Virtual Archaeology Review, **7**(14): 13-19, 2016
http://dx.doi.org/10.4995/var.2016.5382

Received: February 5, 2016
Accepted: April 24, 2016

CONVEYING CAPPADOCIA. A NEW REPRESENTATION MODEL FOR ROCK-CAVE ARCHITECTURE BY CONTOUR LINES AND CHROMATIC CODES

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Abstract:

Architectural heritage preservation is based on an in-depth, multi-layered and interdisciplinary knowledge of the cultural heritage sites, especially when they are a combination between natural and artificial, such as rupestrian (cave) architecture often is. Survey and representation of rock-cut architecture is one of the most problematic issues for a number of problems concerning the geometrical complexity of the interior and exterior enveloping surfaces. Laser-scanner is an appropriate tool concerning the registration of geometric and spatial properties of artificial caves in continuity with the external topography, but automatic representations are often unable to convey their hidden geometric and spatial relationships. In the context of a work methodology customized on the rupestrian habitat of Cappadocia (Turkey), the authors developed an original envisioning model in which an associate use of contour lines and chromatic codes transforms traditional orthogonal projections after the numeric model into drawings able to offer a synthesis and transmit the complex forms and relationships of rupestrian settlements.

Key words: Cappadocia, Karanlik monastery, rock-cut architecture, cultural heritage, infographic representation

1. Introduction

Although the technique of laser scanning (together with the photo-modelling) has either contaminated or replaced all surveying techniques practiced until a few years ago, its practice is still poorly controlled. Recorded scans are commonly used to produce eye-catching immersive representations and the wonder they realize has contributed to the success of this form of registration of historical heritage. However, if architectural surveyor's goal is heritage knowledge, then the representation stage requires for critical analysis and hermeneutic actions. The cloud of points after the laser scans should never mark the end of a survey but its beginning. Yet the current practice of the architectural survey, although supported by technologically advanced tools able to quickly record amounts of high-precision data, remains bereft of a solid and standardized methodology of metric data processing.

A briefly summary of the canonical architecture representations can contribute to elucidate the question. The plan is commonly considered the type of drawing that best describes the interiors and the reduction scale 1:50 is the most efficient scale to translate a building into exhaustive drawings. A plan is generated by a horizontal section plan that conventionally cuts the structure as high as the eye of an observer standing on the floor. The resulting line demarcating the sectioned parts is generally integrated by the graphic description of edges and apparent contours of all items placed below the section plan. Sometimes discontinuities among elements like the connecting lines of elements (e.g. lithologic stratigraphy, ceramic tiles, and inlaid wood) are added while discontinuities of surfaces are generally ignored. This conventional way of conceiving the architectural drawing generally results in a comprehensible image representing reality but may cause problems when the architectural work is formed by curved surfaces, like either simple or composites vaults. Such problems become central when one considers a man-made rock-cut habitat that is a sort of inhabited sculpture.

In the traditional practice of architecture survey, after a first phase of acquisition of the basic measures, a geometrical model is built, first mentally and then either graphically or digitally. This model represents the architectural subject through elementary geometric elements, such as parallelepipeds, cylinders, and spheres, which approximate the actual parts of the building. This geometrical model can be sectioned and projected in order to obtain plans, elevations and sections in an appropriate reduction scale and according to a metric tolerance that is proportional to the scale adopted.

The introduction of laser scanning and LIDAR technology has enhanced the digital photogrammetry (Briese & Pfeifer, 2007) and changed this process, which

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DOI: http://dx.doi.org/10.4995/var.2016.5382

was cognitive and representational at the same time. As defined by Boehler and Marbs (2002), a laser scanner uses laser light to measure distances from the sensor to the object in a systematic pattern. Thanks to a combination of a global navigation satellite system (GNSS) receiver and an inertial measurement unit (IMU), it provides the user with a geo-referenced model, with position and orientation system. These “clouds of points” produced by laser scans are extensive collection of points collocated in a system of three-dimensional (3D) coordinates, which are encoded with logical criteria, subdivided into punctual, linear, and areal entities and displayed in several formats according to different export processes.

The cloud of points generated by laser scanner procedure is the visual outcome of the process of measures acquisition. It reproduces the architectural body silhouette but despite the appearance of a defined numerical model (points model), it still requires a long processing stage to represent the morphological and chromatic features of the artefact in a consistent and univocal way to result in a scientific document of reality. Moreover, specific elaborations, which are required to respond to the demands from different research fields, like History of Art and Archaeology (Bianchini, Borgogni, & Ippolito, 2015), must be developed without censoring spatial and geometric data.

2. Rock-cut architecture in Cappadocia

The knowledge and preservation of architectural heritage are based on a deep, layered and interdisciplinary knowledge of the sites, especially when the architectural monuments are on the edge between natural and artificial as well as between archaeology and landscape, like rupestrian architecture often is.

In the last years the authors have had the opportunity to experiment a work procedure to meet the needs of both metric precision and correctness of the final graphic outcomes. As a survey team of a national research on rupestrian architecture in Italy and Cappadocia, authors have focused on the survey and representation of rock-cut architecture (Carpiceci 2013; Carpiceci & Inglese 2015). This is one of the most problematic issues for a number of problems concerning both the geometrical complexity of interior and exterior surfaces and the habit to enquire the built environment according to the Cartesian approach formed upon the everyday experience of the traditional “orthogonal” architecture.

Rupestrian architecture has its constructive specificity in being cut out of natural rock formations: this means that interior space is realized by subtracting matter rather than adding and assembling parts. As a consequence of this way of producing space, there is no direct relationship between interior and exterior surfaces. The external look of a rupestrian church is made of the natural surface of a cliff or a stepped hill. The interiors shaped by the ancient builders generally replicate rooms and forms after traditional architectures of the same ages. They can be easily reduced to their models such as boxes, columns and pillars, vaulted ceilings, sail vaults, pendentives and domes. At the same time, their surfaces have been carved with continuous formal variations that cannot simply be considered as an effect of builders’ incompetence, as it has been commonly interpreted.

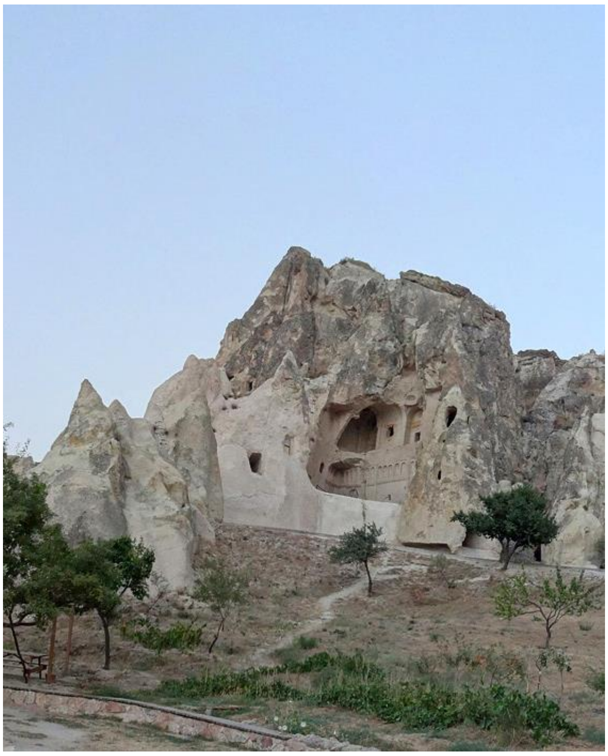

Figure 1: Goreme, Open Air Museum, Karanlik Monastery.

3. The case of the Monastery of Karanlik

The Open Air Museum in Goreme contains a remarkable number of religious settlements carved inside a large vertical semi-circular cliff linking the upper plateau to the lower valley (Carpiceci & Inglese 2015), where other rooms can be found inside the famous conical formations. Some of the settlements open their windows and courts to the natural exedra like the so-called Monastery of Karanlik (the Dark Church), which possibly harboured one of the most important communities of Goreme (Fig.1).

The rooms of this monastery were carved on three levels around a large C-shape courtyard. A short side presents the entrance, via a staircase leading to the upper level where there is a small entry (narthex), a side chapel and a quadrangular tetrastyla church with three apses, whose walls and vaults were completely painted by the 11th century (Figs. 2, 3).

Figure 2: Interiors represented in equirectangular panoramic projection. Goreme, Open Air Mousum, Karanlik Kilise.

Figure 3:Photomapped *ipografia* after meshed model. Karanlik Kilise.

The longitudinal side of the courtyard leads to several anonymous rooms as well as the dining hall (refectory) at the same level in the courtyard. Like in many of other Cappadocian monasteries the function of this kind of rooms is generally detectable due to the presence of a long table and a single annular seat, all of them clearly obtained by excavation. From this room a narrow staircase leads up but is stopped halfway (second level) by a millstone door. The steps then lead up to the third level where, in addition to several anonymous rooms, there is a sort of pseudo-oratory or meeting room in a privileged position for taking light from the façade upper windows and overlooking the courtyard. Beyond place and size, the importance of this room is underlined by both the architectural form similar to the structural components of the church and the presence of red monochrome decorations (Fig. 4) that are probably older than the church's paintings (Krautheimer 1986; Carpiceci et al. 2015a).

4. Methodological notes

Scans have been achieved with a small and light laser scanner FARO Focus3D X130: such an ultimate tool can be easily carried in the narrow and dusty caves of Cappadocia and guarantees a high daily productivity.

Spherical target shapes have been extensively used during the recording of individual clouds as they can be

Figure 4:Photomosaic of the Vaults of the pseudo-oratory. Karanlik Monastery.

placed along longitudinal paths and geometrically identified with every angle of vision. This operational practice resulted in the total abandonment of the topographic network that once was needed to spatially compose all the reference targets in the different rooms.

Surveying the painted surfaces within many of the rooms has required a special consideration (Carpiceci & Colonnese, 2014; Carpiceci, Inglese & Colonnese, 2015b). With the existing artificial lighting, RGB scanner recording procedure produces bad pictures that do not record the chromatic data of the surfaces. A proper registration through high definition cameras and with a controlled uniform light on all of painted surfaces would have required too much time. An acceptable compromise has been found in recording a black & white cloud by the reflectance in a complete darkness.

The external surfaces of Karanlik Monastery have been scanned at sunset while the internal surfaces of its rooms have been scanned in the dark of the night, for three consecutive days. This procedure responds to the problem of the crowd of tourists walking in this monument all day long. Spherical targets were disposed to favor the subsequent assembly of the scans together with homologous points that are easy to find in the sharp discontinuities offered by the cuts in the tuff rock. This procedure has resulted in a good definition of the painted surfaces, leaving a special and parallel photographic campaign the task of surveying the colour data of surfaces.

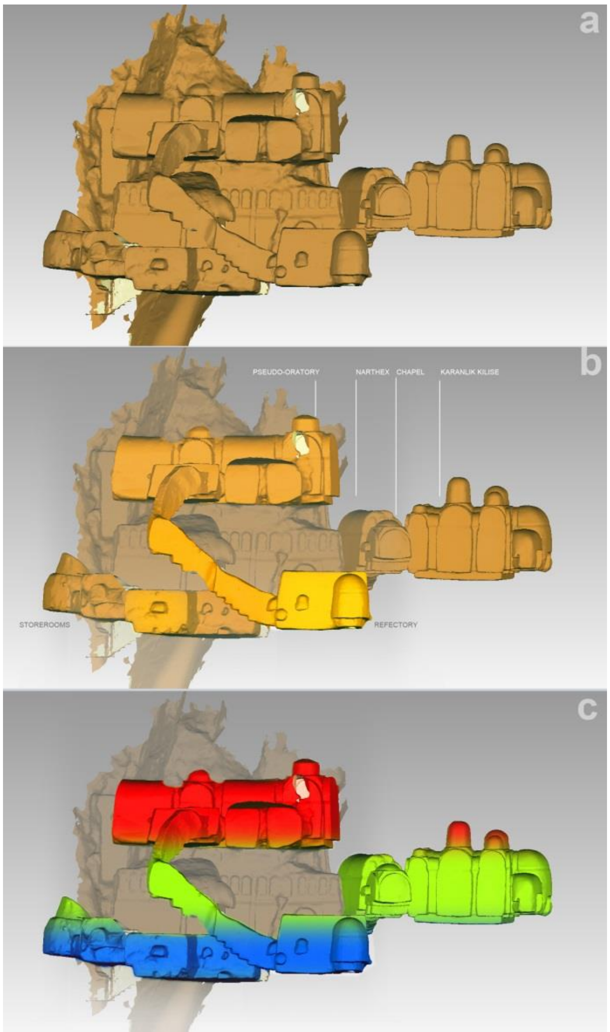

Figure 5:Meshed model after laser scanning, view from the east: a) Basic view of internal volums; b) Atmosphere treated view to enhance apparent deepness; c) Color treated view of main rooms related to the grouped contour-line representations. Karanlik Monastery

After the registration, the numerical model (per points) has been processed and translated into a meshed model (per surfaces). This model has been used to understand the organization of the interiors and decide the strategy of following representations. The model of the interior volumes has been treated to optically enhance the deepness effect, according to the principle of the atmospherical density or "prospettiva aerea" as defined by Leonardo da Vinci (Fig.5). But, of course, this kind of images offers only a partial comprehension of the complex organization of the carved settlement.

The sculptural nature of rock-cut architecture makes it impossible to envision rooms unambiguously through apparent contours or edges. Even advanced representations of rupestrian monuments after laser scanning are elaborated almost exclusively through photomapping and generally focus on internal spatial systems (Andaloro, Bixio, & Crescenzi, 2013). Therefore, the authors opted for a contour line representation, like in topographic charts. This was also suggested by the morphological continuity between interiors and exteriors. A number of significant section plans have been identified according to their ability to describe the complex morphology of the settlement: horizontal for the plans and vertical plans for elevations and sections.

In the cartographic practice, the equidistance (i.e. the constant gap between successive contour lines) is conventionally set at 1/1000 of the denominator of the scale of representation in meters. An equidistance of 5 cm is usually set for a canonical 1:50 architectural representation, but tests undertaken by the authors with this step have not given a readable result. The authors have consequently decided to adopt an equidistance of 10 cm that allows contour lines to describe the architectural shapes without becoming a sort of confusing background noise produced by excessive visual data.

The next step is the choice of the reference plans to produce the horizontal sections and the vertical sections. While a plan cannot but refer to a horizontal section plan, the vertical sections require a careful choice to describe most of the architectural characteristics of the rock-cut rooms whose configuration is so changing. In this case, authors have oriented the vertical sections in a perpendicular way to the longitudinal axes of the larger decorated rooms (Fig.6). By producing a number of sections driven by the position of the significant section plans adopted with regular intervals, this graphical strategy allows an efficient visualization of the tufa wall surfaces. In particular, it points out the relationships among the several rock-cut rooms and between them and the natural external surface of the rocky cliff, referring to the section plane chosen. To make sense of the horizontal and vertical complexity of the whole settlement as well as the 3D relationships between the rooms, an experimental representation has been developed by multi-colored contour lines.

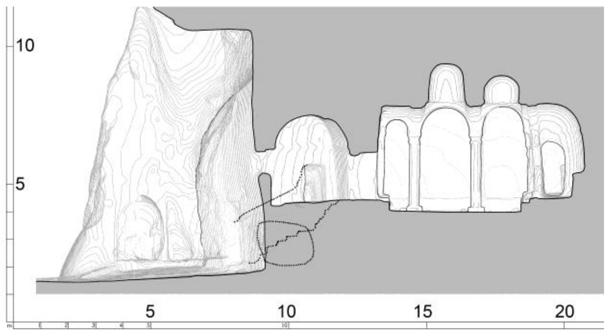

Figure 6: Longitudinal section through the church. Karanlik Kilise.

Figure 7: General plan: lower level in blue; middle level in green; upper level in red. Karanlik Monastery.

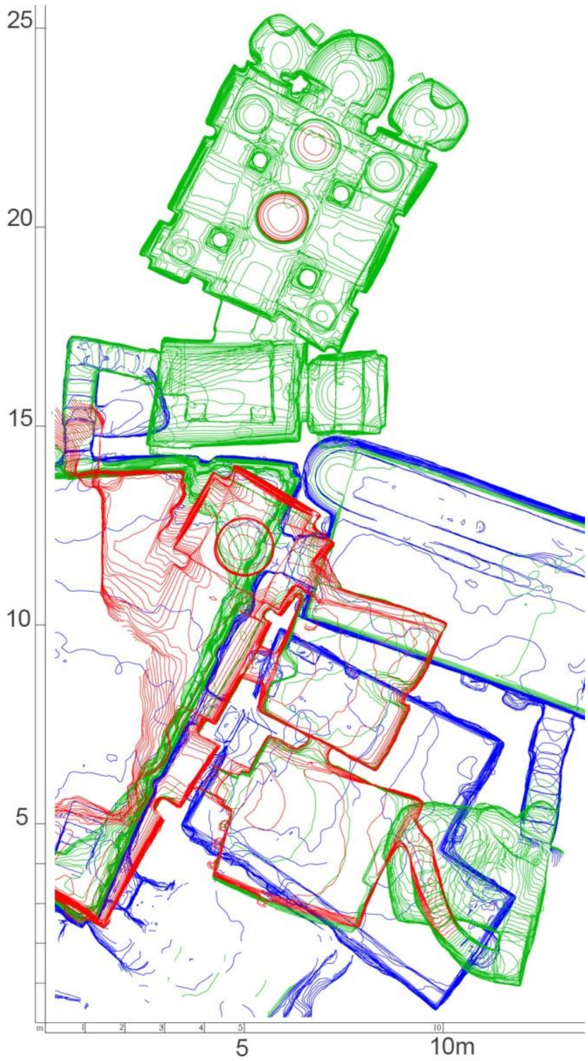

Figure 8: General plan, detail. Karanlik Monastery.

The procedure to realize this type of representation is formed by two main steps: transparency and assemblage. The former step is to leave sectioned parts unfilled and to maintain the background surfaces conceptually transparent in the orthogonal projections, in order to let the lower contour lines visible. The latter step is to divide the contour lines in groups referred to a single level and to assign them a different color.

In this kind of representations, each color allows the reader to quickly identify all the rooms and corridors sharing approximately either the same altitude or depth relative to the section plane. At the same time, the succession of colors helps the reader to relate the environments with what lies either above and below them or before and behind them (Figs. 7, 8). Moreover, it is evident that interiors show a natural continuity with the external surfaces.

5. Knowledge after drawings

The famous *Edifices de Rome Moderne* contains the results of the surveys of the most celebrated buildings of Rome. Those idealistic drawings made by the French draughtsman Paul-Marie Letarouilly represent an attempt to correct, perfect and translate in seducing images the most famous Renaissance buildings according to the 19th century idea of Renaissance. This is an approach historically shared by many other scholars. Architectural representations of rupestrian habitat seem to have been generally influenced by the quest for the idea behind the tangible form, too.

Until a few years ago, the drawings of Cappadocia rupestrian architecture were obtained with traditional procedures and showed plans and sections with rectangular rooms, definitely regularized if not invented. They were a direct representation of that geometrical model that every surveyor builds in his or her mind to study and gradually master an architecture configuration. However, this sort of aggregation of parallelepipeds and cylinders should be only a stage of the process and not the final graphical result.

Such an attitude is testified i.e. by the drawings made by Père de Jerphanion (1925) (Fig. 9), Nicole Thierry (1963) or Lyn Rodley (1985) (Fig. 10), which have been widely used by art historians and archaeologists to speculate and conjecture on builders' procedures and targets. In their plans, walls and openings appear as if they were built in masonry, with a constant thickness and orthogonal mutual T-junctions. Some of the rooms either of the examined settlements or near to them are generally ignored or censored. Their plans look systematically extracted out of their physical environment. Vertical sections are partial or missing and generally no altimetry information is reported in the drawings. This appears a serious omission in the case of Cappadocian morphology. Opposite than traditional architecture, in such a rock-cut architecture neither a wall can be assumed as a vertical surface nor a floor as a horizontal plane and this "natural" quality strongly influences its experience.

These drawings represent the effect of an excessive critical contribution of their authors as their way of translating the actual form of caves into traditional rectified architectures-like drawings would indirectly convey arbitrary interpretation and generate misunderstandings.

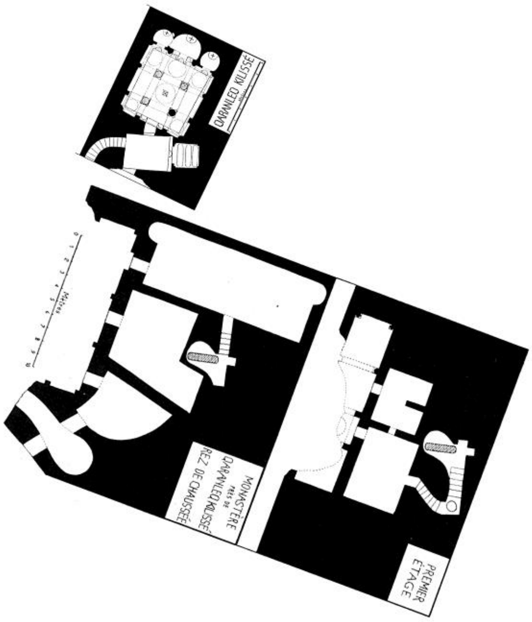

Figure 9: Plan of the church, first, and third level according to Jerphanion (1925-42). Karanlik Monastery.

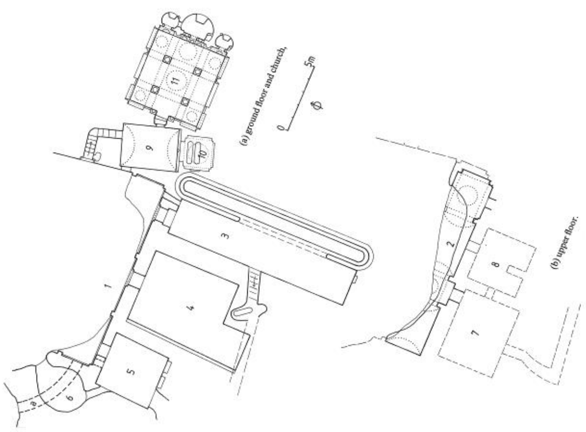

Figure 10: Plan of the first and third level according to Rodley (1985). Karanlik Monastery.

The 1990s surveys by Robert Ousterhout (2005) demonstrate a different attention to actual form of rock-cut rooms, and contemporary studies by Veronica Kalas (2009) testifies that she is aware of the importance of representing the actual deformations of plans. But also in their works, only few sections describe the actual altimetry of sites and the natural and morphological presences nearby are quite totally neglected. Instead, the authors believe that a neutral and faithful representation of actual forms by contour lines can:

- describe the strong continuity between external natural surfaces and internal carved rooms;
- suggest meanings and intent beyond the cliché of the “rough imitation of traditional Byzantine architecture”;
- cast a new light on constructive intents;
- emphasize the visual perceptive role of paths, openings and curved surfaces.

Moreover the use of polychromatic drawings to envision the relationships between distant rooms may contribute to form new hypothesis on both their uses and their transformation stages. For example they are able to reveal unpredictable geometrical relationships between distant rooms, as in the case of the church and the rooms of monastery, despite the triangular shape of court and the rotated entry hall.

6. Final considerations

The observations on the drawings produced by Jerphanion, Rodley, Ousterhout and Kalas demonstrate that, also in virtue of a proper use of a laser scanner, in the last century, the representation of rock-cut architecture has been moving from the practice of a spontaneous description of formal impressions to a representation based on a stricter interpretation that is always supported by punctual metric operations. Although not in final form, the representation for contour lines after point clouds definitely denotes a more geometric strictness and therefore it is able to confute things the surveyor’s eye had falsely caught and represented. In this case, the objective eye of the machine has the power to capture and reveal forms with a precision that is beyond the capability of human senses and traditional survey instruments. At the same time, surveyor’s critical approach is required to develop images that are able to produce and convey knowledge about both tangible objects and invisible relationships between them, such as the chromatic interpretation of contour-lines on plans proposed by the authors.

Authors are aware that much is yet to be done in terms of processing and representation. The quality level of digital heritage products is to be implemented through at least three elements. First of all, it must be clear that the points cloud “is not” the survey but only a good start. Second, surveyors’ critical approach cannot be eluded but applied to guide processes and products toward both their final users’ expectations and a general knowledge development. Third, the representation is the key moment in which these challenges take place and both historical and transformation hypotheses take shape. Most of all, it is the theatre stage in which the negotiation between the urgency of preserving the last remains of remote societies and the short-terms planning of our capitalistic society face each other. Such a delicate task should never be totally left to a machine.

Acknowledgements

This paper is a collective work of the three authors. In particular, M. Carpiceci has edited *Introduction* and *Final Considerations*; F. Colonnese has edited *Methodological notes* and *Knowledge after drawings*; and C. Inglese has edited *Rock-cut architecture in Cappadocia* and *The case of the Monastery of Karanlik*. It is part of a larger study on rupestrian habitat from the Italian national research called “Arte e habitat rupestre in Cappadocia (Turchia) e nell'Italia centromeridionale. Roccia, architettura scavata, pittura: fra conoscenza, conservazione, valorizzazione”, whose National Coordinator is Maria Crocifissa Andaloro, and Scientific Director of Sapienza University unity is Marco Carpiceci.

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