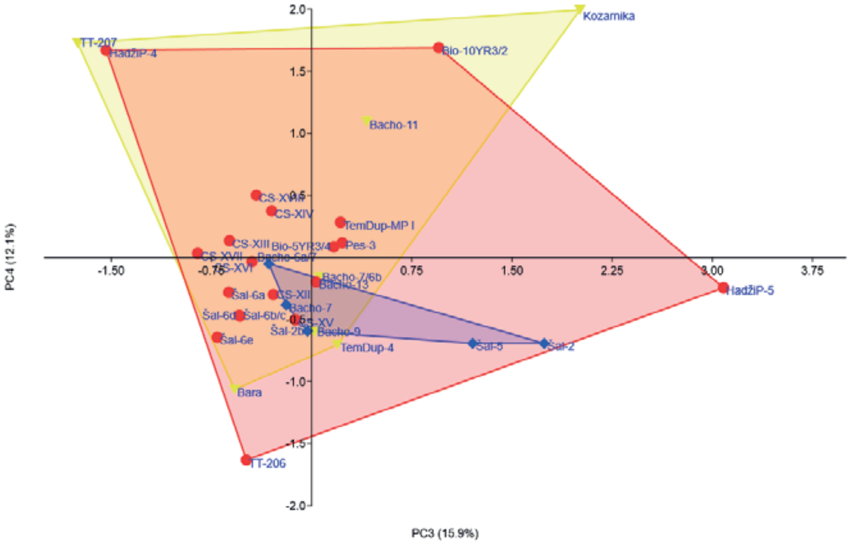

Figure 4. Bivariate plot of scores for the third and fourth principal component. Groups as in Figure 2, abbreviations as in Table 2.

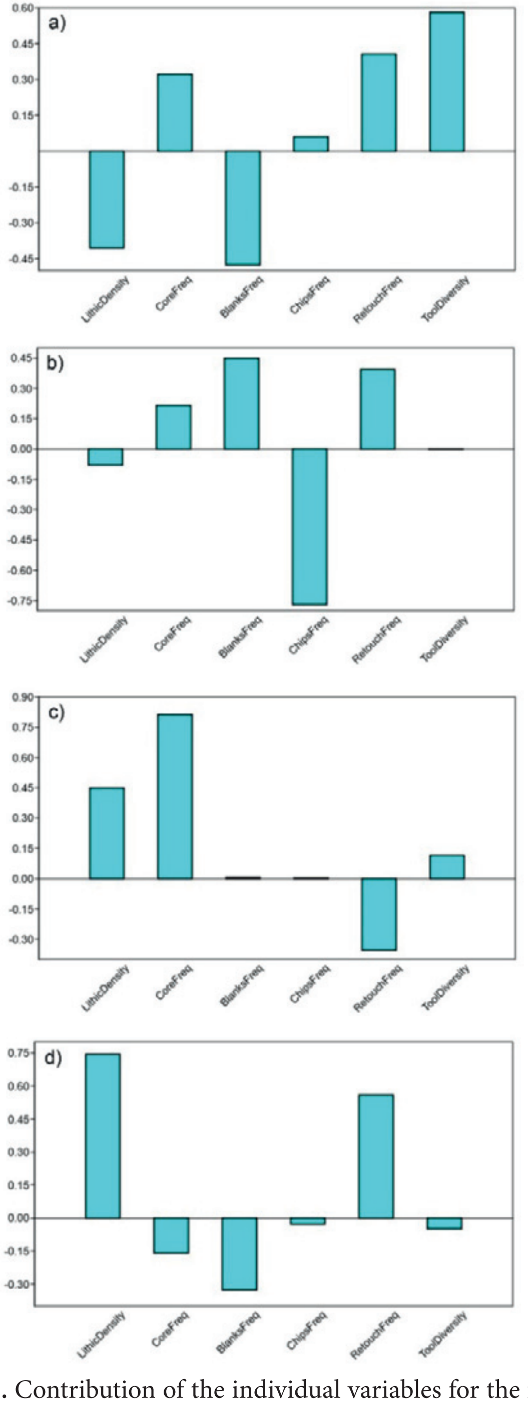

Figure 5. Contribution of the individual variables for the first (a), second (b), third (c), and fourth (d) principal component.

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УТИЦАЈ ЕРУПЦИЈЕ ВУЛКАНА У ФЛЕГРЕЈСКИМ ПОЉИМА (CI) НА ОБРАСЦЕ НАСЕЉАВАЊА ПАЛЕОЛИТСКИХ ЗАЈЕДНИЦА ЦЕНТРАЛНОГ БАЛКАНА

Ерупција вулкана на Флегрејским пољима, која се одиграла пре око 39,85 ± 0,14 хиљада година, била је једна од највећих ерупција у касном плеистоцену и највећа ерупција на простору Медитерана у последњих 200 хиљада година. Ова мега-ерупција је оставила снажне последице на функционисање екосистема, регионалну и глобалну климу, а процењује се да су наслаге туфа умањиле насељиву површину за готово 30%.

Како бисмо испитали последице ове ерупције на обрасце насељавања палеолитских заједница на простору централног Балкана, из литературе су прикупљени подаци са 10 археолошких налазишта, који се датују у период пре и после ерупције. На основу прикупљених података, спроведене су две врсте анализа променљивих: биваријантна (WABI) и мултиваријантна (PCA) анализа, које се користе за реконструкцију образаца насељавања праисторијских заједница.

Резултати обе анализе указали су на промене у обрасцима насељавања након CI ерупције. За разлику од локалитета који се датују у период пре ерупције, а које одликују веома варијабилни обрасци насељавања, локалитети из периода након ерупције показују знатно мању варијабилност образаца. Ове локалитете одликује потпуно одсуство резиденцијалних и логистичких кампова, те се могу определити у логоре „трагача". С друге стране, промене су уочене и у географском положају локалитета. Примећено је да се приобални и подунавски појас, који су и били под највећим утицајем ерупције на основу наслага тефре, напуштају, а да се заједнице померају ка унутрашњости Балканског полустрва.

Промене у динамици насељавања ловачко-сакупљачких заједница су обично последица више фактора, међутим, чињеница да су се овакве промене на Балканском полустрву догодиле баш у периоду након CI ерупције, указује на значај ове природне катастрофе на животе палеолитских људи.

Кључне речи: Ерупција вулкана на Флегрејским пољима, обрасци насељавања, Балканско полуострво, средњи и горњи палеолит

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