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Article

Color of Small Ochre Fragments from the Upper Paleolithic Sites Kapova Cave and Kamennaya Balka II (Russia): Combining Visual Color Identification and Cluster Analysis

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Abstract: A technique for characterization of color of small ochre samples was proposed. The technique includes visual color determination with the aid of stereomicroscope and Munsell Soil Color Chart, conversion of Munsell values to CIE L*a*b* coordinates, cluster analysis and principle component analysis (PCA). The technique was applied to ochre samples from Kapova Cave and Kamennaya Balka II Upper Paleolithic sites. Characterization of the color of a statistically significant number of pigment samples makes it possible to identify the relationships between different structural features of the cultural layer, reliably identify a wide range of artistic practices in parietal caves in addition to the actual creation of drawings, and also possibly serves as a chronological marker at multi-layered sites.

Keywords: ochre; upper paleolithic; mineral pigments; color characterization; munsell color system; parietal cave

1. Introduction

An important problem in studies of parietal caves is the determination and accurate description of the color of the pigments. The variability of the colors of the paintings itself is usually less than for pigments found in the cultural layer and at the cave floor level [1–3]. Determining the color of pigments on cave sites allows for a broader and deeper analysis of both the technologies for producing paint for drawings and the range and scale of practices of using paint materials outside the context of creating parietal cave art.

The data on the color of pigments allow us to expand the understanding of the use of pigments on open-air archaeological sites, especially taking into account the spatial analysis of the studied area of the cultural layer and the identification of functional features of its activity areas.

The study of numerous samples of pigments found on Upper Paleolithic sites demonstrated a variety of forms, compositions, and colors of these pigments. P. Vandiver noted in one of her early works [4] that the pigment color depends on the degree of grinding of raw material and the admixtures of various minerals. The description of color in [4] was based on subjective perception.

The development of less subjective approaches to describe color of archaeological pigments is an important area of research for many years. A simple approach is to use visual comparison of sample color with some kind of color scale – e.g., Munsell Color Chart.

C. Couraud [5] was one of the first to use the Munsell color system to determine the color of pigment samples from three sites of the Arcy-sur-Cure group (Grotte du Bison, Grotte du Renne, l'Abri du Lagopède). The author points out that the perception of color strongly depends on the lighting conditions and on the personal skills of the researcher. It is noted that the color of the pigment differs on different sides of large samples that show traces of processing. When the top layer of a

large sample is removed, the color becomes brighter. In addition to the Munsell system notation, the author also used generally accepted color names, such as red, yellow, and blue.

The Munsell color system was used by researchers of the Middle Paleolithic layers of the Qafzeh cave to describe the color of the samples [6]. Several other characteristics of the sample were also recorded. The color of the samples was correlated with their chemical composition: the samples were red or pink in most cases. Yellow samples were practically not found; however, the ochre having a yellow color contained goethite and maghemite.

We should note that authors of these works have described the color of fairly large ochre samples. In many cases, a description of the color of small samples is required, for which it is difficult to compare their color with the color scale when observed with the naked eye.

The description of color in Munsell scale coordinates makes it difficult to use modern statistical tools to work with large data sets. Therefore, in a number of studies, other colorimetric systems were used, such as CIE L*a*b*. Experimental data were obtained using diffuse reflectance spectrophotometers or cameras.

In an experimental study in 2006 [7], devoted to the dependence of the color of ochre pigments on their composition, the authors used a diffuse reflectance spectrometer to determine the color. Both modern and 19th century ochre samples were studied, 29 samples in total. One of the main drawbacks of this approach is the necessity of preparing flat samples. The results were recorded as CIE XYZ values and subsequently converted to the CIE L*a*b system. This system allows us to visualize data as points in a three-dimensional space. Authors conclude that for the studied ochre set, it is preferable to use a* coordinate for differentiation of samples; moreover, there's a clear quantitative relationship between a* and total concentration of iron oxides. The content of goethite (yellow ochre) was correlated with the b * values, and the addition of hematite (red ochre) increased the a * value of the color. The mixture of white minerals (quartz, dolomite, calcite, and gypsum) increased the L* coordinate.

The work devoted to the study of the Upper Paleolithic pigments of the Hohle Fels cave [8] also contains a technique for describing the color of the samples. Large samples (larger than 5 mm) were used to make streaks on white unpolished ceramic plates. The plates were then photographed under the same conditions and lighting; photographs were exported to Adobe Photoshop, where the colors were measured using the CIE L*a*b system. Unfortunately, the publication does not mention color calibration, for example, using ColorChecker.

A similar method of color determination was tested in the studies of materials of African sites several years earlier [9,10] , but no color calibration was performed before photographing ceramic tiles. The 'ceramic plate streak' approach requires partial destruction of the pigment sample; moreover, it is not applicable to small lumps or powder samples.

Quantitative information about the color of ochre can be interpreted together with other data about the archaeological site. For example, in the paper by Velliky et al. [8], the authors discussed (see Figure 7 from [8]) the dependance of the predominant color of ochre in the cultural layer of the cave on the dating of this layer.

In this paper we propose a new approach for determining the color of small ochre samples. The approach requires simple and portable experimental equipment: a stereomicroscope and a Munsell scale; so it could be used in expeditions. The approach also includes the conversion of data from Munsell coordinates to CIE L*a*b* coordinates, making it possible to use cluster analysis to search for patterns in the obtained data.

2. The Archaeological Sites

We studied Upper Paleolithic pigments from Kapova Cave and the open site Kamennaya Balka II (Russia). The choice of these two sites is justified by the fact that they represent different site types, a parietal cave and a residental settlement site. Due to the differences between the functional types of the sites, comparison of pigments from them is of particular interest.

Kapova Cave is located in the Southern Urals on the Belaya River. The underground cavity is a system of halls and corridors located on three hypsometric levels. The lower level is occupied by the underground Shulgan River.

The first Upper Paleolithic wall paintings in the cave was discovered by A. Ryumin in 1959 [11]. In 1960-1978, the archaeological study of the cave was headed by O. Bader [1]. In 1982-1991, V. Shchelinsky's expedition conducted excavations in the Chamber of Signs, where the Paleolithic cultural layer was discovered and studied [12]. Since 2008, research in the cave has been conducted on a regular basis by the South Ural archaeological expedition of Lomonosov Moscow State University under the leadership of V. Zhitenev [2].

Currently, there is every reason to argue that Kapova Cave is an underground sanctuary, both in terms of the location of wall paintings and in terms of the location of human activity traces [2, 13]. Various types of archaeological evidence of the Upper Paleolithic period were discovered in Kapova Cave: visiting areas; isolated 'depots' of mineral pigments; 'palettes' and stones with ochre marks (these objects were hidden between large rocks and in some cases covered by stones or slabs); slabs with fragments of images; traces of artistic activity such as dried drops of paint, etc.

Calibrated results of radiocarbon dating of human activity in the Kapova Cave in the Upper Paleolithic period give an age from 19600 – 16300 cal BP [2]. The results of the radiocarbon dating are in agreement with the results of the ^{230}Th-U dating [14].

In the Dome Chamber of Kapova Cave, nine horizons of visiting with Upper Paleolithic cultural remains were recorded in Late Pleistocene deposits [2].

The Upper Paleolithic open site Kamennaya Balka II is located on the right bank of the Don River. The sites of Kamennaya Balka (Kamennaya Balka I, II, III) were discovered by M. Gvozdover in 1957 [15], research was conducted from 1957 to 1971, and then resumed by N. Leonova in 1978 of the Don Archaeological Expedition, Faculty of History, Lomonosov Moscow State University (for example, ref. [16]). Currently, the Kamennaya Balka II is being studied by the Don Archaeological Expedition of Moscow State University under the leadership of E. Vinogradova [17].

The site is a long-term open-air settlement [16]. More than 2000 m² have been excavated on the site to date. Three cultural layers, representing three different Upper Paleolithic settlements, are identified on the site. The main (second) cultural layer of the Kamennaya Balka II dates back to the time of 18 000-16 000 cal BP and is represented by lines of hearths, pits, including "pits with hammered bones", faunal remains, production zones and residential areas, probably including light ground dwellings [18]. The cultural layer contains areas with a high concentration of split flint, bones, coal, ash, and lumps of ochre, as well as personal ornaments made of mollusk shells.

The characteristics of the cultural layers and archaeological horizons for the sites studied in this work are discussed in detail in the following publications: for Kapova Cave in the article [13, with references], and for Kamennaya Balka II – in the article [19, with references].»

3. Materials

Pigment samples from Kapova Cave were: lumps and pieces of pigment found from 3rd to 7th horizons of visiting from the Dome Chamber; isolated pigment traces and small pigment piles from the Chamber of Chaos and the Chamber of Drawings. A total of 165 Kapova cave pigment samples were studied. No sampling of the mural paintings was carried out.

The pigment samples from Kamennaya Balka II are represented by 702 samples, mainly of the main cultural layer from the entire excavated area of the archaeological site.

Samples were collected using tweezers under a microscope during the study of small fragments from the cultural layer. Samples were placed in polyethylene zip-bags or 1.5 mL polyethylene test tubes, depending on the sample size, assigned a serial number, which was written on the outside of the bag or test tube. Samples were dried without heating at room temperature.

4. Methods

The samples (867 pieces in total) were studied by visual observation using a stereomicroscope (Zeiss Stemi 2000-C), magnification x5. The samples were illuminated with a halogen lamp (3100 K

color temperature). Most observations were carried out with ambient room incandescent lighting. Some observations were replicated without artificial room lighting, under diffuse daylight conditions. No differences in color evaluation were noticed.

Munsell Soil Color Charts (published in 2019, 2009 revision) were used for color evaluation.

The pigment sample was placed on the microscope sample stage, focus was adjusted as necessary, and then separate pages of Munsell Soil Color Charts (MSCC) were placed (one by one) near the sample in such a way that both the sample and the color swatch of the MSCC were simultaneously visible through microscope optics, see Figure 1. Nearest color match was recorded.

Figure 1. Photo illustrating the process of matching MSCC color patches with sample color during microscopic investigation.

Several observations were replicated by another observer; no significant variations in color values were observed.

The color of heterogeneous pigment samples (mainly of loamy nature) was determined as the most represented in the sample. It is possible to record several different color values for different parts of the sample, but in the present study, we have not used this approach.

The samples were studied after at least several months of storage, so they were air-dried at ambient temperature and humidity.

4. Results

4.1. Data Processing

The Munsell color system describes color by three coordinates: color tone (hue), lightness (value), and chromaticity (chroma). Initially, the system was built on the basis of discrete (categorical) color intervals. This feature of the Munsell system facilitates the qualitative interpretation of data, but significantly complicates the application of those quantitative statistical methods that require continuous data distribution.

An approach to solving this problem was proposed, for example, in [20]. The authors proposed a simple geometric interpretation of the three coordinates of the Munsell system, which allowed them to obtain a continuous distribution of data on the color of archaeological ceramic samples.

Modern colorimetric coordinate systems, such as the widespread CIE L*a*b, are inherently continuous; moreover, CIE L*a*b is constructed so that the geometric distance between two points in this coordinate system is directly proportional to the difference between the two corresponding colors [21]. This feature significantly facilitates the use of data clustering methods based on the Euclidean metric.

An additional advantage of the CIE L*a*b system is that for photos taken with color calibration scales, even with an entry-level camera, but under uniform lighting conditions, it is possible to convert the color in RGB coordinates to CIE L*a*b coordinates [22]. The RGB coordinates of the sample color on the photo depend on illumination, camera model, etc., but the CIE L*a*b coordinates (with the help of color calibration) are hardware and illumination-independent. In the future, this approach may allow quantitative comparison of the color of images on the cave walls with the color of small fragments of ochre collected from the cultural layer.

Conversion from Munsell coordinates to CIE L*a*b* could be carried out by interpolating tabular values, see for example [23].

There is an open source software library named Colour [24], which allows color conversion between different color coordinate systems. In this paper, we propose using the following procedure for a quantitative statistical interpretation of the color of small fragments of ochre:

1. Visual determination of the sample color using Munsell Charts and optical microscope.

2. Conversion of the sample color from the Munsell coordinates to the CIE L*a*b coordinates using the Colour library. The library does not contain a function for direct conversion from Munsell to CIE L*a*b* coordinates. We have applied a chain of three functions: colour.munsell_colour_to_xyY(munsell_colour), colour.xyY_to_XYZ(xyY), colour.XYZ_to_Lab(XYZ). Color data were also approximately converted to RGB coordinates for plotting (for illustrative purposes only) by function colour.XYZ_to_sRGB(XYZ).

3. Correlation and cluster analysis of the obtained data set in CIE L*a*b coordinates.

A fragment of the data set on the color of the samples is given in Table 1 (the first 20 samples from the Kamennaya Balka II site), the full data set is provided in Supplementary, Tables S1 and S2.

Table 1. Color of ochre samples from the Kamennaya Balka II site (example fragment of the complete data set).

Sample ID	Munsell color	CIE L*a*b color
KB2-001	2.5YR 4/8	40.74, 29.84, 33.82
KB2-002	10R 5/6	51.00, 25.80, 19.30
KB2-003	2.5Y 8/4	80.53, 4.57, 23.91
KB2-004	2.5YR 7/6	70.86, 22.85, 22.65
KB2-005	10YR 7/6	70.86, 10.89, 35.05
KB2-006	5YR 5/6	51.00, 19.89, 28.51
KB2-007	10YR 6/8	61.05, 13.97, 48.58
KB2-008	5YR 4/4	40.74, 15.14, 18.53
KB2-009	2.5Y 7/6	70.86, 6.40, 37.79
KB2-010	7.5YR 5/6	51.00, 16.51, 32.37
KB2-012	2.5Y 8/4	80.53, 4.57, 23.91
KB2-013	2.5YR 6/6	61.05, 22.92, 22.94
KB2-014	10R 4/6	40.74, 26.61, 19.39
KB2-015	2.5YR 4/6	40.74, 23.76, 24.08
KB2-016	2.5Y 8/4	80.53, 4.57, 23.91
KB2-017	2.5Y 7/6	70.86, 6.40, 37.79
KB2-018	2.5Y 8/6	80.53, 5.70, 37.66
KB2-019	2.5YR 4/8	40.74, 29.84, 33.82

Data were processed using the agglomerative clustering method [25]. A similar approach, agglomerative clustering, was used to analyze data on the colors of glass beads in [26], however, they used the "homemade geometric" coordinates based on the Munsell system, and not the CIE L*a*b coordinates.

At each iteration, the agglomerative clustering algorithm combines the two samples which are nearest to each other (in CIE L*a*b* coordinates) into a cluster; procedure is completed when all samples are combined into one cluster. During clustering, a tree diagram is formed that displays the

"similarity" of the samples. The "leaves" of a tree are single samples, the "branches" are clusters, and the "trunk" is a cluster that unites all samples. The clustering results are presented in the form of a tree diagram in Figures 2 and 3 for the Kapova Cave and the Kamennaya Balka II site, respectively.
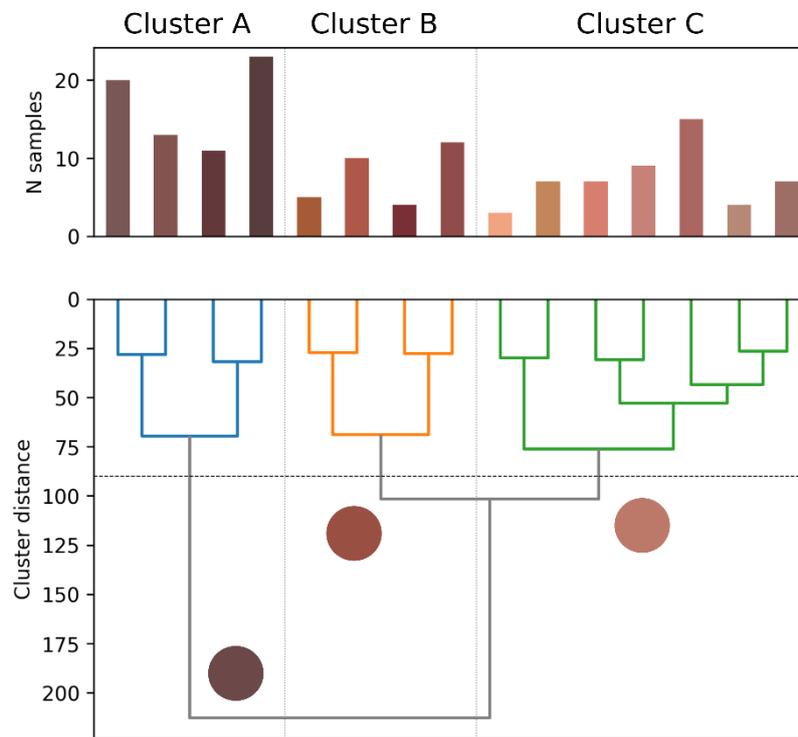
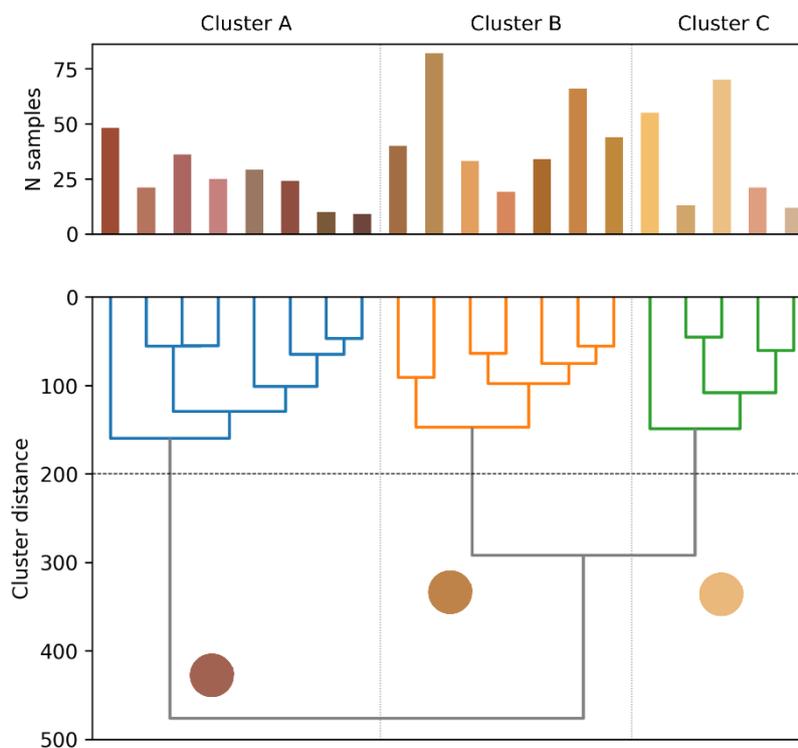**Figure 2.** Tree diagram of clustering results for ochre samples from the Kapova Cave.

Figure 3. Tree diagram of clustering results for ochre samples from the Kamennaya Balka II site.

The dendrogram is shown in the lower part of the Figures 2 and 3. The Y-axis is the distance between the center of the mass of clusters in L*a*b coordinates, which is a measure of the visual difference in the color of the samples. The horizontal dotted line is the «cut-off» level, which determines the number of clusters.

The upper part of the Figures 2 and 3 shows a bar chart corresponding to the "branches" of the tree. The height of the bar shows the number of samples in this cluster, and the color of the bar is the average color of the samples in this cluster.

There are no strict rules for choosing the "cutoff" level, that is, the difference in color that we consider sufficient to divide samples into clusters. It is recommended to strike a balance between the final number of clusters and the variability of the sample characteristics within a cluster. We have chosen this level in such a way that for both data sets (for the the Kapova Cave site and for Kamennaya Balka II site), the final number of clusters was equal to three. The cut–off level for the data for the Kapova Cave was established at 85, and for the Kamennaya Balka II site was established at 200. So, the differences between the three clusters for the Kamennaya Balka II site are significantly greater than for the Kapova Cave. This is due to both the greater heterogeneity of the set of samples from the Kamennaya Balka II site and its greater number compared to the set of samples from the Kapova Cave.

Our initial attempts to use elbow plot method for the selection of the number of clusters did not give a clear picture for our data - there is no pronounced inflection point for either Kamennaya Balka II and Kapova Cave.

Therefore, the decision to choose the number of clusters equal to three was made based on two factors. First, we took into account that there are three predominant colors of ochre on each site. For Kapova Cave, the main colours are dark brown ochre, dark red ochre and bright red ochre. For Kamennaya Balka II there are bright red ochre, dark yellow ochre and bright yellow ochre, respectively. Second, our visual color observations were supported by the shape of the dendrogram – the separation of the groups of samples is visualised by length of the branches of the tree.

In the lower part of the figures (on the tree diagram) the average colors for each of the three clusters A, B, and C are also shown as circles.

To construct a two-dimensional projection of a three-dimensional dataset (e.g., CIE L*a*b color coordinates), principal component analysis (PCA) is an obvious tool of choice. This method reduces the dimensionality of the data without a significant loss of information. The new coordinates are a linear combination of the original ones. We applied the PCA to both data sets (the colors of the samples from the Kapova Cave and from the Kamennaya Balka II site), and created scatterplots in new coordinates (PC1 and PC2 - the main components 1 and 2), see Figures 4 and 5 and corresponding Figures S7 and S8 from Supplementary Materials. The size of each dot on the scatterplot indicates the number of single observations of this particular sample color. Due to the discrete nature of colors in Munsell tables, many samples are described by exactly the same color, thus complicating the interpretation of a simple scatterplot. The colors correspond to the colors of clusters A (blue), B (orange) and C (green) in the tree diagrams (Figures 2 and 3). The lower part of the figure also shows the colors of some arbitrary chosen samples, indicated in the scatterplot by numbers. Red ellipses indicate the area in which samples belonging to a particular cluster are located with a probability of 95% (that is, 2 sigma).
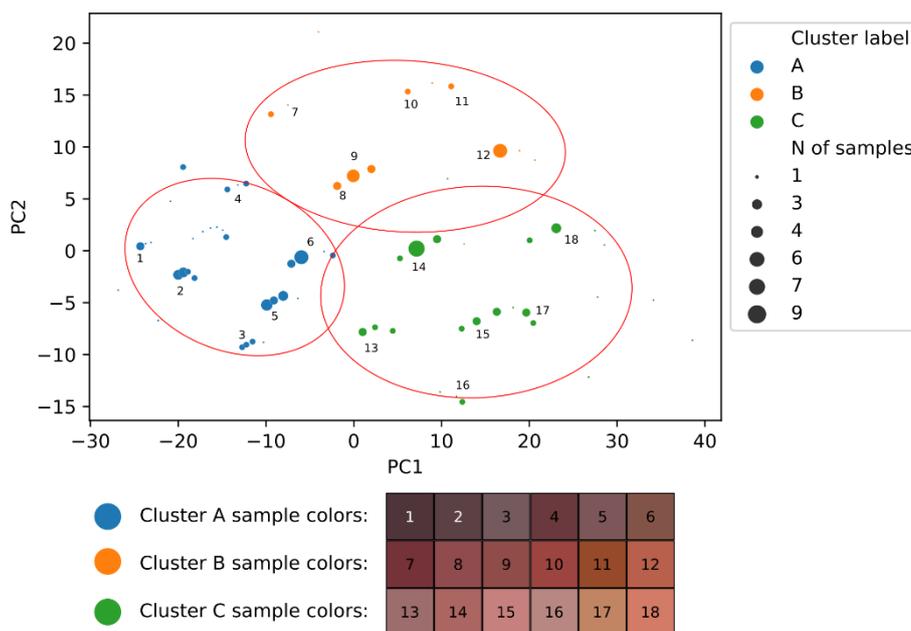
Figure 4. Scatterplot of the PCA transform of ochre color data from the Kapova Cave.
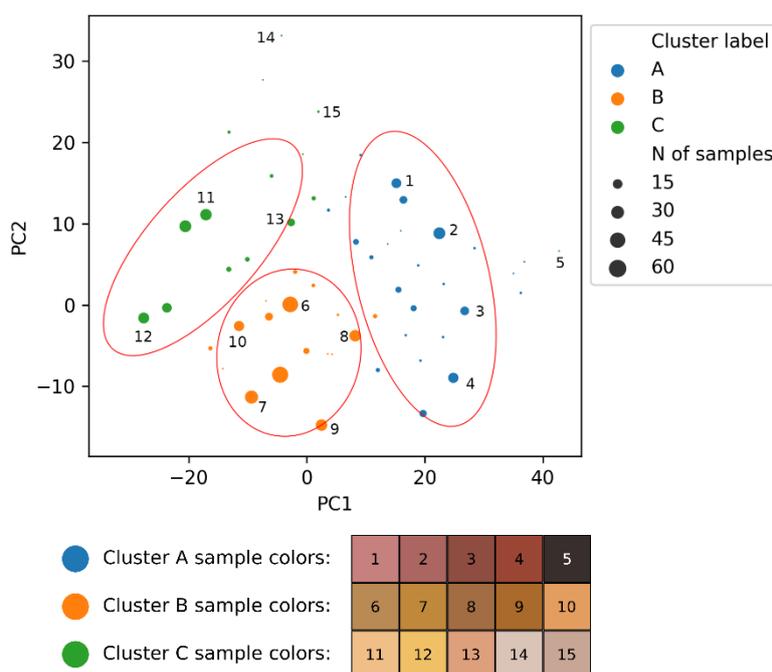

Figure 5. Scatterplot of the PCA transform of ochre color data from the Kamennaya Balka II site.

4. Discussion

The results of the approach evaluation on the example of Kapova Cave materials demonstrate wide opportunities for a more effective analysis of the spatial distribution and refinement of traces of human behavior in parietal caves.

Information about the colors and their correspondence to a particular color cluster for different locations of the Kapova Cave is presented in Figure 6. Similar information for Kamennaya Balka II is presented in Figure 7. The X axis shows the proportions of samples belonging to a particular color or cluster. The cluster designations correspond to the designations in the previous figures.
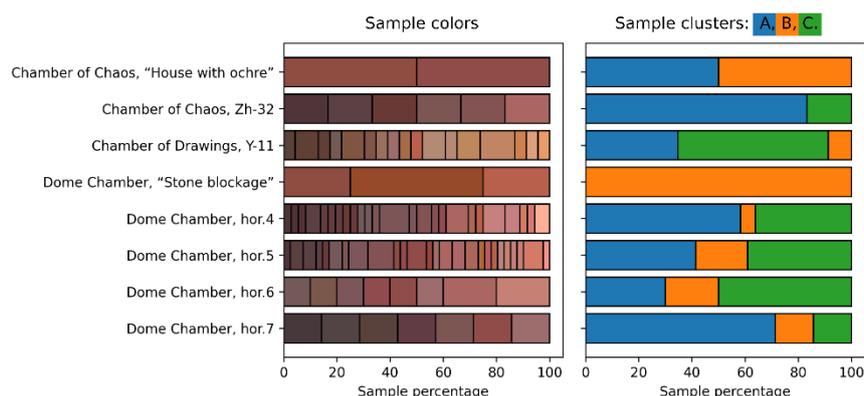
Figure 6. Colors of ochre samples from different locations of Kapova Cave.

The wide variety of colors in each cultural horizon of the Dome Chamber's visiting area is directly related to the wide range of activities carried out in this part of the cave [2]. The low level of diversity of the color palette in separate isolated objects pigment's concentrations of the 'House with Ochre' and the 'Stone Blockage' is obviously associated with the homogeneity of the materials within the framework of one type of activity. The average value at pigment's concentrations points Zh-32 of the Chamber of Chaos and Y-11 of the Chamber of Drawings is associated with quite intense, but limited, activity next to the wall images. The results of the study of the materials at these two points are particularly interesting because of the obvious difference in terms of their formation and the context of their location in the underground cavity. The accumulation of pigment in the Chamber of Drawings is located very close to the Eastern panel of paintings but has traces of a more diverse use than just a stock of pigment for artistic activity. The ochre is mixed here with a specially collected significant number of different forms of speleothems, evidence of making personal ornaments and/or use of exotic raw materials (serpentinite, which was used to make beads found in the Upper Paleolithic layer of the Chamber of Signs), as well as with brought (collected) bat bones. It has direct analogies to other objects in this chamber. Although it is far from the drawings, it is in a very close context with the accumulation of drops on the floor. In the Chamber of Chaos, the material comes from a rather narrow space between two blocks (with a large amount of charcoal, fragments of speleothem, some of which are painted, and pendant from drilled pebble); however, it is very difficult to give a functional definition of it and to understand the time of accumulation of materials, including pigments.

The results of the clustering of the colors of the samples can serve as an important verification tool of the conclusions presented. A more obvious difference in the form of heterogeneity of the individual clusters represented between the cultural horizons in the Dome Chamber is probably related to the peculiarities of the activities organization on each of the horizons on a fairly wide area, the expected size of which can be assumed by analogy with the visiting site in the Chamber of Signs, studied in the 1980s by the expedition led by V.E. Shchelinsky. The cluster of sq. Y-11 near the Eastern Panel of the Chamber of Drawings, which is quite close in terms of the representation of different clusters, is, as already mentioned, evidence of various activities near the drawings.

These features of the two points related to the distribution of pigments of all three allocated clusters make it possible to suggest that individual places next to the wall images, where not only traces of activity on their creation are recorded, but this, from the point of view of the topography of the cave - horizontal areas from 8 m², next to walls convenient for viewing, have explicit, but ephemeral from the point of view of their functional definition, the practice of using paints of more diverse colors than are represented on the walls. This becomes especially obvious in comparison with other objects studied, where the functional limitation of the practices of using colorful pigments at all levels of analysis of archaeological materials confirms this with all evidence.

A comparison of the pigments from the visiting horizons in the Dome Chamber demonstrates a certain difference between the 4-6 and 7 horizons associated with the dominance of the darkest, almost black, and purple colors.

At the same time, it may be that pigments from horizons 4-6 of the Dome Chamber and square Y-11 in the Chamber of Drawings have something in common, but ocher from horizon 7, apparently, is more strongly connected with pigments from square Zh-32 in the Chamber of Chaos.

It is yet difficult to say whether two accumulations of pigment are connected to each other, since there is only one cluster for the Stone Blockage, which, in general, is represented almost everywhere, and it cannot be attributed to those groups where this cluster is present in greater numbers. Since there is no such cluster in Zh-32, it can mean that the Stone blockage's pigments are less associated with Zh-32 and, consequently, with horizon 7, which is quite consistent with other archaeological data. And pigments from the House with ochre, respectively, is not connected with the Zh-32 and horizon 7 either, but it is connected with horizons 4-6.

The peculiarities of the two points (Y-11 and Zh-32) related to the distribution of pigments and all three allocated clusters make it possible to suggest that some places near the wall images, where not only traces of activity on their creation are recorded, have obvious traces of practices of using paint of more diverse colors than are represented on the walls.

This becomes especially obvious in comparison with other objects studied, where the functional limitation of the practices of using colorful pigments at all levels of analysis of archaeological materials confirms this with all evidence.

Possible relationships between individual points with colorful pigments can be discussed after geochemical comparisons of samples, and the planning and goal setting of this study will be much more correctly using the available data on their clustering by color.
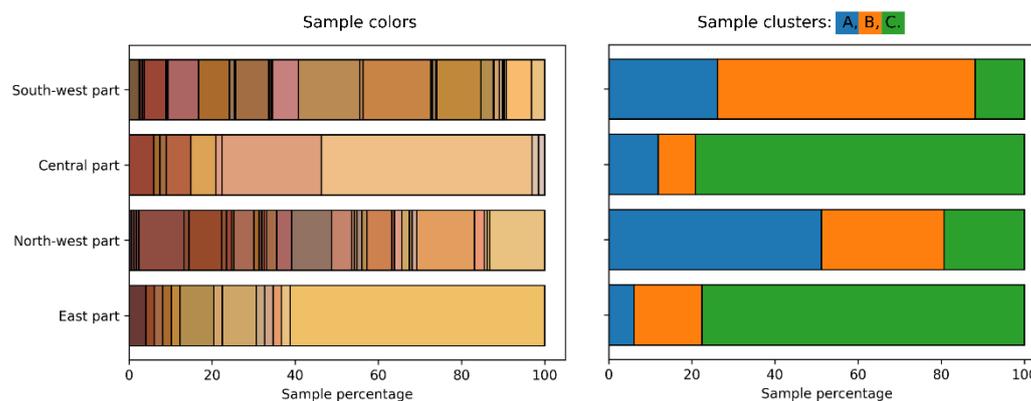

Figure 7. Colors of the ochre samples from different locations of Kamennaya Balka II.

The significant homogeneity of the Kamennaya Balka II, presented in Figure 7, deserves special attention. Since the main cultural layer of the site, the materials of which are being considered, are traces of, apparently, several episodes of visits and seasonal residence of a large group of people, the question of the degree of monoculturalism of the population that left traces of its activities always arises. The stone industry and analysis of the main structural features of the cultural layer, along with other traces and consequences of archaeologically recorded human behavior, fully confirm the thesis of a single cultural affiliation of the population, the results of whose activities formed the cultural layer. We can draw similar conclusions based on the analysis of personal ornaments from shells. Unfortunately, the bone industry, like osteological materials, is extremely poorly preserved. That is, the bone industry is usually considered the most significant, after the stone industry, component of the definition of a closely related or identical degree of cultural kinship. Therefore, the results of the multifactorial analysis of pigments [27] provide important additional arguments to confirm both the uniform cultural appearance of the material culture of the bearers of Kamennaya Balka traditions and the shortest chronological gaps between individual episodes of visits. The homogeneity of the color palette confirms previously available information and provides new materials for studying human

life strategies both at Kamennaya Balka itself and in terms of obtaining raw materials in the vicinity of the site. The large excavated area allows us to fully approach the identification of a new layer in the household and symbolic activities of people at open sites of the Upper Paleolithic. The possibility of using mineral paint pigments as a parallel approach to the bone industry to discuss closely related cultural ties of the population in the Upper Paleolithic should be further discussed.

5. Conclusions

Based on the color characteristics of 867 pigment samples from the collections of two Upper Paleolithic sites, it can be concluded that the usual color diversity of pigments (ochre: 'scarlet', 'cherry', 'pink', etc.) includes much more color variations from dark brown to almost white, multifactorial analysis of which - with appropriate methodological approaches – can bring significant additional information about the features of the structure of the studied sites. After analyzing published data on determination of the color of ochre pigment samples, it can be concluded that several sites of the Upper and Middle Paleolithic showed a relationship between the colors of pigment and minerals in the paint composition, for example, red pigment colors correspond to hematite and yellow pigment colors – to goethite. Data on the color of the samples obtained from the materials of Kapova Cave and Kamennaya Balka II open prospects for further comparison with the chemical composition of the ochre pigments.

The color palette of the pigments is also an important indicator of the variety of directions of their use. In Kapova Cave, the colorful pigments at different levels of visit in the Dome Chamber differ from the color of the wall images, with the rare exception of scarlet, while the pieces of ochre from the cultural layer of the Chamber of Signs are in many ways similar to the scarlet and cherry drawings in the cave. The individual concentrations of pigments (hidden between blocks) in the Chamber of Chaos are similar in color to single cherry-colored figures, but differ sharply from more than 90% of the scarlet drawings on the walls of this chamber (and the rest of the cave). However, the color of the pigment from the concentration in the immediate vicinity of the Eastern Panel of the Chamber of Drawings and the symbolic object under the Arch of the same chamber generally corresponded to the color parameters of each other and to the paintings on both panels in this chamber. At the same time, the color of the spots and fragments of drawings on the tiles from the "Stone Blockage" in the Dome Chamber was similar to the color of the wall, but the red palette was much richer in the collection of grains collected during the fieldwork there. At the same time, the situation with cherry paint is repeated, it is present, although in small quantities. Consequently, fixing the presence of different shades of pigments and the context of their detection allows us to obtain important additional information about the diverse household and symbolic practices carried out on monuments, as well as to give impetus and direction for advanced study of the issues of obtaining mineral raw materials, methods of its processing, and use both on individual sites and in regional and time comparison.

Moreover, the results of clustering (determining differences and similarities in the colour variations of pigment samples' groups), make it possible to isolate and identify (at least initially) the interrelated areas of human activity both in the Upper Paleolithic underground sanctuaries, where there is a limitation of ordinary archaeological material and its discrete distribution over the area of different parts of the cave, and in open-air sites, where a palimpsests of habitat episodes are common. Thus, the approach under discussion is an additional tool in the methodology of studying the spatial interposition of related clusters of human activity and the methodological selection of specific interdisciplinary research tools for reasoned conclusions about the relationship (and therefore about archaeological synchronicity) or its absence at specific areas on different types of the Upper Paleolithic sites.

The application of the discussed approach on other Paleolithic sites also shows its efficiency and significance. For example, the preliminary results of the study of pigment on a limited number of samples from the cultural layer and the male burial of the Sungir site had shown the possibility of solving questions about a more fractional stratigraphic division of different levels of cultural remains, field studies of which took place more than 50 years ago. The scientific and practical significance of

the approach under discussion proved itself well in the study of Upper Paleolithic wall paintings of Ignatievskaya Cave. It made it possible to reasonably abandon the hasty decision of cleaning several walls of soot and preserving drawings that had not yet been identified.

The results of the study of colorful materials from Kapova Cave and Kamennaya Balka II demonstrate the correctness, reliability, and validity of the discussed approach to pigments as a mass material. Only such a technique allows us to cover the entire archaeological material of the site, which contains many exceptions, differences, and subtleties. The study of pigments in the Upper Paleolithic cannot be complete without paying attention to their archeological context and household and symbolic use.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Table S1: Kapova Cave ochre samples - colors, Table S2: Kamennaya Balka II ochre samples - colors.

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Data Availability Statement: We encourage all authors of articles published in MDPI journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required. Suggested Data Availability Statements are available in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics.

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