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ZUZANA BLINKOVÁ, PETR NERUDA

SPATIAL DISTRIBUTION OF THE MAGDALENIAN ARTEFACTS (LAYER 6) IN THE KŮLNA CAVE (CZECH REPUBLIC)

ABSTRACT: The Magdalenian layer 6 belongs among the most significant archaeological horizons in the Kůlna Cave. The extent of the layer and the quantity of archaeological finds enable us to analyse the spatial distribution of the artefacts retrieved in the course of the excavations K. Valoch conducted between 1961 and 1976. In view of the then system of documentation, which does not fulfil the current requirements for georeferenced data, we had to formulate a new system of localisation of the information and to utilise geographic information technologies for their processing and visualisation. Although the resulting model is not entirely precise, on the grounds of comparing the distribution of various groups of tools we identified function-specific zones that reflect the structured behaviour of the humans within the cave. At the same time, the so-called Magdalenian layer 6 turned out to be most probably a result of repeated visits, and it cannot be definitely excluded that a sparse rather indistinctive Epigravettian assemblage might be hidden in the inventory. The article also discusses the issue of the relevance of reconstructions based on older documentation of finds, in which the individual items were not surveyed in a three coordinate system.

KEY WORDS: Kůlna Cave – Magdalenian – Spatial distribution – GIS

INTRODUCTION

The main problem with archaeological artefacts is their static character in relation to historic time. If we want to employ artefacts for the reconstruction of human behaviour, we have to quest after the approaches, and determine how to acquire information of a dynamic character from a static resource. In the analysis of an archaeological site, one of the options available is examining spatial contextual information, i.e. mutual relations both among the discovered artefacts and between them and the ambient environment. In doing so our starting point is that in most cases the distribution of archaeological objects is not arbitrary (in the case of more or less intact situations); hence their spatial distribution reflects human activities at the site. If we

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interpret the find situations correctly, we are capable of defining human behaviour in space and time with a certain probability. One of the proven modern methods for assessing archaeological sites and finds is their spatial analysis by means of geographic information systems (GIS) that provide us with tools for the evaluation of spatially oriented data and their visualisation; this makes the interpretation of the data much easier.

The accuracy of analyses and interpretations is directly dependent on the quality of the documentation of archaeological situations and finds. Modern research puts stress on georeferenced data that can be easily analysed by means of a computer. In this way we can identify also the negative impacts of post-deposition transformations of an archaeological site, thereby avoiding erroneous interpretations (cf. e.g. Henry 2012, McPherron 2005, McPherron, Dibble 2002).

In the processing of older excavations a frequent problem is the quality of the available data; even though the data often fall short of the current standards, they are crucial for cognisance of the Palaeolithic. One such locality is the Kůlna Cave, at present the only cave site in Moravia, from which spatially oriented data from the Magdalenian are available. In the following contribution we will try to demonstrate that, in applying an adequate approach, even data less valuable from the methodological point of view can provide a range of information important for our knowledge of the behaviour of early human groups.

Geographical definition

The Kůlna Cave is located ca 30 km from Brno, in the cadastral area of the Sloup municipality on the northern margin of the Moravian Karst, the biggest karst area in Moravia (*Figure 1*). The cavern itself is situated in the left part of the half-blind Sloupské údolí Valley that forms the northern part of the Pustý žleb Valley, one of the two main morphologically outstanding canyon formations within the territory of the Moravian Karst. The southern entrance to the cave is 468 m above sea level. The vast, tunnel-shaped cavern has a large SW oriented portal and a smaller northbound entrance. The cavern is approximately 87–91 m long; its maximum width is 25 m and the maximum height 8 m (Valoch 1988: 9–10).

The history of excavations in the Kůlna Cave

The first archaeological excavations at Kůlna Cave were carried out by J. Wankel in 1880 (Wankel 1882), who concentrated on the central part of the cavern, since in his view this was where intact sediments were likely to be found. In the current system of zoning of the cave this would be sector G2 (Valoch 1988: 165). Wankel passed the finds unearthed during his research to the court museum in Vienna (Kostrhun 2005).

M. Kříž followed suite until 1886 (e.g. Kříž 1889, 1903). In the course of his excavation works he had 18 pits cut, of which 11 were allegedly dug to the very bottom. Five cuttings approximately 2 m deep divided the cavern transversely (see *Figure 6d*). The existence of seven hearths mentioned by M. Kříž is noteworthy from the point of view of spatial structures.

In 1887, J. Knies commenced his excavations; he systematically followed on the test pits by Kříž and focused on unexcavated areas. During his digs Knies localised another 10, perhaps 11 fireplaces (Knies 1910, 1911, 1912, 1913, 1914).

No exploratory excavations were undertaken in the cave between the wars. Towards the end of WWII (1943–1945) the Germans built and operated an aircraft factory in the cave (Břečka 2011). Fortunately, prior to the unavoidable adaptation of the cave, the workers of the Archaeological Institute of Prague were allowed to carry out test probing in the entrance area of the cave, and they ascertained a Palaeolithic occupation in several layers. The significance of the discovery convinced A. Rust, a renowned researcher, to recommend as minimal adaptation of the cave as possible (Valoch 2011a: 30). For this reason, the sediments that sloped down from the northern to the southern entrance were levelled in several steps of 80 cm difference in height. More severe damage to the sediments occurred mainly in the rear and central part of the cave, whereas only the uppermost Holocene or Late Weichselian sediments suffered damage in the entrance part. The Germans had a part of the eastern cave side in the southern entrance blasted off to create an artificial rock step, but this caused no substantial damage to the sediments (Neruda 2013).

Concrete was removed as late as in 1959, when K. Valoch started to prepare the cave for a systematic research programme that followed in 1961–1976 (Valoch 1988, Valoch *et al.* 1969, 2011). These works revealed that the Upper Palaeolithic layers remained intact in some areas within the cave (Valoch 1988: 9–10). The entire plan of the cave was divided using a square network of 1 m side length, and larger areas were designated as sectors (A–L, *Figure 1e*). Hitherto unexcavated reference profiles were left among the sectors. The total explored area amounted to 900 m^2 (Valoch 1988, Valoch *et al.* 2011).

K. Valoch performed his most recent archaeological excavations in the cave in 1995 and 1997 (Valoch 2002) because of the archaeological exhibition being prepared in the cave. These excavations were carried out between sectors B and C (square 4-III/O).

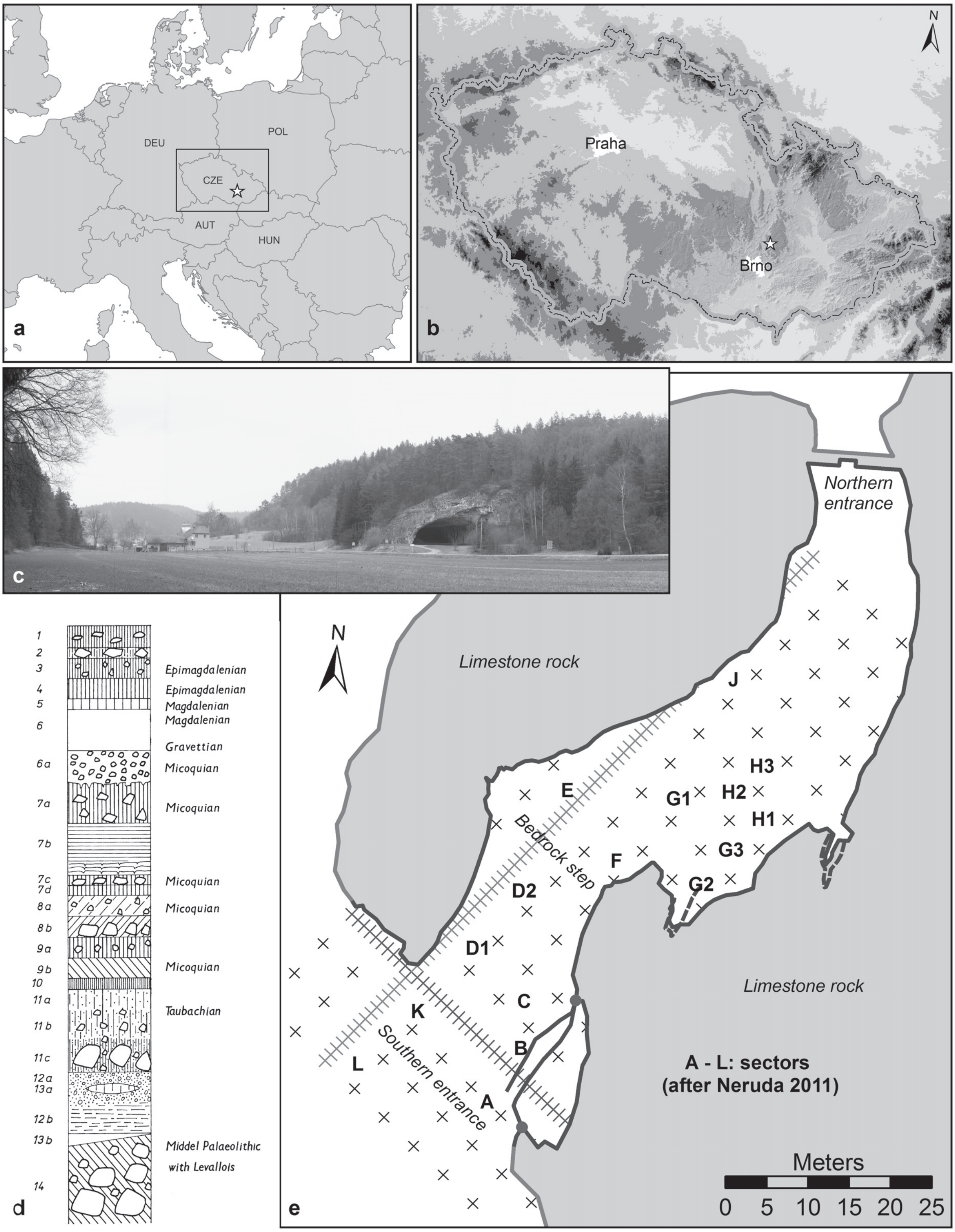

FIGURE 1. a, b, geographic position of the Kůlna Cave; c, the portal of the cave viewed from south-west; d, stratigraphy; e, the ground plan of the cave. The designation of sectors A–L has been modified according to the original designation (Valoch 1988).

Chronological position

The original radiocarbon data for layer 6 were interstratified with the age of the Epimagdalenian layer 4 and fell within the Allerød period (*Figure 2*), whereas from a stratigraphic viewpoint layer 6 should be older (Neruda, Valoch 2011, Valoch 1989). New dates obtained on animal bones in the Oxford laboratory place the age of layer 6 in the period 14.8–14.9 ka cal BP, i.e. prior to the Bølling–Allerød complex (Neruda, Nerudová 2014b). Therefore, the chronological position is comparable to the Magdalenian occupation (layer g/h) of the Pekárna Cave (*Figure 2*).

Character of the input data

The reconstruction of the spatial distribution is based on the finds acquired from the Magdalenian layer 6, which was identified during K. Valoch's research between 1961 and 1976. The previous finds by M. Kříž and J. Knies were not included in the analysis, since it was not possible to make an adequately precise correlation with K. Valoch's stratigraphic scheme.

From our current viewpoint, the quality of the input data is rather poor. Due to the preceding activities the intact layer was either disturbed or completely removed in some places (probing by M. Kříž and J. Knies; construction works during WWII); this rendered a continuous observation of the studied structures in the entire surface area impossible (cf. *Figure 6d*).

Another problem is posed by the system used to document the finds; although satisfactory in terms of the practice prevailing at the time, it does not conform to the standards of today. As they were discovered, artefacts were recorded and drawn in the field notebooks and were allocated consecutive find numbers along with complementary stratigraphic and location details. The spatial positions of the finds were defined using a square network (e.g. 37/M or 14-16/a-D), and the depth interval was noted in some instances (e.g. depth 95–120 cm). In cases of a lower density of finds in a certain area items from several squares were consolidated, though without a unified scheme. Each geological (archaeological) layer was explored in several excavation units (usually 20 cm depth) and the system of merged squares differed in their orientation and scope and therefore it is impossible to display the positions of finds on the cave plan. During the analysis, this was the greatest problem with regard to georeferencing the individual finds (on the issue see Neruda *et al.* 2011).

Another problematic element possibly affecting the outcome of the analysis is the potential intermixture of finds from other cultural horizons. Recognition of the respective layer varied within the area of the cave (Valoch 2011b). Especially in the southern entrance both Magdalenian and Middle Palaeolithic Micoquian artefacts emerged in macroscopically identical sediment (Neruda, Nerudová 2014a), and radiocarbon dates indicate that some of the animal remains belonged to the Gravettian (Neruda, Nerudová 2014b, *Table 1*). However, a new dataset of samples from layer 6 from the interior part of the cave, where the sediments are

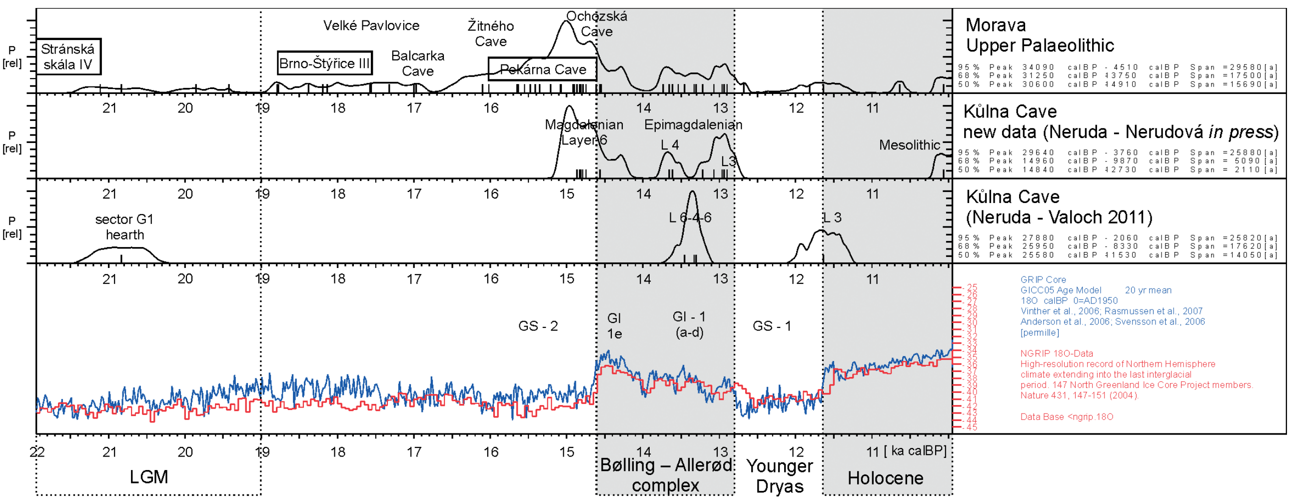

FIGURE 2. Chronological position of the Magdalenian layer 6 in the context of the Kůlna Cave and the Upper Palaeolithic sites in Moravia. Radiocarbon data calibrated by CalPal2007 (Weninger *et al.* 2007) and IntCal09 calibration curve (Reimer *et al.* 2009). The interval for Late Glacial and Holocene cf. (Walker *et al.* 2009), LGM, Last Glacial Maximum according to (Clark *et al.* 2009).

TABLE 1. Number of finds, median and mean of merged squares for individual groups of artefacts.

Group of finds	N	Merged squares	
		Median	Mean
Cores	26	1.5	2.6
Blanks	275	2.0	3.1
Tools	113	2.0	3.6
Hard animal materials	118	2.0	2.6
Others	21	1.0	1.4

differentiated better (*Figure 2*), is very homogeneous and does not show any contamination. Instead, possible contaminations are likely to appear locally and pertain to animal skeletal remains.

At present, primarily the collection of stone artefacts complemented with hard animal materials bearing evidence of use-wear (cut marks, grooves, proofs of processing, etc.) can be used for the reconstruction. So far, the other osteological material has not been processed in detail. The utilisation of hearths identified by M. Kříž and J. Knies is arguable (summarisation cf. Kostrhun 2005: Fig. 5), because the fireplaces cannot be reliably correlated with either the current stratigraphy or with layer 6, and within K. Valoch's excavations areas with concentrations of charcoal were rather rare.

THE METHODOLOGY OF DATA ACQUISITION, PROCESSING, AND ANALYSIS

All finds in the depository of the Anthropos Institute (Moravian Museum, Brno, Czech Republic) underwent a critical revision aimed at verifying the accuracy of their stratigraphic classification and the completeness of their localisation details. The items were compared to the drawings in the field notebooks compiled by K. Valoch, and those with preserved information on the find layer and square from which they were unearthed, were set apart. That part of the collection recorded as waste, or originating from collapsed profiles, was not included into the analysis. The finds retrieved by J. Knies and M. Kříž were rejected for similar reasons, since they were unsuitable for identifying a clear correlation with the stratigraphic system devised by K. Valoch.

Two main groups of details on the individual items – localisation data and attribute data – were gathered for the geodatabase. The find number according to Valoch's field notebooks was selected as the unique identifier. The localisation data comprises information on the situation of the find according to the field notebooks (sector, square, and depth), and also the translated relative coordinates (X and Y) within the unified square network – the Cartesian system (on the method see below).

The attribute information included the technological, typological, and petrographical classification of lithic items and the principal taxonomic and anatomical determination of hard animal materials with a pertinent classification of anthropic modifications (cut marks, grooves, breaking, etc.).

Method for georeferencing of the available data

In view of the fact that we cannot simply display the position of finds on the plan of the cave (using different marks in individual squares), it was necessary to use specific methods of spatial analysis provided by geographic information systems (GIS). This allows the study of the interrelationships among points (in our case finds), together with any information (e.g. technological classification), even in such cases when the position of points in the space is not exact (so that a find is located to the spatially defined area). Appropriate analyses are provided by ArcGIS™ programme (Spatial Analyst Extension).

To meet the requirements of the programme it was necessary to convert the localisation of finds from the excavation system (e.g. area of squares 15-18/K) into points with X and Y coordinates of the Cartesian system. We based our conversion on the original square network Valoch used for segmenting the excavated area. The individual squares were localised using letters and numbers – e.g. 19/R (letters and numbers are on the "x" and "y" axes, respectively). The zero point is coincident with the prior reconstructions of the Middle Palaeolithic occupation of the site (Neruda *et al.* 2011: 27), i.e. between bands a/A on the X axis and I/II on the Y. Positive values increase from the zero point to the right (towards the east) and upward (to the north), negative values rise to the left and downward.

Subsequently we determined the centres of the squares (e.g. 18/H) or areas comprising more square metres (e.g. I-3/R-T), and the coordinates were established according to the distance from the 0 point of the square network (e.g. X = 14, Y = 26). All of the finds that were discovered within a certain area were georeferenced in conformity with the coordinates of the centre of this area (Neruda *et al.* 2011). For the analysis proper the georeferenced finds were divided into groups according to selected attribute information (cores, blanks, tools, waste, hard animal materials, etc.). Given that the plan of the Kůlna Cave was newly created in real geographical coordinates (for Czech Republic the projection of Křovák S-JTSK-East_North was used), it was essential to convert the relative coordinates of counted points (centres of square metres to which the finds were shifted) to the same system.

Methods for visualisation of the spatial analysis

The principal manner of visualisation of spatial data is a plan with points representing individual finds (in the ArcGIS programme it is a shapefile with a dataset of point geometry type). Nevertheless, in the case of the Kůlna Cave we are confronted with the problem that the spatial co-ordinates of the finds were not taken individually, and for the purpose of the spatial analysis it was necessary to move the items into a position in the centre of the area from which they originated. This constrains a number of objects to cluster in a particular spot, and so the objects overlap and cannot be displayed and analysed individually. Within the one group of finds we can express the quantitative aspect in a categorised point layer, where the number of finds at a given location is reflected in, for example, the size of the symbol used to locate that spot. However, in most cases there are several groups of objects (cores, blanks, bones, retouchers, etc.) relating to the same point; hence the symbols overlap again. The visual assessment of the quantitative aspect accordingly becomes difficult, if not impossible.

A feasible solution is to utilise the density rasters for the individual studied groups of items. They are calculated from a point dataset (a shapefile with the point geometry) is transferred into a continuous layer (a bitmap), and the colour of the individual pixels reflects the quantitative aspect (the density within a certain area). Since we had to investigate linkages between objects' spatial relationships in the context of other spatial processes, overlapping of map layers can be very advantageous. Rasters (bitmaps) are not suitable and therefore it is necessary to convert them into vector graphics (in ArcGIS – shapefiles with polygonal geometry), that include statistically significant quantities of artefacts. Such visualisation enables using of specific vector graphic techniques (crosshatching of the areas in different lines and colours), and the layers representing the individual groups of items can thus be overlapped (cf. *Figure 6a, b*).

Method for data analysis

We have opted for the density raster calculations of the ArcGIS™ Spatial Analyst extension as the principle type of spatial analysis (on the issue of the chosen method see Discussion). Simple layers of points for the individual groups of items served as the input data.

A prerequisite for density raster calculations is the definition of the searching radius, in which further values (further finds) for the calculation are tracked. The most logical variable capable of having a possible impact on this issue appeared to be the number of squares, from which the items were merged at individual excavation depth units (the area e.g. 10-12/K-M is 9 sq. m.). The values for the individual areas mostly differ, and fluctuate from one square to more than 10 merged squares, in which the finds were recorded at their unearthing. For the purpose of the analysis the searching radius established for individual groups of finds was based on the median of the merged squares (*Table 1*) so enabling the elimination of extreme values. Within the calculation of a raster it is possible to choose two types of visualisation – so called Simple type and Kernel type that differ in projection of density. Drawing on previous experience with the reconstruction of the Middle Palaeolithic spatial distribution in the cave we chose the Kernel type (Neruda *et al.* 2011) that is continuous and therefore better for modification (see next).

For the assessment of individual accumulations in the cave it was advantageous to create distribution plans of find accumulations distributions in vector graphic (polygon shapefiles) that can be superimposed on each other (all analysed features are visible). Nevertheless, the density rasters must be modified according to unified rules to enable mutual comparisons of the rasters and to display only areas with significant appearances of finds. The raster image was categorised into five intervals as consistent with the standard deviation function, while zero values were omitted from the raster. In a few instances, it was only possible to categorise the raster image into four groups (cf. *Figure 3a–b, d*). As regards the comparison of the ratio of flakes and blades, in this case we also selected a variant with the same real density values in both groups of objects (cf. *Figure 4a–b*).

Subsequently the rasters were re-classified and two variants were generated. In the former the interval with the lowest value of density was eliminated and the four (or three) remaining intervals were uniformalised at the same pixel value (value 1). In the latter variant two lowest intervals were eliminated, i.e. only three (or two) intervals with the highest density of finds were entered into further analysis. In both cases, we acquired rasters with two pixel values – 0 for the area without finds or only their minimum representation, and 1 for the areas where finds occurred in a higher density. These raster

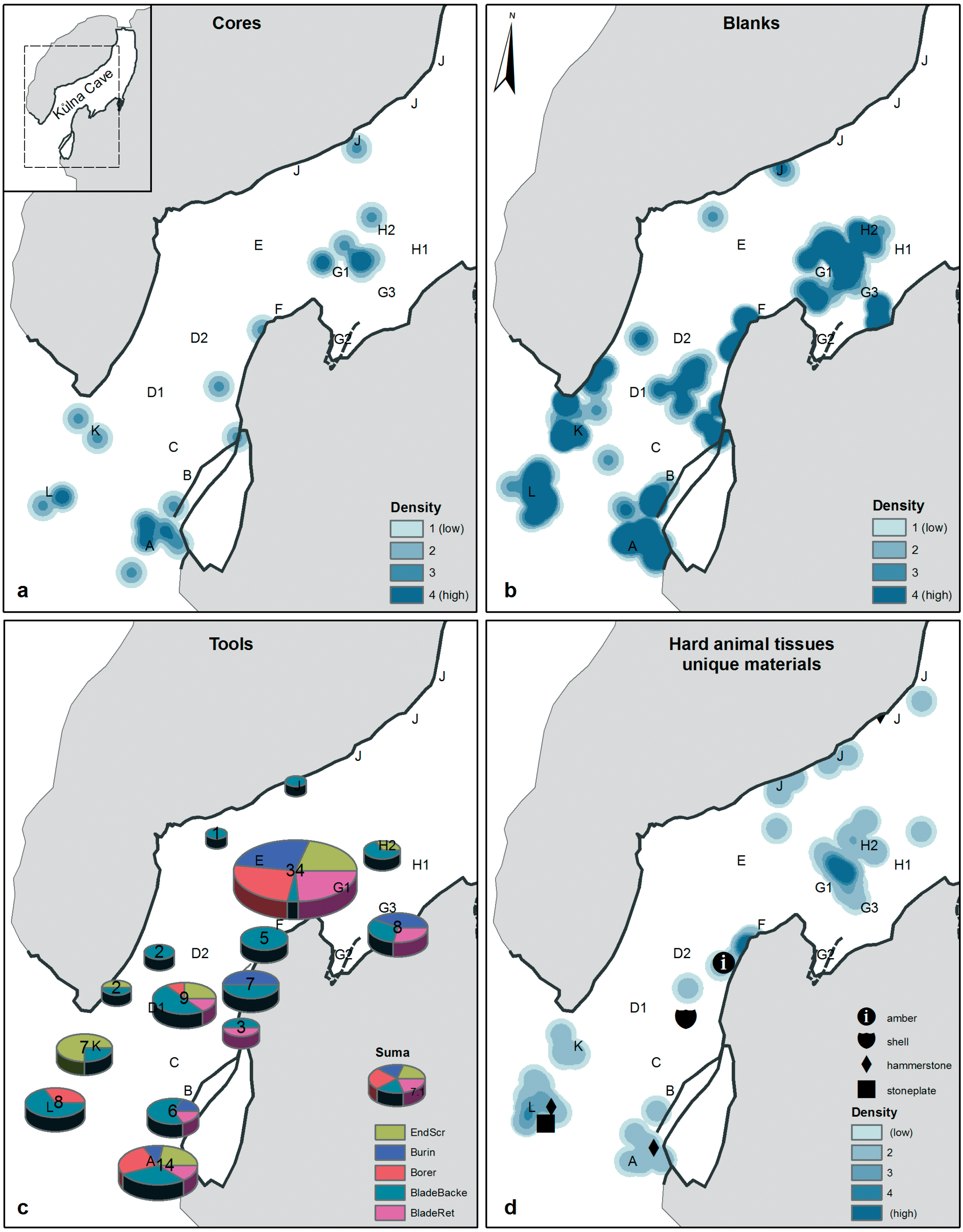

FIGURE 3. Distribution of the individual groups of finds: a, cores; b, blanks; c, charts representing the composition of tools in the individual areas; d, hard animal tissues and other unique materials. A–L, denomination of sectors (Valoch *et al.* 2011).

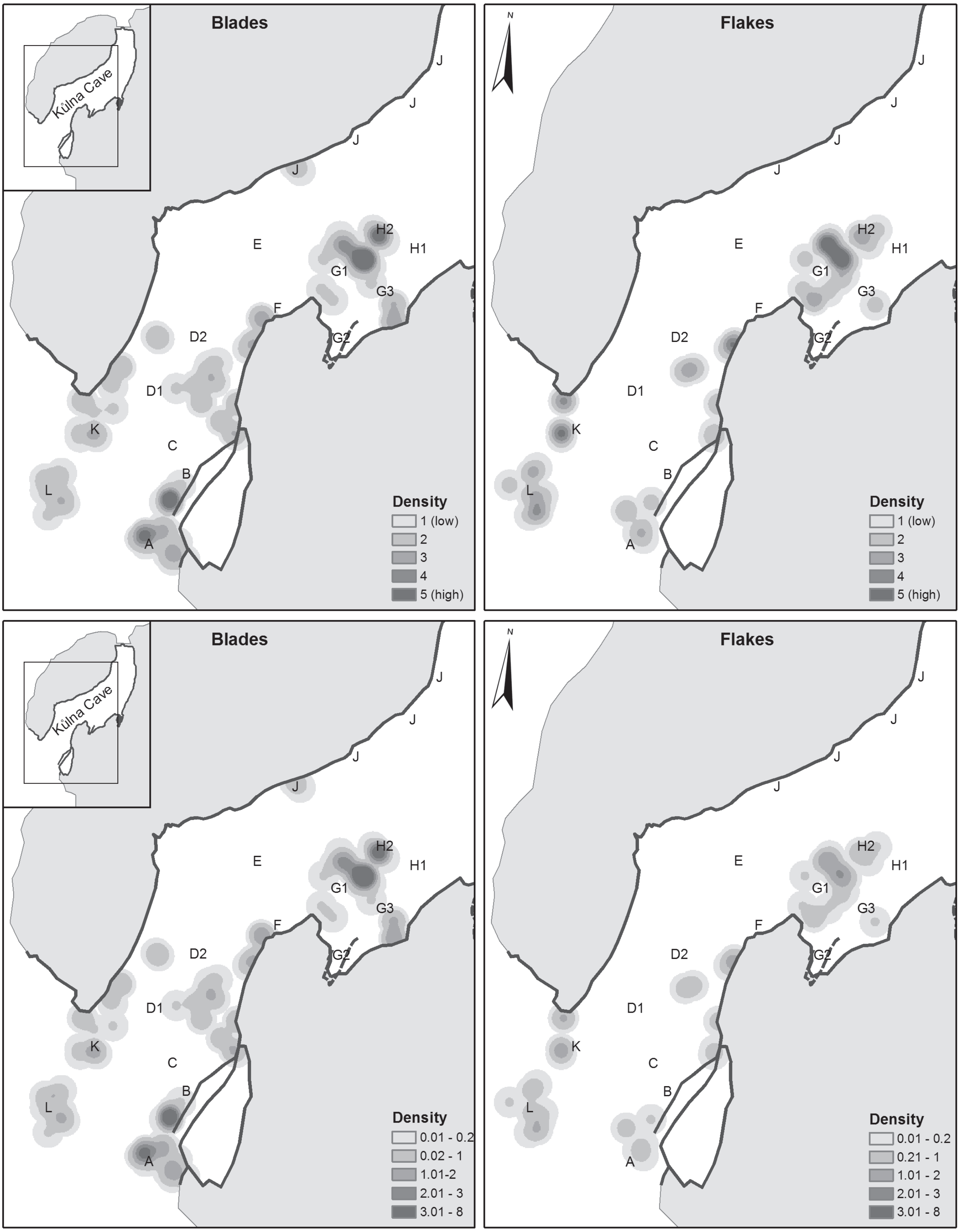

FIGURE 4. Distribution of blades and flakes in the layer 6. a, comparison of relative density; b, comparison in absolute density intervals.

images for the individual groups of finds could be converted into vector shapefiles (polygon geometry) that are more easily visualised using a broader scale of graphic elements for the differentiation of areas. The individual layers modified in this way could be mutually overlapped and the correlation of the individual studied attributes compared in the common model (*Figure 6*).

For the analysis of tools we utilised a different type of visualisation by means of a categorised point layer, whereas all the tools originating from one sector (defined by K. Valoch) (*Figure 1*) were newly georeferenced into one point (in most cases this fits approximately to the centre of accumulation of other finds), and their proportion was rendered through a pie chart, the size of which reflects the total quantity of finds within a certain area in the cave (cf. *Figure 3c*).

We had to utilise point layers also for the analysis of the spatial distribution of the lithic raw materials used. To avoid extensive overlapping that would hide a lot of items, and make impossible the visual comparison of distributions within the plan of the cave, the points were manually shifted into such positions that their locations underwent as little change as possible, but at the same time all were visible on the plan (cf. *Figure 5*).

RESULTS OF THE SPATIAL ANALYSIS

The first group of finds to be analysed were cores and their fragments. We succeeded in differentiating altogether 26 items in the collection. From the density raster we prepared (*Figure 3a*) it is obvious that this part of the industry was concentrated especially in two locations – in sector G1 and at the right-hand side of the southern entrance in sector A. Although cores were found also in sector L, the area of concentration was rather limited there.

The most numerous group of analysed artefacts are products of knapping (flakes, blades, and waste), of which K. Valoch's excavations yielded 319 items. The largest and richest concentrations occurred in sector G1 (or H2) again. Accumulation of blanks in sector L is much more obvious than in the instance of cores, and other places in sectors B, D2, F, or K come through (*Figure 3b*). From the technological viewpoint it was desirable to divide blanks into blades (*Figure 4a*), the bulk of which were the target products, and flakes, which we can mostly link to the initiation of the raw material and the modification and repair of cores. For a more precise comparison of both groups of tools (taking into account their quantitative ratio) the rasters of the blades (241 items) and flakes (77 items) were classified into the same density intervals (*Figure 4b*). Apart from the concentration in the northern part of sector G1 and in the southern part of sector H2 we can observe a higher representation of blades also in sectors A and B at the right-hand side of the southern portal (*Figure 4a–b*). To a lesser extent blades occur along the left cave side, but blades appear there also in places without flakes (sector D1, western part of sector D2, and sector J). Flakes are most numerous in sector G1 and sector K, or L. The low proportion of flakes in sectors A and B is of interest (*Figure 4b*). It clearly follows from the comparison of both rasters that the individual sites within the cave differed. In the area of sectors G1 and H2 the occurrence of both blades and flakes culminates in contrast to sector A, where blades markedly dominate, or sectors D1, D2, and J, from where only blades are evidenced. The proportion of flakes increases in sectors L and K and F; thus the representation of both technological components becomes virtually equal.

Analysis of the distribution of 113 tools (*Figure 3c*) originating from virtually the entire area of the cave reveals some interesting features. The density of items culminates in sectors G1 (H2) and A (or B) with high frequencies also present in sectors G3, F, K, and L. At the same time it is evident that the individual areas of the cave (or the accumulations of tools) mutually differ in the frequencies of individual types of Upper Palaeolithic tools. The main concentration in sector G1 is characterised by a balanced ratio of implements like end scrapers, burins, and borers, while the frequency of blades and backed bladelets is low. Sector A yielded similar tools, but the number of backed components is markedly higher. Individual spots along the cave sides contain only two types of tools, and sometimes only backed artefacts are represented (most markedly in sector F).

The 118 items of hard animal material that K. Valoch divided out of the osteological material because of the presence of use-wear show a somewhat different distribution from the other artefact groups (*Figure 3d*). Again, the most striking accumulation is found in sector G1, with smaller quantities evident in sectors F and L. A higher proportion of fragments of hard animal materials in sector J is also of interest.

The last group of analysed artefacts (21 pieces) consists of worked stones and hammerstones, and sporadic finds of amber and fossil shells (*Figure 3d*). Interestingly, only a very small quantity of heavy-duty implements were retrieved, confined to the entrance section of the cave (sectors A and L), and no similar artefacts were recorded in the area with the most complex evidence structure in sector G1.

The final observed attribute to be considered was the distribution of used lithic raw materials that we divided into three basic groups – northern silicites (erratic silicite, the silicite of the Kraków-Częstochowa Jura Region, and the chocolate-type silicite), radiolarites and the Moravian cherts (spongolite, the chert of the Olomučany type, and other Moravian Jurassic cherts). However, only the groups of northern silicites coming from Poland and Moravian silicites can be compared in terms of quantity (*Figure 5*). The distribution of the raw materials clearly indicates that the processing of northern silicites was primarily under way in the middle part of the cave in sectors G1 and H2, whereas Moravian cherts were much more numerous in the southern entrance part of the cave (sector L), within which northern silicites were not even represented.

On comparing the derived rasters, we can identify several concentrations within the cave that mutually differ in the composition of their finds (*Figure 6a–b*). One of the most outstanding find accumulations, deeply situated within the cave, is the area between sectors G1 and H2 (the division of the concentration into two parts is related to the retaining of a reference profile). This is apparently one of the most important places within the cave: a great quantity of lithic blanks (primarily blades, but also a significant proportion of flakes), cores and stone implements (of all cardinal types) were discovered here as well as ample hard animal materials with anthropic impact. The composition of artefacts indicates that, apart from other activities, not only the primary production of blanks was undertaken here but also the manufacture of stone tools proper and their utilisation in further processes, both alimentary and technological. This conclusion is somewhat at variance with the absence of heavy-duty stone implements, although generally a minimum of these are found in the Magdalenian layer 6. An intriguing phenomenon is the marked proportion of imported high-quality lithic raw materials from the north (erratic silicite and silicite of the Kraków-Częstochowa Jura Region), from locations at distances exceeding 100 km.

Another location with a comparable range of finds was identified in the south-eastern part of the southern entrance (sectors A and B). It differs from sector G1 in the frequencies of individual components, with flakes (*Figure 4*) and hard animal materials (*Figure 3d*) occurring less often, while the proportions of backed bladelets (*Figure 3c*) and Moravian cherts increase (*Figure 5*).

Moravian cherts dominate in the concentrations on the left side of the southern entrance, and in front of the cave in sectors L and K (*Figure 5*). Apart from the composition of the raw materials, however, these locations are also distinguished by a smaller proportion of blades and by a differing typological composition (*Figure 3c*) dominated by backed bladelets (sector L) or end scrapers (sector K).

We can identify considerable differentiation between the individual accumulations in sectors D1, D2, or F, where the quantitative representation of tools is less and backed bladelets dominate. In these areas a minimum of cores were retrieved, and the share of the debitage (blanks) is negligible compared with the main concentrations (*Figures 3, 4*).

Regarding the entrance and the exposed part of the cavern P. Kostrhun has proposed the existence of various shields, tents, and huts (Kostrhun 2005); however, this hypothesis cannot be corroborated by our analyses to date. The identification of such structures would necessitate application of the ring and sector method for analysing the distribution of the industry (Stapert 1990), but the original system of documentation does not allow us to do it.

DISCUSSION – INTERPRETATION OF THE SPATIAL ANALYSIS

The current tendency to resurrect older excavation data using geoinformation systems entails certain risks that influence the quality of the acquired information. We have to take into account a number of limiting factors that require assessment within the particular data processing methodology. The key problem with the analysis of spatial structures in the Kůlna Cave is the accuracy of the resulting reconstruction. First of all, we have to stress that not all the artefacts left behind by the Magdalenian hunters in the cave were included into the analysis. The finds from the excavations by Wankel (1882), Kříž (1889, 1903) or Knies (1910, 1911, 1914) are not suitable for a reliable utilisation, since these cannot be unequivocally linked to a particular layer in compliance with the stratigraphic scheme of K. Valoch (1988). It is evident from the reports and photographs of the period that the western part of the cave in particular was significantly damaged by amateur digs, and the northern part by the German adaptations linked with developments during WWII (summarised in Neruda 2013). Therefore, it is clear that the reconstructed picture cannot be entirely complete, and it has to be regarded as such.

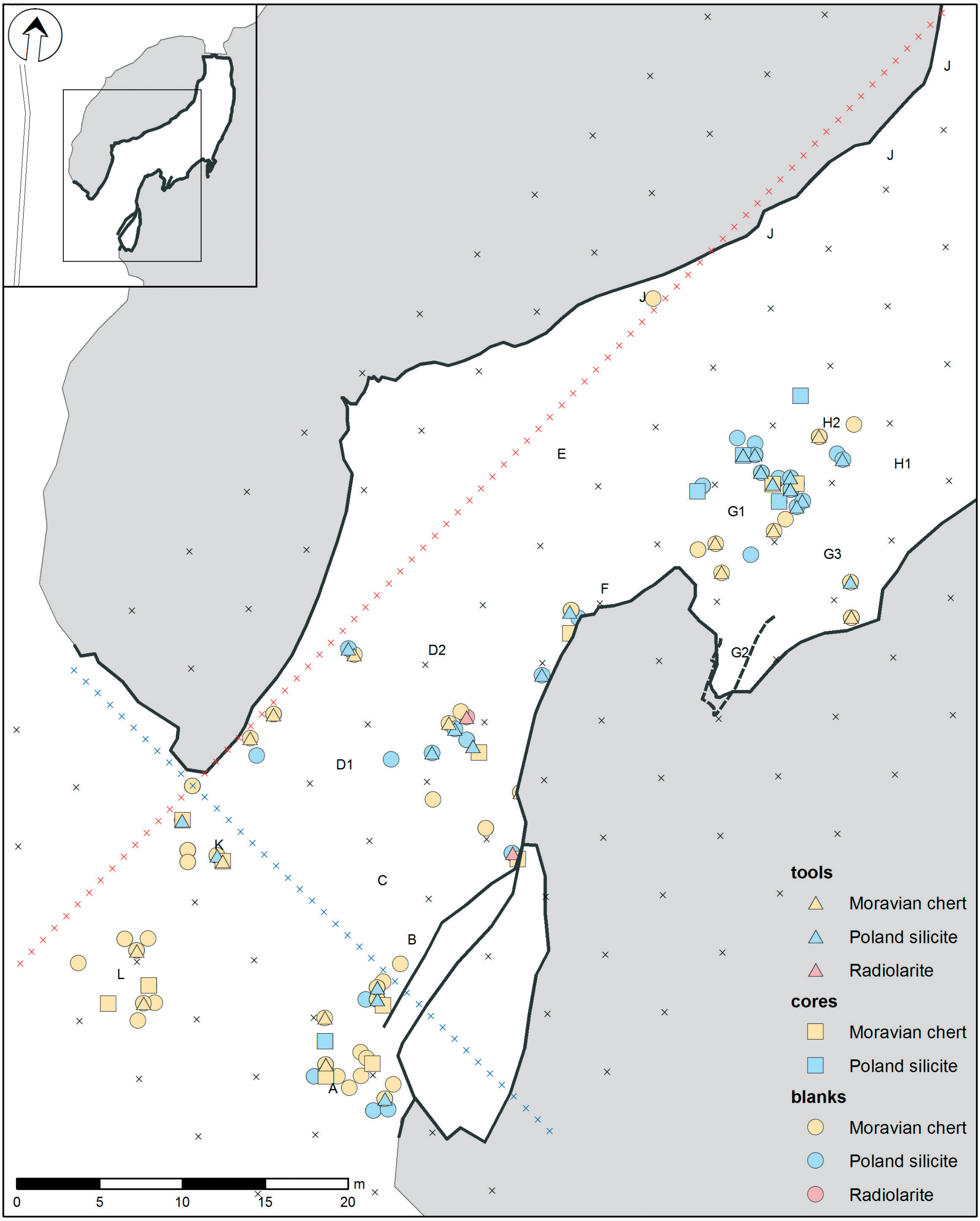

FIGURE 5. Distribution of raw materials.

The second problem that relates to the precision of the analysis and its discriminatory ability involves the system of documentation and the method of reconstruction (as mentioned above). The first evident deviation of the model from the real status at the time of the Magdalenian occupation of the cave is linked to the inconsistent recording of the finds in conformity with the set network of squares, i.e. with the selected method of georeferencing. To a certain extent this method has averaged the distribution of the finds, although the deviation of the individual finds from their respective original positions should not exceed 2 m (see *Table 1*). Theoretically, a searching radius for the calculation of density rasters could be 1 m but using such "short" radius, we can display any pseudostructures that look like results of anthropic activities. Considering that the real (original) position of finds (not recorded precisely) was shifted, means we cannot describe the real spatial distribution of finds. Indeed, it appears more appropriate to apply the larger searching radius of 2 m (meaning a precision of 4 m), to eliminate artificially created pseudostructures. Of course, as a result, the picture of the distribution is more generalised and some important examples of interesting human behaviour can disappear. The problem is the taphonomy of information does not enable more precise reconstruction, nevertheless within the space of the entire cave such error is, in our view, acceptable.

The third factor that has to be taken into consideration when evaluating the results is the method of visualisation. We primarily opted for the continuous layer of data (a raster), which shows the fluctuation of density in the cave area. For the calculation of this raster we chose the density raster function with the accuracy established according to the median of the number of merged squares, which was calculated for the individual groups of finds in layer 6. We will acquire somewhat different shapes of the ascertained concentrations through the change of searching radius (on the issue see Neruda *et al.* 2011), or through the change in the method of calculation (e.g. the Kriging method). Nevertheless, in this respect we have to emphasise that our goal has been to detect the locations of the concentrations and their composition rather than to analyse their shapes. This is impossible because of the deviations that result from shifting the finds to the centres of merged squares. Therefore, if we examine the derived concentrations within the scale of the entire cave, regardless of their shapes, the chosen method of generating rasters is insignificant and has no impact on the outcomes of the spatial analysis.

The last factor to limit the reconstruction is the vertical distribution of the finds; this cannot be reliably evaluated because of interval measuring of depths with no standard benchmark as base point. For this reason the finds originating from one stratigraphic layer were treated as of uniform depth for that layer without further division according to the inner microstratigraphy, although the real deposition of the archaeological finds can result from a number of recurrent occupations (see below).

The whole of the southern and middle part of the cave was settled, but different parts vary in their information value. For instance the original archaeological situation close to the western cave side in sector E suffered great damage from the older excavations, in contrast e.g. to sector G, in which layer 6 was much better preserved and thus was suitable for more detailed documentation (on the issue of the damage to the layers see Neruda 2013). It follows from the study's underlying rationale that the results of the analysis have to be viewed at the correct "resolution". We can utilise the spatial analysis for seeking similarities and differences between larger areas in various parts within the cave, i.e. for identifying fundamental principles of the behaviour of Palaeolithic hunters in relation to the occupied cave. In contrast, detailed analysis of the *individual* concentrations or relations among the finds cannot be performed, since most of the artefacts have been moved from their original places of deposition.

Despite problems related to the taphonomy of the site and the method of analysis, we succeeded in tracing several concentrations of marked differentiation in the cave. In this respect we have to resolve three cardinal questions. Are we working with a homogeneous collection, or is it a palimpsest of repeated visits? Are there any significant differences among the concentrations that would indicate functional differentiation in the individual areas within the cave? How can we interpret empty areas, or areas yielding a minimum of finds within the cave?

The deposition and post-deposition processes in the cave (more details on the issue in Neruda, Nerudová 2014a, Valoch 2011b), the taphonomy of the site (older modifications of the cave filling), and the methods of documentation K. Valoch applied to the material all render study of the homogeneity of the assemblage very difficult, if not impossible. The finds from layer 6 are not scattered more or less regularly in the entire space; on the contrary, they form marked accumulations that are relatively clearly delimited (at least in sector G1; the anterior digs might have distorted the situation in the other areas).

Layers of disintegrated charcoals, at least some of which represent the hearths discovered during the excavations conducted by J. Knies and M. Kříž, bear upon the issue of homogeneity of the assemblage retrieved from layer 6 (summarised by Kostrhun 2005). Although we cannot unequivocally associate these "hearths" with layer 6, certainly a majority are tied with the late glacial settlement of the cave, and hence also the Magdalenian. It is apparent from the spatial reconstruction of their situation within the cave that with many fireplaces the buffers of 1.8 m radius from the centre of the hearth overlap (*Figure 6d*); this should be evidence of their non-contemporaneity (on the issue cf. e.g. Binford 1996, Gamble 1986, Henry 2012). Therefore, although we cannot unambiguously correlate this observation with the spatial distribution of the artefacts unearthed during Valoch's excavations, it is a sign that more than likely indicates a repeated occupation of the Kůlna Cave during the Last Glacial Maximum and the Late Glacial.

If layer 6 artefacts result from recurrent occupations, however, it is more likely that the same group of humans revisited the cave, since the activities were concentrated in the same places.

In this respect it is worth mentioning the radiocarbon date from the hearth in sector G1 that was identified during Valoch's excavation (Valoch 1974). Valoch stated that the finds retrieved from layer 6 were not connected with this fireplace, and the radiocarbon date seems to support this. Charcoals from the hearth were dated at 20.8 ka cal BP (17,480 ± 155 14C BP; GrN-6103), whereas the samples of hard animal materials from layer 6 repeatedly yielded dates around 14.7–14.8 ka cal BP (Neruda, Nerudová 2014b). For instance, the finds from the Stránská skála Hill (site N. IV) are of a similar age (Svoboda 1991) and no material has been identified in the Kůlna Cave that would definitely corroborate its occupation towards the end of the LGM (26.7–20/19 ka BP, dating according to Clark *et al.* 2009). This period is not preserved in the sedimentary record either. The uppermost Micoquian 6a layer is in direct contact with the Magdalenian layer 6, with both consisting of the same loess; the two horizons differ only in the content of debris. Therefore, we can neither confirm nor exclude sedimentation within the LGM.

On the other hand, we can give a clearer answer to the question whether the individual concentrations show signs of distinct activities. On comparing e.g. the concentration in sector G1 and the right hand-side of the entrance in sector A, it seems obvious that slightly dissimilar operations were performed. Apparently, a larger-scale primary processing of raw material (cf. the representation of flakes from preparation stage of core reduction) was done in sector G1; sector A was more likely the area for consuming the finished products in further processes. We could perhaps put down the decrease in the number of burins to a lower share of hard animal materials.

The concentrations in sectors L and K appear to be totally different, both on the grounds of technology and typology, and the representation of the processed raw material, since this is where – with some exceptions – only the Moravian cherts were captured. Both the specific function of the place, where exclusively a certain type of raw material had been processed, and representation of an entirely different technocomplex (Epigravettian?) provide explanations for the differences. In such case we would have to link the relatively clear delimitation of the individual concentrations most likely with the morphology of the cave which would be a major influence on e.g. the microclimatic conditions in the individual parts of the occupied space; this means that not only tradition but also external influences would have played their role in the selection of a place.

Although the functional differentiation of the individual accumulations has been demonstrated, it is noteworthy that in comparison to the Middle Palaeolithic horizons (especially layers 7a and 6a, where the individual areas are complementary in terms of function) the Magdalenian structures appear to be somewhat less diversified (Neruda 2011). This is directly contradictory to the views of Pettitt (1997), who emphasises the simplicity of Middle Palaeolithic spatial structures and the complexity of zoning of the settlement area in Upper Palaeolithic localities.

The schematic of the hearths discovered in the course of the anterior excavations can be employed also in the evaluation of the "vacant" areas in the Kůlna Cave. Most of these do not coincide with the concentrations of finds from Valoch's excavations. This is because in these areas diggings significantly disturbed the original archaeological layer and the finds were removed (sectors C, D1, or E); as a consequence the representation of finds in these areas is so low (*Figure 6c, d*). To the north of sector H and E the original find situations of the Late Glacial had been disturbed by the modifications made to the cave during WWII (Břečka 2011, Neruda 2013). According to M. Kříž the area between his trench XII (*Figure 6d*, on the right) and the northern entrance (probe IX) was archeologically sterile (Kříž 1889). We can therefore infer that while this area was greatly damaged by the German building works (Neruda 2013), its utilisation by late Pleistocene humans was rather limited.

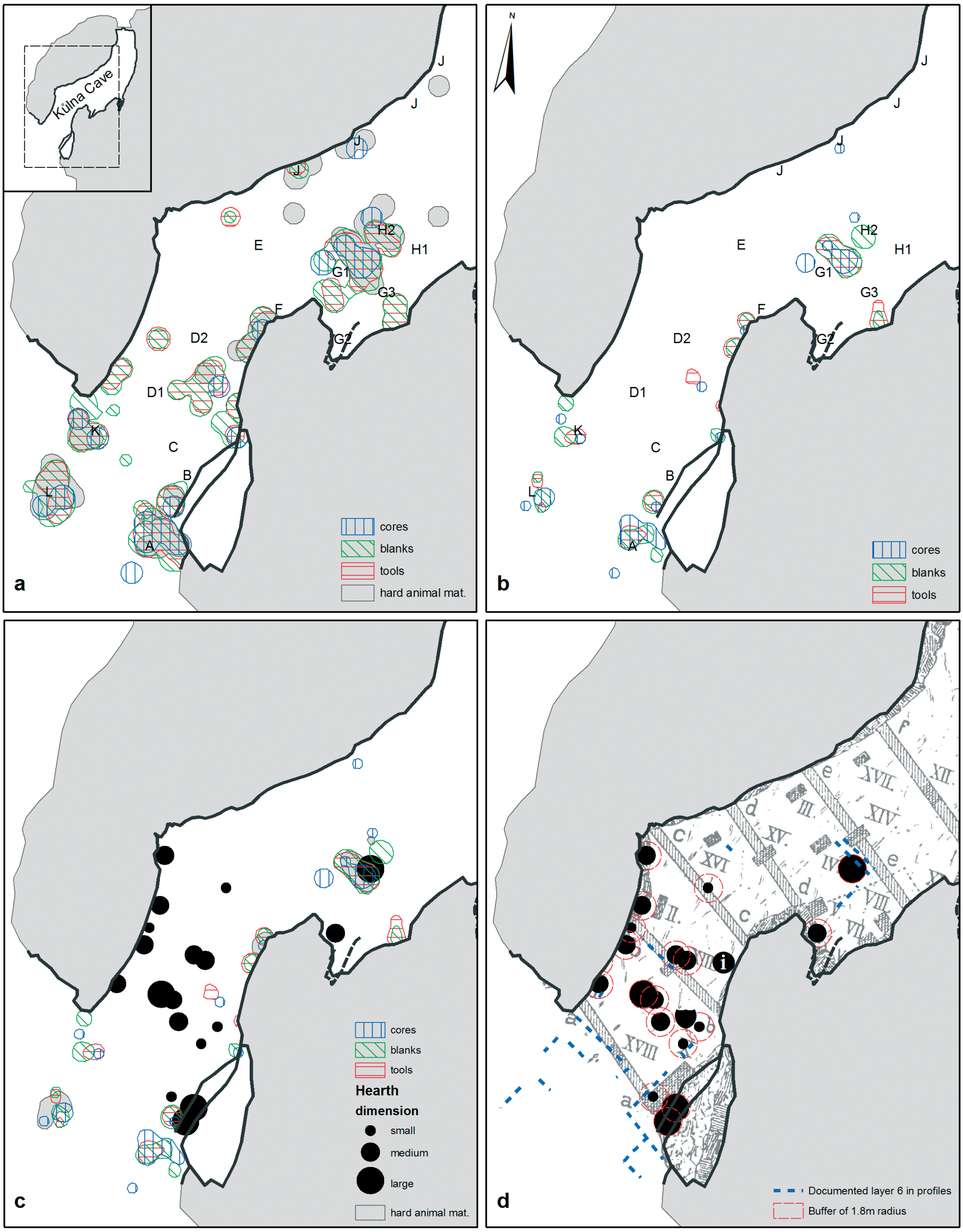

FIGURE 6. Synthesis of the spatial analysis. a, range of the finds in the density interval 2–5; b, range of the finds in the density interval 3–5; c, relation of hearths to accumulation of finds; d, correlation of Kříž's plan of probes (Kříž 1889), hearths identified by M. Kříž and J. Knies (Kostrhun 2005), and extension of layer 6 in the profiles of K. Valoch excavations.

CONCLUSION

The spatial analysis of the cave has shown that utilisation of geographic information systems enables us to draw new findings even from older excavations. On choosing pertinent procedures even less promising data (from the viewpoint of spatial identification) can be converted into a format, which enables an assessment with the modern tools of geographic information systems. Although the resulting model is not fully detailed, it still provides at least partial insight into the dynamic facets of human behaviour.

Analysis of the spatial distribution of the finds has shown quite clearly that the occupants structured the area of the cave in a particular way. The individual places within the cave might have served different purposes (e.g. the exploitation of the Moravian cherts), although functional differences between the individual accumulations of finds or their interpretation is less clear-cut than e.g. with the Middle Palaeolithic structures identified in this cave (Neruda 2011).

At the same time, analysis has revealed that the spatial distribution of the finds can be an outcome of repeated revisiting, probably by the same group of hunters. On the strength of the radiocarbon data from the hearth in sector G1 we cannot even exclude the possibility that during the LGM, humans of another technocomplex (Epigravettian?) visited the site as well.

It would be constructive to compare the findings reported here with other Magdalenian cave sites. There is only one comparable locality in Moravia – the Pekárna Cave in the southern part of the Moravian Karst – that could serve as a suitable analogue (Lázničková-Galetová 2010). Unfortunately, georeferencing of the finds from this cave is even more difficult than in the instance of Kůlna.

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Blinková Zuzana
Institute of Archaeology and Museology
Faculty of Arts
Masaryk University
Arne Nováka 1
602 00 Brno
Czech Republic
E-mail: zuzana.blinkova@gmail.com

Petr Neruda
Moravian Museum
Historical Museum
Anthropos Institute
Zelný trh 6
659 37 Brno
Czech Republic
E-mail: pneruda@mzm.cz