INTERDISCIPLINARIA ARCHAEOLOGICA

NATURAL SCIENCES IN ARCHAEOLOGY

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Soil Chemistry to Support Old Map Analysis of the Built-up Area of an Abandoned Settlement. Case Study from the Romanian Banat

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ARTICLE INFO

Article history:

Received: 23rd May 2019

Accepted: 8th June 2020

DOI: <http://dx.doi.org/10.24916/iansa.2020.1.8>

Key words:

multi-element analysis

XRF

GIS interpolation

settlement development

old maps

abandoned village

ABSTRACT

This paper focuses on the combination of geochemical methods and old map analysis to study landscape and settlement development. It is well known that historical land use of abandoned rural settlements affects soil chemistry and vegetation composition. We wanted to find out whether it is possible to distinguish various historical land uses when we know the current chemical composition of the soil; in particular, whether it is possible to recognize the presence of an abandoned village. Geochemical measurement was combined with old maps and grey literature analysis. The model area in the Romanian Banat Mountains is well documented by preserved old maps and is even documented by a land allocation plan from the beginning of the 19th century colonization. This unique document was compared with other old maps, and the spatial development of the rural settlement in the Romanian Banat was analysed. The geochemical methods revealed interpretable patterns, but in situations of little-known historical context (we do not know which households were really inhabited); the use of other supporting methods (archaeological topography, geophysics) is recommended.

1. Introduction

The landscape is still changing, and many authors (Antrop, 2005; Dossche *et al.*, 2016; Wulf *et al.*, 2016) have stressed that landscape changes in Europe have accelerated from the end of the 18th century. Landscape studies focused on land use and land cover changes have a tradition in all parts of Europe (Jepsen *et al.*, 2015; Kuemmerle *et al.*, 2016), as well as in selected regions and land categories (Forejt *et al.*, 2017; Skaloš *et al.*, 2011; Šantrůčková *et al.*, 2015; Wulf *et al.*, 2016). The Romanian mountains seem to be a stable area in macroscopic analyses on a European scale (Jepsen *et al.*, 2015; Kuemmerle *et al.*, 2016), but important settlement and land use/land cover changes have occurred there since the nineteenth century (Cepřaga, 2014; Romportl *et al.*, 2014; Šantrůčková, Fanta, 2014; Kovář *et al.*, 2019). These changes were connected with the resettlement of Romanian mountains at the beginning of the nineteenth century, which caused an intensification of agriculture and

mining activities (Šantrůčková, Klvač, 2014). On the other hand, the Romanian mountains are still one of the hotspots of the traditional cultural landscape in Europe due to their isolation, geographical conditions and ethnographical diversity (Solymosi, 2011). The study of the first settlement activities and landscape changes at the beginning of the nineteenth century requires the combining of different sources and methods. Our paper proposes the combination of geochemical methods used by environmental archaeology with the study of cartographical sources and old grey literature.

The relationship between human settlement activities and the soil part of the biosphere has been intensively studied over the decades, which has introduced a wide spectrum of topics: the influence of the soils on the placement of human activities in the landscape; the interaction between human activities and the soils; the role of soils as one of the basic archives of archaeological evidence; and the role of human activities as a pedogenic factor (Bork *et al.*, 1998; Walkington, 2010; Fanta *et al.*, 2018). Nevertheless, there are also incentives for a more comprehensive research, as many projects are still focused on either an historical or a

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natural perspective, without the two perspectives being brought together. For example, Rainer Schreg (2014) writes about the need to use an ecological approach in landscape archaeology, where the traditional approaches typically aim only at the reconstruction of the environment. We see the topic from another side: a lack of archaeological and paleoenvironmental methods being combined with purely historical topics – and with medieval and modern periods (at least in the central European area, where environmental archaeology chiefly researches prehistoric times).

Soils at archaeological sites are studied in many ways: macroscopically (Kristiansen, 2001); micromorphologically; and geochemically. Some studies have focused on using phosphorus (Holliday, Gartner, 2007), and other studies have focused on using multi-element analyses. These analyses have mostly focused only on the differentiation of basic archaeological features (houses, fields, hearths, *etc.*), on the verification of human activities, and on analysing the spatial distribution of these activities (Davidson *et al.*, 2007; Nielsen, Kristiansen, 2014; Roos, Nolan, 2012). The topic of the spatial extent of particular activities (*e.g.* manuring) or land-use types (arable field, pastures, meadows, gardens) has also been studied (Entwistle *et al.*, 1998; Entwistle *et al.*, 2000; Salisbury, 2013). A study coming from Romania (Pîrnău *et al.*, 2020) has also been published.

It is well known that historical land use of abandoned rural settlements affects soil chemistry and vegetation composition, even over the long term (Hejman *et al.*, 2013; Hejman *et al.*, 2013; Součková *et al.*, 2013). Therefore, our question was whether it is possible to distinguish various historical land uses if we know the current chemical composition of the soil; in particular, whether it is possible to recognize the presence of an abandoned village. The present study focused on the settlement development of Eibenthal village in the Romanian Banat, which was colonized in the 1820s by Czech inhabitants. This village was selected to be a model area because the village history is well documented by preserved old maps (even by a land allocation plan from the beginning of this colonization). Moreover, the story of recolonization, place translations and shifts are typical for many settlements in such history (Hill, 2013; Klápště, 2012).

Our aims were the following: 1) to determine if the Eibenthal settlement was realized to the full extent as recorded on old maps and 2) to determine how this question can be answered using spatial analysis of geochemical patterns. To sum up, we want to examine whether simple geochemical analysis can be helpful for the historical geographical research on abandoned settlements and what are the limitations of this approach.

Figure 1. Location of the study area and Eibenthal village. Map sources: ESRI, Word (2017), Romanian topographic map 1:25 000 (probably 1970s).

2. Materials and methods

2.1 Description of study area and history of the Eibenthal village

Eibenthal village is located in southwestern Romania (Mehedinți County), in the neighbourhood of the Danube River, which creates a natural border between Romania and Serbia (Figure 1). The village lies in mountainous terrain on the southern edge of the Carpathian Arch, in the Banat Mountains. The village lies in a deforested area within huge forests. The slopes around the village are covered by mosaics of fields, meadows and pastures that are now endangered by abandonment and spontaneous reforestation (Romportl *et al.*, 2014).

This area was recolonized rather late. Eibenthal is one of six current Czech villages in the Romanian Banat: Eibenthal (Eibental), Gârnic (Gerník), Bigăr (Bígr), Ravensca (Rovensko), Sfanta Elena (Svatá Helena), and Șumița (Šumice). The area was recolonized as part of the Habsburg monarchy military border after the defeat of the Turks and their displacement behind the Danube River in the late eighteenth century. The arrival of Czechs to the Banat region dates back to the 1820s. The Czech settlers recolonized mainly higher woody areas. The aims of this recolonization were to deforest the area in order to cut wood and extend

agricultural land, to establish a new settlement after the Turkish conquest and to strengthen the protection of borders (Iordache, 2007). The settlement of the Czech villages was predominantly organized by military border officers. Before the settlers arrived, military officials measured off parcels of land for future houses and fields that were to be allocated to the immigrants (Pavlásek, 2010). Each family was allocated approximately 7 ha of land (5.2 ha of fields and 1.7 ha of meadows). There were common pastures. Land was distributed to each family so that no one received land that was more fertile or more easily accessible than the other families; as a result, each family's holdings were spread throughout the cadastral territories of the planned villages. Military offices prepared provisional homes (sunken huts or wooden cottages) for the settlers (Pavlásek, 2010; Štěpánek, 2005). However, the land that they were allocated was mostly old growth forest. The colonists had to first cut the forest and pull out the stumps to farm their allocated fields and meadows. The provisional lodgings that they received were not sufficient, and diseases began to spread. In some places, once deforestation was started, there were water shortages. Due to all of these hardships, settlements were established slowly; some had to be relocated, and others were even abandoned (Gecse, 2013; Urban, 2005). Therefore, in the first two or three decades of their existence,

Figure 2. Detail of the study area on the present orthophotomap (2007) and old allocation plan (1826).

these new settlements were very unstable. Some colonists tried to return to the Czech lands; others wanted to relocate to already existing villages in flatter and more fertile areas of Banat. Military officers, however, opposed such actions because they needed people to settle less fertile areas at higher elevations (Jech *et al.*, 1992; Šantrůčková, Klvač, 2014). The settlement of Czech villages in the Banat region stabilized in the middle of the nineteenth century.

The popular tradition says that Eibenthal village was originally founded far away on the northern slope and plateau (Figure 2), but after several years it was moved to the present and more suitable position near the stream (Urban, 2005). The population in Eibenthal grew from 356 inhabitants in 1830 (Czoernig, 1857) and peaked before WWII (960 inhabitants in 1930) (Urban, 2005). Two waves of decolonization occurred after WWII: the first occurred just after WWII, and the second started in the 1990s. In the years after WWII (1946–1949), Czechoslovakia invited Czechs from abroad to colonize Czech borderlands from which the Germans were expelled (Heroldová, 1986; Vaculík, 1993). More than one-third of the inhabitants left Eibenthal (Secká, 1995). The second decolonization wave started after the fall of the Communist

regimes in Czechoslovakia and Romania in 1989 and still continues. The migration is economically motivated, and only approximately 200 inhabitants live in Eibenthal now (Šantrůčková, Klvač, 2014).

2.2 Old maps

Four old maps are available for Eibenthal village and its environment; one map is at a large scale, and three maps are at a medium scale (old military maps of the Habsburg Empire).

The large-scale map is titled *Grund Eintheilungs Plan von dem Orte Eibenthal* (Plan of land allocation in the place named Eibenthal), and according to the text in the map sheet, the map was made in 1826 by sergeant Georg Gimbosch and was confirmed by supply officer Pavich (Figure 3). This map is kept by the Regional cadastral office for the Mehedinți Region in Orșova, Romania (Oficiile de Cadastru și Publicitate Imobiliară, Orșova). It has a graphical scale (ca. 1:2880). The map consists of four parts. According to the legend, the map contains fields, meadows, pastures, house plots, and vegetable gardens that are numbered. Furthermore, paths, water streams, and forests are shown on the map, and relief is demonstrated by hatching. On the map, the village (88 houses) is located not only around the water

Figure 3. Plan of land allocation in the place named Eibenthal made in 1826.

Figure 4. Analysis of the built-up area of Eibenthal village on the old and present maps. Legend: 1 – Map from 1826; 2 – Second Military Map from the mid-nineteenth century; 3 – Third Military Map from the 1870s–1880s; 4 – Contemporary orthophotomap from 2007.

stream but also on the northern slope, including the church/chapel (Figure 2). In contrast, the present village is located only around the stream (and is longer), and the church is in the bottom of the valley. There are fields and grasslands on the northern slope, and there are no houses or church. It is highly probable that the map shows the planned distribution of the houses and agriculture land as prepared by the military officer for the new arriving colonists.

The old military maps (Biszak *et al.*, 2014; <http://mapire.eu/en/>) show the spatial development of the village environment in the eighteenth and nineteenth centuries. The First Military Mapping of Temeschwarer Banat (1769–1772) shows the situation before Eibenthal's founding, and there were only forests. The Second Military Mapping of Hungary (1819–1869) depicts Eibenthal only in the Tisovița valley; the agricultural land is on the northern slope, and a church is not present. Eibenthal, including the church, is located in Tisovița valley in the Third Military Mapping of Hungary (1869–1887), and there are more houses depicted than on the Second Military Maps. The coal railway crossed the northern slope along the contour line.

For the further analysis, we used the map from 1826, and Second and Third Military Maps. We bought scanned sheets of these maps. The maps were georeferenced on the base of the present orthophotomap (2007) by GIS (ArcGIS 10.1).

Then, the boundaries of settled areas were digitalized on each of the old maps and on the present orthophotomap and it was visualized (Figure 4).

2.3 Research design

The area was sampled according to the old maps to verify the location of the previous settlement. A former railway (now an unpaved road) borders the sample area from the south, and the church and some houses around it (as depicted on the allocation plan) are in the centre of the sampled area (Figures 1 and 2). The area is now used as agricultural land (mainly fields, pastures and orchards).

The data were obtained by a direct field profile measurement using a portable ED-XRF (PXRF) analyser Delta Professional manufactured by Olympus InnovX in the Soil Geochem measurement mode for applications of XRF spectrometry, see Canti and Huisman (2015). Every measurement was performed for an interval of 1 minute with 30 s of a 10 kV beam and 30 s of a 40 kV beam. The PXRF model used yields data in the form of weight ppm. The quality of the device measurements was successfully tested by BAS Rudice Ltd. (further information are available on www.bas.cz) on 55 reference materials (e.g., SRM 2709a, 2710a, 2711a, OREAS 161, 164, 166, RTC 405, 408). All the field measurements with GPS coordinates are listed in the Dataset S1 (see Supplementary Online Material).

Table 1. Basic statistical description of chosen elements. Length stands for the total number of samples, count for successfully measured samples and NAs for unsuccessfully measured samples leading to blank cells in table of measurements. Sigma stands for median of 3-sigma values of the elements. Intervals depict how many 3-sigma intervals cover the range of element content. LE (the last variable) stands for light elements (from H to Na) which are measured in total together due to XRF method limitations. Elemental content in mg/kg.

	Si	P	S	K	Ca	Mn	Fe	Zn	Rb	Sr	Zr	Pb	Th	LE
length	154	154	154	154	154	154	154	154	154	154	154	154	154	154
count	154	154	154	154	154	154	154	154	154	154	154	154	154	154
NAs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
max	230600	17381	9958	61800	99200	2656	62075	199	88	398	355	39	48	953100
mean	82740	3058	3298	9941	25649	913	11500	92	28	128	96	16	23	842391
sdev	46359	1860	1386	7427	15693	542	11051	30	16	63	56	6	10	58293
median	78050	2794	3128	8046	23064	798	8146	92	23	117	87	16	23	853300
MAD	46035	1408	1449	4798	13592	465	9044	31	15	56	47	6	10	54782
min	2201	130	372	2188	4231	184	175	23	4	33	12	2	4	633000
sigma. med	700	109.5	65.5	86	170	33	87.5	5	1	2	2	2	3	1400
intervals	165	80	75	348	281	39	355	19	43	93	87	11	9	116

2.4 Statistical analyses

Our dataset was comprised of many elements, from which we have chosen just some for the further analyses and interpretation (mainly due to insufficient number of successful measurements and invalid data due to a high proportion of sigma3 intervals to the element content). Our analyses used the following elements: Si, P, S, K, Ca, Mn, Fe, Zn, Rb, Sr, Zr, Pb, Th, and LE (light elements – H to Na concentrations were grouped together due to the principles of the PXRF method used). The basic matrix therefore consisted of 14 variables and 140 cases. For basic statistical information see Table 1.

In none of the analyses made we work with the original concentration values. The geochemical data can be generally characterized as (usually) of non-normal distribution (Limpert *et al.*, 2001; Reimann, Filzmoser, 2000) and as compositional data (Reimann *et al.*, 2012; Reimann *et al.*, 2008). According to Reimann *et al.* (2008), we therefore decided to use clr-transformed data. The abbreviation “clr” stands for centered log-ratio: the data were divided by the geometric mean of the data points, and then, the values were $\log_{10}$ transformed. This process helps to avoid problems with compositional data, where the variable cannot reach any value, but this process is limited by the values of other variables (Reimann *et al.*, 2008). This process enables us to use additional information in the data matrix. We used principle component analysis (PCA) as a basic processing method not only to facilitate the interpretation but also to help distinguish between the possibly different inputs of elements into the soil environment.

Using PCA, we should emphasize some aspects of this process. There are many archaeological-geochemical studies. Many of them work with multi-elemental data, but they do not use them as a multi-variate data set – they just evaluate the elemental content separately for each element (e.g. Entwistle *et al.*, 1998; 2000; Wilson *et al.*, 2005; 2008; 2009; Šmejda *et al.*, 2017; 2018). There have also been research and studies presenting and evaluating the data in a

multivariate way using PCA (or other methods like cluster analysis – see, e.g. Salisbury, 2013; 2016). But by using PCA we do not focus on reducing the number of variables (as this is the usual aim with a following choice of obtained components for further analysis and interpretation). As our previous research showed, in some cases, the non-significant components (from the viewpoint of eigenvalue or explained variability) can also bear an anthropogenic signal from the past. Therefore, we use PCA in a more exploratory way of working. This comes from the reality of the content of elements in soils actually coming from various different inputs (e.g. the usual anthropogenic indicators such as P, Zn, Sr can also come from the geological background). Such an approach has helped us to distinguish the different inputs of elements (in a study of Spindelbach this was mainly the case for P – Horák and Klír, 2017; in a study of Lovětín it helped to distinguish different inputs, e.g. for Sr – Horák *et al.*, 2018). Regarding the input data for PCA, we used the entire matrix of clr-transformed elemental content as well as elevation. We used an R environment to perform the analyses and interpolations (IDW method). We interpolated element content and principal component (PC) scores.

3. Results

The location of Eibenthal village on the oldest map from 1826 differs from the location on the old military and present maps. The map from 1826 presents the Eibenthal area in the Tisovița valley, similarly to the Third Military Map, and on the northern slope along two small creeks. The narrowest village area is presented on the Second Military map from the mid nineteenth century, where there is mainly one row of houses along the single main street and Tisovița stream. Eibenthal village on the Third Military Map (1870s–1880s) is also located only in Tisovița valley alongside the street and stream, but the area is larger than on the previous map, and

Figure 5. Interpolated content of Si (in ppm) in the sampled area.

Figure 6. Interpolated content of Mn (in ppm) in the sampled area.

Figure 7. Interpolated content of P (in ppm) in the sampled area.

Figure 8. Interpolated content of K (in ppm) in the sampled area.

the houses on the eastern side are in two rows. The present village area (2007) is based on its state from the end of the nineteenth century, but the area is a little larger because of scattered houses along the road to coal mines in Baia Nouă and along the road to the Danube River (Figure 4).

Elemental content in some cases reached presumed values and relations according to other studies focused on using PXRF in archaeological/paleo-landscape studies (Horák and Klír, 2017; Horák *et al.*, 2018; Šmejda *et al.*, 2017; 2018). However, some of the results were in some aspects different

Figure 9. Interpolated content of Ca (in ppm) in the sampled area.

Figure 10. Interpolated content of Zn (in ppm) in the sampled area.

Figure 11. Interpolated scores of PC1 in the sampled area.

Figure 12. Interpolated scores of PC2 in the sampled area.

from expectation based on those studies. As an example of this we could state Pb (a little lower content), and P or S (of higher content).

According to the spatial distribution of elemental content, we could say that there was no element whose content (and its gradient) would clearly distinguish the area of mapped

Figure 13. Interpolated scores of PC3 in the sampled area.

Figure 14. Interpolated scores of PC4 in the sampled area.

Figure 15. Interpolated scores of PC5 in the sampled area.

Figure 16. Interpolated scores of PC6 in the sampled area.

households against the surrounding areas. We have found two patterns according to the planned built-up area. The first pattern was based on a distinct gradient in a north-south

direction and loosely copied the elevation of the terrain. Such elements were Si, S, Ca, Mn and Pb (see Figures 5, 6 and 9). The other, second, pattern was not easy to describe, but

according to the planned households, we could say that the second pattern was at least somehow manifested in more parts of the households in the lower and higher elevations. As examples, we could state P, K, Fe, Zn, Rb or Zr for this pattern (see Figures 7, 8 and 10).

The PCA extracted 15 components, but we further present and discuss only PC1 to PC6 as the other components only explained a very low proportion of variability. For information concerning the PCA, see Table 2. The first component PC1 explained over 35% of variability. It was positively linked to P and S and to a lesser extent to K, Ca, Zn, Th and LE. It was negatively linked to Fe, Rb, Sr and Zr. The second component PC2 explained over 15 % of variability and was positively linked to elevation, K and Sr and negatively to Si. The third component PC3 explained over 10% of variability and was positively linked to Ca and negatively to Si. PC4 explained almost 9% of variability and was strongly linked to Mn (positively). PC5 explained almost 7% of variability and was linked mainly to Zn (negatively). PC6 explained almost 6% of variability and was linked mainly to Pb (negatively).

Spatial characteristics of the PCs 1–6 can be described as they recorded similar patterns to those of the contents of elements: PC1 and PC3 followed the pattern of a distinct north-south gradient, and PCs 2, 4, 5, 6 recorded that somewhat unclear pattern in which both main parts of the planned households reached similar values (for examples, see Figures 11–16).

4. Discussion

4.1 Elemental content and PCA results

Geochemical research in areas of previous human activities has been performed many times in the past. We might mention the searching of sites using the “almost undeniable” human indicator phosphorus (*e.g.* Zöllitz, 1983, generally Holliday and Gartner, 2007), using analyses of the content of many elements (Entwistle *et al.*, 1998; 2000; Wilson *et al.*, 2005; 2008; 2009), or also using multivariate analyses on the same (Salisbury, 2013). Such methods usually work regardless of the measurement method or method of extraction. Previous studies have used, for example, the ICP method, but this generally works with other methods like PXRF (Horák and Klír, 2017; Horák *et al.*, 2018; Janovský and Horák, 2018; Janovský *et al.*, 2019; Šmejda *et al.*, 2017; 2018). Although PXRF gives the total content of the elements, studies using ICP usually work with just the fraction after digestion, which does not give total content. Nevertheless, we see the results as being comparable between studies: not by absolute values, but by the complex of elements which are usually interpreted as human activity indicators (see citations above). Such “indicator” elements are usually always the same. Also, for example, Wilson *et al.* (2005) used nitric acid for their extraction method, which gives pseudo-totals, but obtained similar results.

Such studies are methodologically based on two principles: i) searching the unknown location of a site

Table 2. PCA results: loadings of variables for PC1 to PC6.

	PC1	PC2	PC3	PC4	PC5	PC6
elevation	0.43	0.59	−0.1	0.36	0.11	−0.38
Si	−0.24	−0.56	−0.52	0.18	0.41	0.02
P	0.75	0.03	0.36	−0.14	0.36	−0.06
S	0.79	−0.21	0.20	−0.10	0.29	−0.08
K	0.42	0.52	−0.34	−0.26	0.11	0.27
Ca	0.50	0.18	0.69	0.03	−0.12	−0.12
Mn	0.17	0.18	−0.21	0.88	−0.07	0.13
Fe	−0.76	−0.47	0.27	−0.08	−0.03	0.14
Zn	0.50	−0.37	0.23	0.32	−0.52	0.24
Rb	−0.86	0.35	0.10	−0.06	−0.05	0.01
Sr	−0.56	0.69	0.19	−0.03	−0.08	0.00
Zr	−0.78	0.46	−0.06	−0.05	0.01	0.07
Pb	−0.48	−0.33	−0.11	−0.02	−0.23	−0.69
Th	0.67	0.21	−0.42	−0.17	−0.20	−0.14
LE	0.52	−0.04	−0.40	−0.40	−0.45	0.04
eigenvalue	5.33	2.36	1.61	1.35	0.99	0.85
% variability	35.52	15.72	10.7	8.97	6.62	5.66
cumulative %	35.52	51.25	61.95	70.92	77.54	83.19

based on those “almost undeniable” indicators such as P, or on the interaction of more of such elements (and, of course, sometimes it does not work); ii) the analyses are performed in an area of known historical/prehistorical activity, or more of such activities, enabling some patterns in elemental composition to be distinguished, based on those known activities.

As the situation of Eibenthal was based on the plan, with its unknown state of realization, and thus with an unknown state and distribution of potential human activities, the research was a variant of the first principle. In such a case as this, clear interpretation would need clear and well distinguished patterns of human indicator elements, or principal components connected to them. As such potential indicators, we could see these elements in our dataset: P, K, Ca, Mn, Zn, Sr and Th, based on cited studies. By a “well-distinguished” pattern, we mainly mean the general gradient of high content in the area of houses and their close vicinity (courtyards, gardens), with lower values in the area of, presumably, manured fields and the lowest values in the open landscape.

We did not find any such pattern which would be recorded in the area of all households, but we did find some patterns loosely similar in their distribution connected to some parts of the households (the northernmost part or the northern part, plus a few households from the southern part). As we did not know which parts were actually inhabited (even if there were any at all), the following interpretations are presented in two variants and are strongly speculative. Only the “human indicator” elements and the principal components (PCs) connected to them are discussed.

The pattern of high values manifested mainly in the northern part of the area was found in the case of the element Ca, and in PC1 and PC3. The pattern connecting the northern and southern parts of the area was found to be recorded by the elements P and K, and PC4 and PC6. Therefore, we could speculate that, according to such results, potential human activity and the inhabitation of households were connected either to the northern part only, or to both the northern and southern parts. No distinguished human indicator or PC was clearly connected to the central part of the area around the church/chapel. We can definitely reject the possibility of all households having been inhabited intensively for any considerable length of time. Such a situation would probably leave more clear patterns than was found (for a comparison, see H, J).

We have two main problems to deal with in both interpretations: they are strongly speculative, as we do not have any independent mean of testing the results; and the material is imprecise (we do not know the realized state of the planning and weather is it methodical). And the spatial distribution of potential human indicators was following the aforementioned pattern only very loosely: there were high values not only in the area of households, but also farther away in the fields. We could expect at least some gradient, even if the fields were manured. This problem was not just an artefact coming from the interpolation’s setting (we tested

more variants with similar results). To get better and clearer results in potential future research of this or similar sites, it would be helpful to use more methods. For the geochemical data, it would be good to use some other methods and extractions to obtain not only the total content of elements, and to use a more focused sampling design with a denser grid. To find possible underground features, geophysical methods should be used. The field application of such methods, or the planning of a sampling design, should also be based on the results of previous archaeological-topographical surveys. We could say that in cases of an unclear historical context (where knowledge of which households were inhabited is imprecise); the geochemical mapping needs to be supported by the use of further different methods and denser sampling grids.

4.2 Eibenthal households

Geochemical mapping is able to reveal spatial patterns that may be interpreted as the results of past human activities, settlement or agriculture. We could not interpret these patterns clearly mainly due to the lack of context (geological, soil, historical). We did not find any PC or element that could be clearly connected to Eibenthal activities. However, based on a comparison of the PCs or elements that could be interpreted in this way (with only some probability); it seemed that there was no united pattern. These PCs indicated that there was no unity in the sampled area from the village settlement point of view. There was either a high diversity in household management (technical or agricultural), or some of the households did not exist or existed only for a limited period of time. Because the first option was not probable from a historic point of view (the purpose of settlement, the ways of realizing it), and the second option was more probable (hard beginnings of colonization, attempts to abandon the sites and movement to more suitable localities), we see the second option as being more suitable to the above-mentioned (yet still speculative) interpretation of Eibenthal. However, it was not unusual that the original plans differed from the later realized situation; similar complications with village foundations have also been observed in medieval central Europe (Klápště, 2012).

The popular oral history revealed in the grey literature also supports the above hypothesis. According to the popular history, Eibenthal village was removed to the present position several years after its foundation. The previous position of the village should be on the northern slope and plateau, but the precise localization varies according to different authors (Gecse, 2013; Urban, 2005). This would be in accordance with the geochemical mapping, which definitely did not find records of intensive inhabitation over the whole area. According to the local oral history, the reason for the transfer was the water shortage that occurred after deforestation. Meanwhile, the old military maps of the Second and Third Military Surveys depict the real position of the village in the second half of the nineteenth century. The map from 1826 is a unique document of a planned colonization that was never realized to the extent envisaged.

5. Conclusion

The first aim of the paper was to determine if Eibenthal's settlement was carried out to the extent that was recorded on old maps. It was proved that the oldest map from 1826 depicts the planned rather than the actual extent of the settlement, which means that the map from 1826 is a very important and rare document. Some authors (Gecse, 2013; Jech *et al.*, 1992; Secká, 1995; Urban, 2005) indicate that the military officer prepared the plans for the households and fields before the Banat villages were settled in the 1820s, but none of these plans were published. This plan of the prepared settlement was found by chance in the cadastral office in Orșova when we asked for the stable cadastral maps. This unique document was compared with other old maps, and the spatial development of the rural settlement in Romanian Banat was then analysed.

The geochemical mapping revealed possible human activities connected with settlement and agriculture in this area, but not with a pattern that could be well interpreted – and we would recommend the use of other different methods in similar contexts as the case here. Nevertheless, the results seemed to be in accordance with the popular history (Gecse, 2013; Urban, 2005), according to which some settlement activities were carried out in this location but were abandoned.

Acknowledgments

This work was supported by the Internal Grant Agency of the Faculty of Environmental Sciences, CULS Prague, Grant No. 4219013123139 “Vliv geografických faktorů na vybrané procesy v dějinách osídlení – The influence of geographical factors on selected processes in settlement history” and by Institutional support from the Silva Tarouca Research Institute for Landscape and Ornamental Gardening, No. VUKOZ-IP-00027073.

Data availability

The original geochemical data are available in Dataset S1 (see Supplementary Online Material).

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