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# DIGITAL ROCKS. AN INTEGRATED APPROACH TO ROCK ART RECORDING: THE CASE STUDY OF OSSIMO-PAT (VALLE CAMONICA), MONOLITH 23

## 1. Introduction

Prehistoric rock engravings are an invaluable source of information about ancient societies. Their creation, by the carving of figures on smooth rock surfaces, either by striking the surface with stone tools (pecking technique) or by scratching it with pointed instruments (graffiti technique), demonstrateds the ancient artists' possession of an extraordinary set of skills. The outcomes, especially those pertaining the Copper Age, are as magnificent as they are incredibly complex, and documentation and recording are some of the challenges of our research. Studying rock art is dealing with symbols, and dealing with symbols is working with their graphic reproduction (tracing).

In 2014 I was charged with the recording and tracing of the engraved monoliths from the Chalcolithic sanctuaries of Cemmo (Poggiani Keller 2009c) and Ossimo-Pat (Poggiani Keller 2009d), in Valle Camonica (BS, Italy), in the context of the project *Siti di culto e cerimoniali megalitici di Valtellina e Valle Camonica*, coordinated by Raffaella Poggiani Keller, in sight of the imminent publication of the two sites. This led to a critical examination of all the different methods of rock art recording, in order to evaluate which was the most suitable for this demanding task. It soon enough became clear that it was necessary to develop an integrated method for recording and tracing, benefitting from all existing methods and implementing new technologies to achieve the best possible result.

## 2. Rock art recording in Valle Camonica

Since their discovery in 1909, rock engravings of Valle Camonica have been observed, studied, and recorded. The more the study evolved, the more methods of recording were developed, in order to fulfill the different scientific needs. The methodological evolution in rock art studies followed a path parallel to that of the study itself, sharing moments of quick growth with stages of stagnation.

In this paragraph, several aspects of the history of rock art documentation in northern Italy will be addressed, with focus on Valle Camonica - Unesco Site n. 94: here, scientific debate on methodology has been ongoing since the 1960s (Anati 1966); moreover, Valle Camonica is an appropriate case study, not just because it is the main centre of rock art in Italy and one of the most important in Europe, but also because its scholars have always had to face the issue of superimpositions between figures. To properly manage this feature, that is both a major foothold for the sequences of relative chronology and an element of complexity and debate, strongly affected the evolution of the methods for recording rock art, because overlapping figures are often ambiguous, difficult both to read and convey.

For a general overview about the history of rock art research in Valle Camonica, the reference points are Tarantini 2009, Marretta 2009 and Poggiani Keller 2009e, and for a methodological perspective, with some controversial points, Arcà *et al.* 2008. In other works of Andrea Arcà (1999, 2016) it is possible to find some reflections about rock art recording and general methodology, with an overall open approach to new technologies. The clearest analysis of methodology has been produced by Alberto Marretta (2014a), along with successful implementations of new technologies, like the direct digital vector tracing (Marretta *et al.* 2013).

History of methods for rock art documentation in Valle Camonica will not be addressed from a chronological point of view, but in light of their response to the most pressing needs of the research, that can be summarised as such:

1. Visibility: the need to see clearly all the figures carved on a rock surface. The best possible visibility of the source is probably the most pressing issue when dealing with an iconographic study, and rock carvings can prove fairly tricky to be seen. This is due to a number of reasons, such as the original lightness of their appearance, the erratic degree of conservation, or even their position.
2. Abstraction: the need to see the engraved figures free from distracting elements, such as the colour of the rock surface, natural scratches or cracks or even the presence of vegetation. Tracing rock art is the road to better understanding it and the immediacy of perception, often obtained through the abstraction of the documented forms, is of crucial importance to the study.
3. Accuracy: the precision in the restitution of the figures. It is essential for the final tracing to display not only the precise shape of the figures, but also the correct size of the single impacts on the rock, as well as their density, in order to convey the different execution patterns that could lead to the identification of different tools or craftsmen.
4. Objectivity: if it has been established that every type of documentation, even photography, has an inherent degree of subjectivity (Arcà *et al.* 2008, 379), it is our opinion that absolute objectivity is not a viable goal for the research, nor a desirable one. Rock art recording is entirely aimed at its comprehension and study, and therefore it is a subjective action, outcome of personal knowledge, capability and thorough method. Objectivity, in this particular case, is the need to produce the most faithful representation of the figures carved on the rock by using all available technological tools, while at the same time offering different graphic renderings of the same figures, as for example photographs with artificial lighting.

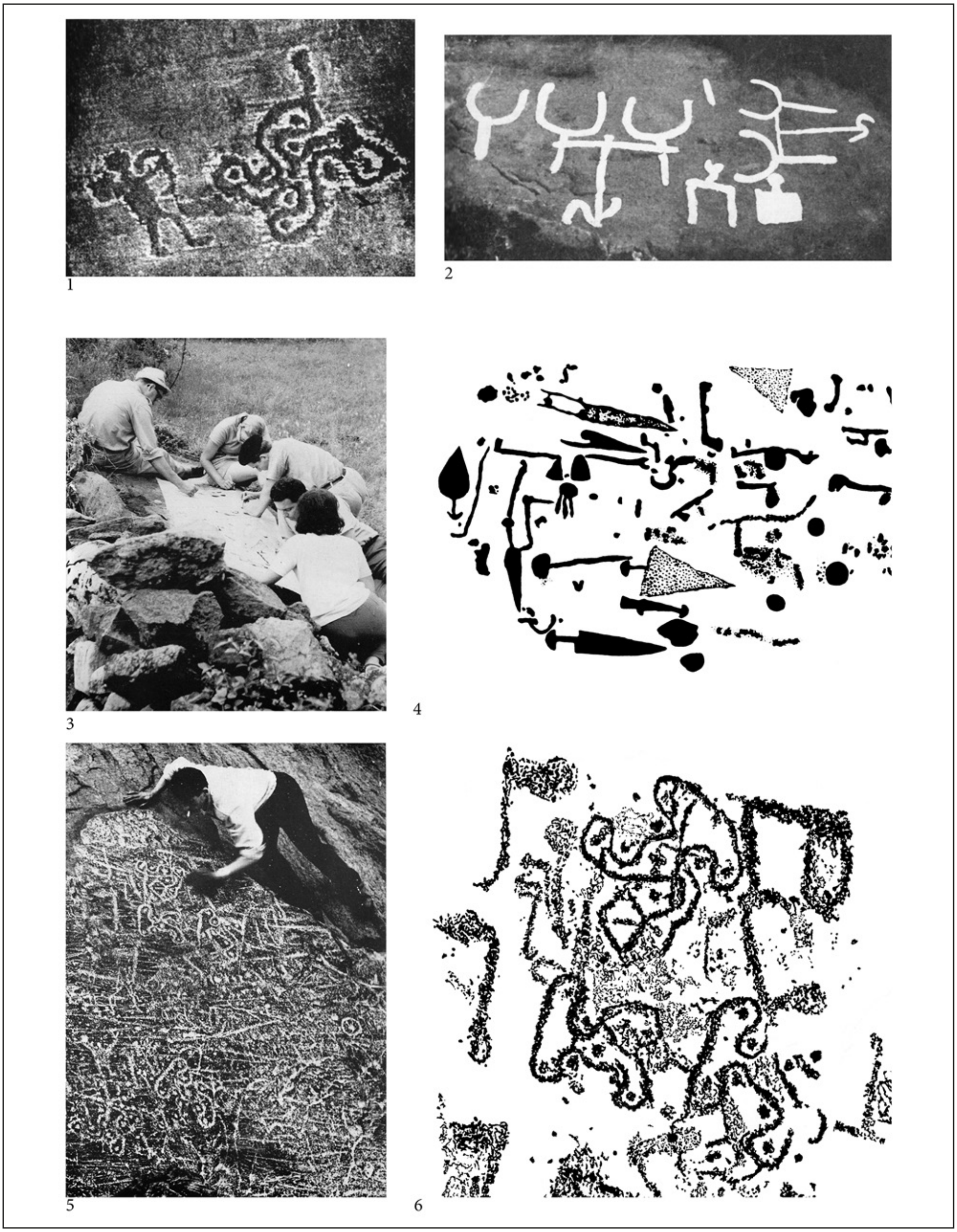

Fig. 1 – Rock art recording methods in Valle Camonica. 1) Bedolina (Capo di Ponte, BS) photograph from Altheim and Trautmann (Marretta 2009, 29); 2) Cimbergo, rock n. 8 (Glob 1954); 3-4) Contact Tracing. Luine, 1963, rock n. 14 (Anati 1982, 146); Neutral Method + Contact Tracing. Luine, 1968, rock n. 30 (Anati 1982, 164-165).

The evolution and the fortune of the main methods of rock art recording, in Valle Camonica, will now be briefly described in light of these needs of the research.

## 2.1 *Photography*

Photography has been the primary choice and is still in widespread use. It was the need to enhance visibility and gain abstraction that led one of the pioneers of rock art studies, Raffaello Battaglia (1932, 1934), to photograph engravings with oblique lighting, often after pouring water on them. Led by the same need for abstraction, but with a more invasive approach, Giovanni Marro (1932, 1936) and the German scholars led by Franz Altheim (Altheim, Trautmann 1937, 1940) both resolved to colour the inside of the carvings, or to surround them with white chalk, before photographing them (Fig.1, 1).

This method caused a substantial decline in objectivity, accuracy and visibility, and while the habit of colouring rock engravings is still widely used, mostly for touristic purposes, as in the Swedish site of Tanum, Bohuslän or in Danish rock art sites such as Bornholm, it never became a standard for the engravings of Valle Camonica. When the "neutral method" was introduced (see *infra*), most of the photographs were taken only after preparing the rock (e.g. Anati 1982), while, after its ban, the vast majority of photographic documentation has been produced with the use of oblique lighting. The need for objectivity, accuracy and abstraction necessitated the development of other ways to record the engravings.

## 2.2 *Contact tracing*

The first drawings made were incomplete tracings and sketches, by Paolo Graziosi in 1930, during the study of the Chalcolithic boulder Cemmo n. 1 (Tarantini 2009, 64-67). Other drawings were created in 1950, thanks to Piero Leonardi (1950), while P.V. Glob (1954), in the same year, began tracing, on paper, the outlines of the engravings, previously painted with chalk (Fig. 1, 2). The scholars from the Museum of Natural Science of Brescia also had their own way of transposing the figures on paper, but the evolution of recording methods in Valle Camonica underwent an abrupt change with the arrival of Emmanuel Anati, in late 1956. Due to the experience with Leroi-Gourhan and Henri Breuil, Anati applied the technique of the contact tracing (Fig. 1, 3-4), that consisted of directly tracing the figures on sheets of oil paper, not entirely transparent, placed directly on the rock surfaces. Rocks were always prepared by colouring the carvings, usually in white, to enhance visibility.

The substitution of the oil paper with polyethylene improved the outcome of tracings by contact, but the need for more accuracy and visibility led Anati to radically change the preparation: in the 1960s he developed the "neutral method" (Anati 1960, 33-39), that consisted of painting rock surfaces entirely in white – with 5% solution of Pelikan Plaka Paint, a case in emulsion base (Arcà *et al.* 2008, 353) – and then rubbing the surface with a pad, soaked with black dye, thus creating a high contrast monochrome effect. With the help of the "neutral method" rock carvings were more clearly recorded than ever (Fig. 1, 5-6), and it was possible to identify figures otherwise almost invisible (Anati 1974, 15-18; 1982). Even if the preparation did not really help solve the most complex superimpositions, it quickly became the standard approach. Contact tracing with "neutral method" was used until the first half of the 1980s, when the Soprintendenza Archeologica della Lombardia ("Soprintendenza", from now on) forbade the application of paint on the rocks (Poggiani Keller *et al.* 2005, 120), due to conservation issues. This ban never ceased to raise objections among some of the scholars (Arcà *et al.* 2008, 354-355), and contact tracing in Valle Camonica continued to be used, replacing the "neutral method" preparations with oblique lighting to enhance contrast, and has remained, unchanged, the standard method until the present day, even though some of its key features nowadays appear outdated.

The application of a PVC sheet on the rock surface, even if transparent, significantly reduces both the visibility of the carvings *per se* and the efficacy of the oblique lighting, worsening the already troublesome visibility ratio of several rock engravings. Accuracy is another critical point of contact tracing, especially when dealing with monuments that comprise different execution styles. For example, tracing Chalcolithic monoliths, that often implement different patterns of pecking along with the technique of graffiti, with the use of marker-pens, can pose some issues. Overall, contact tracing seems to entail a critical reliance on the momentary impression of the executor, with a high influence of cognitive biases, irreconcilable with subsequent corrections and implementation of technological tools. On the other hand, contact tracing offers the highest level of abstraction and its outcome is immediately readable, resulting in an optimal tool for further research.

### 2.3 *Rubbing or frottage*

Rubbing never earned praise in Valle Camonica, being considered either obsolete or unfitting for the correct identification of the overlappings, or merely a didactic, promotional tool (Arcà *et al.* 2008, 379). In the late 1990s, seeking accuracy and objectivity and in disagreement with the tradition of contact tracing, Soprintendenza endorsed the use of rubbings with subsequent retracing with dotted drawings on several monoliths from the Copper Age sanctuaries (Poggiani Keller 2000, 2009b). This choice followed the method applied to the site of Sion-Petit Chasseur (Corboud, Curdy 2009; Gallay 2011). The most criticized issue of this method, in Valle Camonica, was the dubious identification of certain figures and the obscure graphic rendering, particularly in regard to the thinnest overlapping figures.

Rubbing, when performed correctly (see *infra*), can deliver a high degree of visibility: its monochromatic contrast effect is very close to the one offered by the banned "neutral method"; moreover, the levels of accuracy and objectivity are very high. The weak point of rubbing is clearly represented by its level of abstraction, which is quite unsatisfactory, especially when compared to the results of contact tracing.

### 2.4 *3D technologies*

The technology most widely used today is Structure from Motion (SfM; for recent application in rock art, see Meijer 2015), while others such as laser scanner, RTI and SLS, despite having been successfully tested[1], were never actively implemented in Italian rock art research for various reasons, among which the lack of versatility, which often pairs with high costs (Arcà *et al.* 2008, 366-375; Cassen *et al.* 2014; Marretta 2014a, 15-18; Bertilsson 2015; Medici, Rossi 2015; Diaz-Guardamino *et al.* 2015). The first use of photogrammetry in Valle Camonica, followed by the systematic implementation of the annual planning was promoted by Soprintendenza in 1992, as well as for the European Project Leader II in 1999-2000, on several rocks of the Parco Nazionale delle Incisioni Rupestri di Naquane (Capo di Ponte, BS): the production of photogrammetric models of engraved rocks has thus been fully implemented for conservation purposes.

SfM can be used to record either the whole rock surface or only the engraved surface. Its effectiveness, in regard to the study of rock art, is directly proportional to the quality of the 3D model: when of high quality, a SfM model can convey a very high level of visibility of the engravings. Due to the possibilities offered by the mesh manipulation systems, an even degree of visibility of the engravings is possible (see *infra*; for a multi-technique analysis, see Cassen *et al.* 2014; for a first, pioneering, active implementation in the tracing process in Italy, see Marretta, Martinotti 2017).

The level of abstraction using SfM photogrammetry is, of course, quite low. This has probably prevented it from becoming the standard method of documentation for rock art, or even to be actively implemented in the actual tracing process of rock art, remaining *de facto* a marginal, as well as spectacular, instrument in the research.

## 3. Case study

The selected case study is the monolith n. 23 from the Copper Age Sanctuary of Ossimo-Pat (Poggiani Keller 2009b, 2009d; Baioni, Poggiani

[1] Laser Scanner was first tested in Valle Camonica in 1992, on the monolith Cemmo n. 4, by Soprintendenza.


Fig. 2 – 1) Map of the major areas of distribution of engraved steles and monoliths of northern Italy; 2) Offerings found in Ossimo-Pat Copper Age sanctuary, Mound A (Poggiani Keller 2017b, 105); 3) Ossimo-Pat Copper Age sanctuary, photograph of the site during excavations (photo taken from the northern part of the site. One of the votive stone circles is clearly visible in the foreground).

Keller 2014), which is one of the most relevant archaeological sites of the entire southern alpine region (Fig. 2, 1), for the variety of its structures and the quality of its engraved monoliths. Excavations, carried out by the Soprintendenza and, in recent years, by the University of Firenze under the direction of Raffaella Poggiani Keller, began in 1994 and are still ongoing.

Ossimo-Pat was a megalithic sanctuary founded in the first half of the 4th millennium BCE and flourished in the Copper Age, with ceremonial structures that were used until the Early Bronze Age; later frequentations,

Fig. 3 – Pat n. 23: night photography.

mainly identified by the presence of fireplaces lit in front of the few monoliths that were still standing, were dated to the late Bronze Age and the Iron Age. The sanctuary occupies an area of more than 4000 m$^2$, encompassing a NS alignment of over 25 whole and fragmented engraved monoliths, still standing or torn down (Fig. 2, 3). This alignment is situated between two areas in which ritual activities took place: in the southernmost area, several mounds were erected, containing votive offerings of artefacts (Fig. 2, 2). The northern area was dedicated to a series of stone circles, also containing votive offerings of similar artefacts as the ones found in the southern mounds, and a monumental tomb.

Monolith Pat n. 23 (Fig. 3), one of the smallest monuments in the site (maximum height 73 cm, width at the basis 55 cm, thickness 21 cm), was found still standing in its original collocation, in the southernmost part of the main alignment (sector B, square H11, US 179).

## 4. Digital Rocks workflow

The methodology presented in this paper was established throughout three years of fieldwork, with a series of tests carried out on inclined, horizontal and vertical engraved rock surfaces, as well as boulders and monoliths. The first phase regards the production of the documentary basis, while the second is dedicated to the elaboration of the documentation and production of the tracing.

### 4.1 *Phase one: production of the documentation*

– "Advanced" rubbing: rubbing was the first type of recording performed, to avoid an execution that, biased by previous observations, highlighted certain parts of the rock. The rubbing method – which greatly benefitted from the experience on the engraved steles of Saint Martin de Corléans, Aosta (Mezzena 1997; Poggiani Keller *et al*. 2016), carried out together with Franco Mezzena and Gianfranco Zidda – consists in the application of a white sheet of paper on the rock surface which is subsequently rubbed with a colouring tool: thus, the protruding parts of the rock are coloured while the lowered parts remain white[2]. Essential steps followed for the execution of an "advanced" rubbing of an engraved rock surface are:

– a sheet of 22 gram tissue paper is secured on the selected area: the paper needs to be perfectly fastened on the rock surface, in order to obtain maximum resolution[3].

– the paper is pressed on the rock surface with fingertips, using a moisturizing tool (e.g. aerosol vaporizer) to soften it. Moistening and hand-pressing exploits the plastic properties of tissue paper, allowing it to reshape its structure on the rock surface and to become a perfect reproduction of the rock surface.

– the paper is blackened, using an inked sheet by hand (e.g. black carbon paper): this allows for the best responsiveness on the rock while avoiding rips on the paper. This is best executed in light layers, evenly on every part of the surface.

The most beneficial aspect of advanced rubbing is that it offers an exact reproduction of the rock surface, it being essentially a paper mould of the rock surface. The paper then was digitized, via high resolution scanning (600 DPI)[4].

[2] Rubbing has a low degree of invasivity, being essentially the physical contact between a sheet of paper and the rock surface, with no use of chemical glues, adhesives or fixatives.

[3] The paper can be secured applying, to the sides of the stone, out of the engraved surface, a common adhesive paper tape. The rock must be preventively cleaned from the dust, for example using a soft brush, in order for the tape to properly work.

[4] The time needed for the execution of a rubbing can widely vary, on the basis of the size of the rock and the definition of the engravings. Field tests can suggest an average time of 30/35 minutes for a sheet of 1×1 m.

– Night photography: Pat n. 23 was photographed at night, with different lighting, to emphasize the various figures carved on the rock, and to produce a complete set of pictures, both general frames and details of single interesting figures. The photographs were taken with a digital reflex camera, mounted on tripod. For the best possible sharpness, use of still lenses and macro is recommended, while LED lights were used with a temperature colour of 3500k, to avoid unwanted orange/yellow dominance.
– Photogrammetry: SfM photogrammetry is a technique already widely used in archaeology and rock art, and it is not the objective of this paper to illustrate how it should be performed (Bertilsson 2015; Meijer 2015, 3-4; Horn *et al*. 2018). For the case study, a digital reflex camera was used with a fixed 50mm lens for the general model of the rock (Fig. 5, 1), and with a 100 mm macro lens for the particular 3D modelling of the engraved face (Fig. 5, 2): this was created from 25 photographs, taken in open daylight, from a selected distance of 30/35 cm and with a standard 60% overlap, resulting in point cloud of approximately 48 million points. Photographs were processed with Agisoft Photoscan Professional (Fig. 5, 1). The precision can be increased through the use of targets, in aid to the model calculation (Sapirstein 2016).
– Contact tracing: the execution of the traditional tracing by contact is optional in this workflow, as it has been substituted with the digital vector tracing, and was not produced for Pat n. 23. In other cases, though, this method was performed, and proved useful as an additional source of information.

### 4.2 *Phase two: elaboration of the documentation and tracing*

#### 4.2.1 Preparing the basis of the drawing

The digitized rubbing was edited with a professional graphic editor, Adobe Photoshop CC 2017. In order to maximize its visibility ratio it has proven useful to produce three different versions (Fig. 4):

– the original version;
– a high contrast version, where blacks and whites are intensified;
– an inverted version, where black and white are inverted, with a slight intensification of contrast. This version of the rubbing often proved decisive to discern dubious details.

The three raster versions of the same rubbing form the basis on which engravings will be traced in vector drawing, ensuring not only an advanced vision of the carvings but also a perfectly and naturally orthoregulated rendering of the surface. The outline of the rock or boulder, along with the natural cracks of the rock surface, will be drawn on the frontal photomosaic exported from the 3D model, previously straightened up on one of the rubbings.

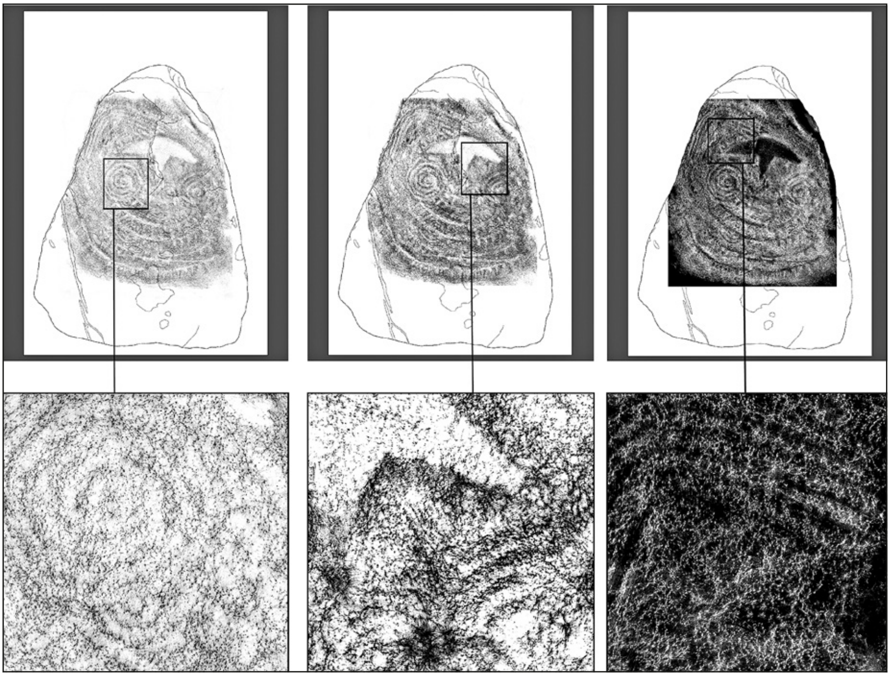

Fig. 4 – Three versions of the same rubbing.

### 4.2.2 Triggering the digital tools

The 3D model of the engraved surface was exported in .obj format and processed with Meshlab, an open source software system for processing and editing 3D triangular meshes and point clouds (http://www.meshlab.net/). Among the most interesting tools offered by Meshlab for the study of rock art, the shader Depthmap stands out (for a successful archaeological application in Valle Camonica, see Marretta, Martinotti 2017, 139-142). This shader – developed by Massimiliano Corsini, Visual Computing Lab, Istituto Scienza e Tecnologia dell'Informazione "A. Faedo", Area della Ricerca, CNR, Pisa – allows for calibration of two virtual thresholds of proximity and distance, from a specific point of view on the 3D model of the rock, in order to actually see, in detailed gray scale, the physical lowered parts of the rock separated from the most superficial ones.

This tool applied to rock art represents a major breakthrough, delivering a visibility not based on chromatic differences created by light (being it natural or virtual: see Cassen *et al.* 2014, 135), but caused by the actual physical depth of the single engraved figures (Fig. 5, 2). Thus, as the primary

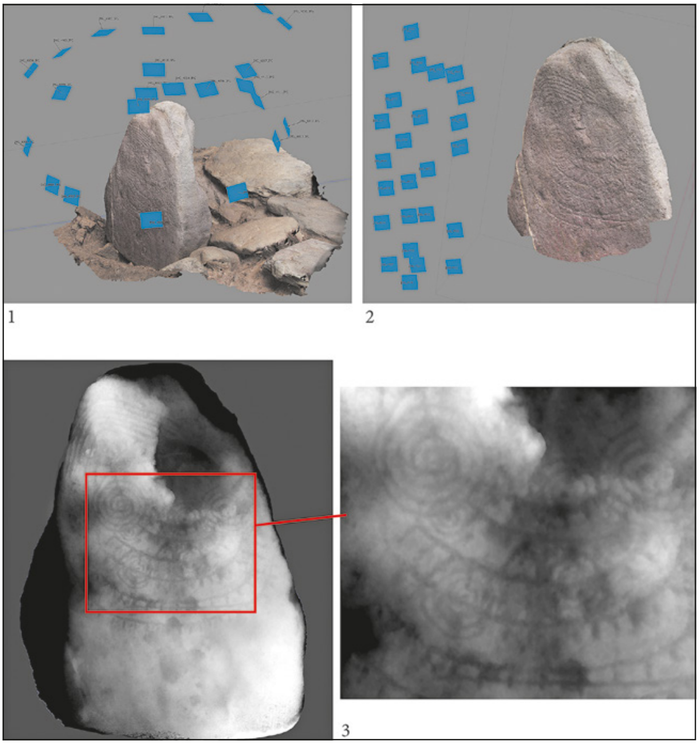


Fig. 5 – 1) General 3D Model of Pat n. 23; 2) 3D particular model of the engraved face of the monolith; 3) Depthmap shader view of engravings.

outcome of Depthmap analyses is the possibility to see the real shape and depth of the engraved figures, its use in rock art can also help to uniquely clarify the correct sequence of overlapping figures, resulting in a reliable and key instrument in the research.

#### 4.2.3 Tracing rock art

Tracing of the engravings was performed with a vector graphic editor, Adobe Illustrator CC 2017, paired with a graphic tablet. The three raster images of the rubbings were loaded in the workspace, each in a different layer, perfectly aligned. The drawing technique is similar to that used in contact tracing, but it is fully digital and has some further features. Tracings were performed using a circular brush to blacken the single hits. Superimpositions were highlighted by artificially separating the overlapping figures from the underlying ones, for a more intuitive identification. The use of a 1:1 sized brush emphasised the different pecking patterns in the final tracing.

Thanks to the use of the graphic tablet, the drawing of every figure, executed by tracing the single hits on the rock, was quick and accurate, while the possibility to zoom in the rubbings to high magnification values allowed to clearly see every small detail of the engravings (Fig. 6). The outline of the rock and its natural cracks were drawn on the photomosaic created from the 3D model loaded on a dedicated layer, using a continuous line, while the dashed line signals the limit of the plain surface.

## 5. Results

The petroglyphs characterize monolith Pat n. 23 as one of the so-called "feminine" anthropomorphic monoliths, a well-identified ensemble in the Chalcolithic Valle Camonica group. The engravings of this ensemble are mostly representations of significant objects, often found in ritual deposits or burials, along with other symbols: these are combined with often complex associations that create visual depictions of the torso of upright feminine figures, lacking the portrayal of physical traits, but provided with a series of garments and ornaments, probably a ceremonial dress.

Pat n. 23 shows a total of 13 figures, systematically disposed organically on the surface, organized on 4 levels of superimpositions. All the figures have been created by pecking, and it is possible to identify at least two different styles of execution (Fig. 7, 2): a slightly bigger and deeper pattern (Pattern 1: 3-4 mm average diameter per single hit), and a lighter pattern, with smaller and shallower hits (Pattern 2: 2 mm average diameter per single hit).

Pat n. 23 shows, from top to bottom (Fig. 7, 1):

A) A decentralized and inverted U-shaped beam of six lines, probably representing a diadem or a sort of headdress. This is a well-represented symbol in Chalcolithic rock art of Valle Camonica, showing great morphologic variety that has often led to different interpretations (Casini 2015, 98-99).
B) A geometric element, usually called "T face", "Cappello da Gendarme" or "Nose-Eyebrows" (Casini 2008, 15-17; Marretta 2014b, 54-55), already known in Valle Camonica, which is usually referred to as a stylized depiction of a human face and is exclusively found on feminine monoliths. This symbol recurs also in some of the main rock art groups of Italian Copper Age, as the Lunigiana and Garfagnana areas, Sardegna and Puglia, the Alpine westernmost sector of Aosta/Sion and in the eastern sector of Trentino Alto Adige. Similar symbols are also found in some of the most representative sites of European Chalcolithic rock art such as in the Iberian peninsula (Northern Portugal, Andalusia, Huelva, Alentejo), southern France (Languedocien Group) and in the Crimean group of Kazanki (for an overview, de Marinis 1994a; Mezzena 1998).
C) Two mirrored spirals, a symbol also present in other monoliths from Valle Camonica as well as in other contexts, like the so called "Gruppo Atesino"

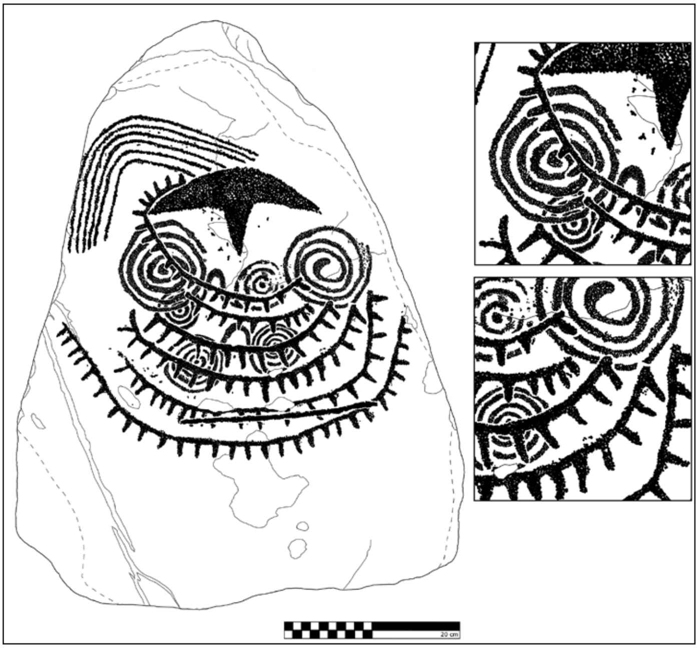


Fig. 6 – Pat n. 23. Vector Tracing.

(Pedrotti, Tecchiati 2013), which probably the depiction of elements of a composite headgear.

D) A series of six curved lines with short vertical inserts. This symbol, very distinctive of the Copper Age rock art of Valle Camonica, is one of the most frequently represented in the feminine compositions, and probably portrays some kind of composite necklace, perhaps with inserts of bone and animal teeth. This is suggested by the objects often found in coeval burials (Foppe di Nadro riparo 2: Poggiani Keller 2017a, 129-130; Corna Nibbia di Bione: Baioni, Poggiani Keller 2014; Baioni 2017).

E) Two double-spiral pendants. This is a prosperous figure in Copper Age iconography, representing a metal artefact that was widespread throughout the European Copper Age. The position of this symbol indicates whether it was part of composite garments, when placed in the central/lower part of the figure, or an earring or part of a composed headgear, when located on the upper part (Casini 1994b). It is worth mentioning that a copper pendant of this exact type was found in the internal chamber of mound A at Ossimo-Pat, placed in some sort of wooden cortex vessel, along with a multi-stringed necklace (Fig. 2, 2; Poggiani Keller 2009d, 230-232).

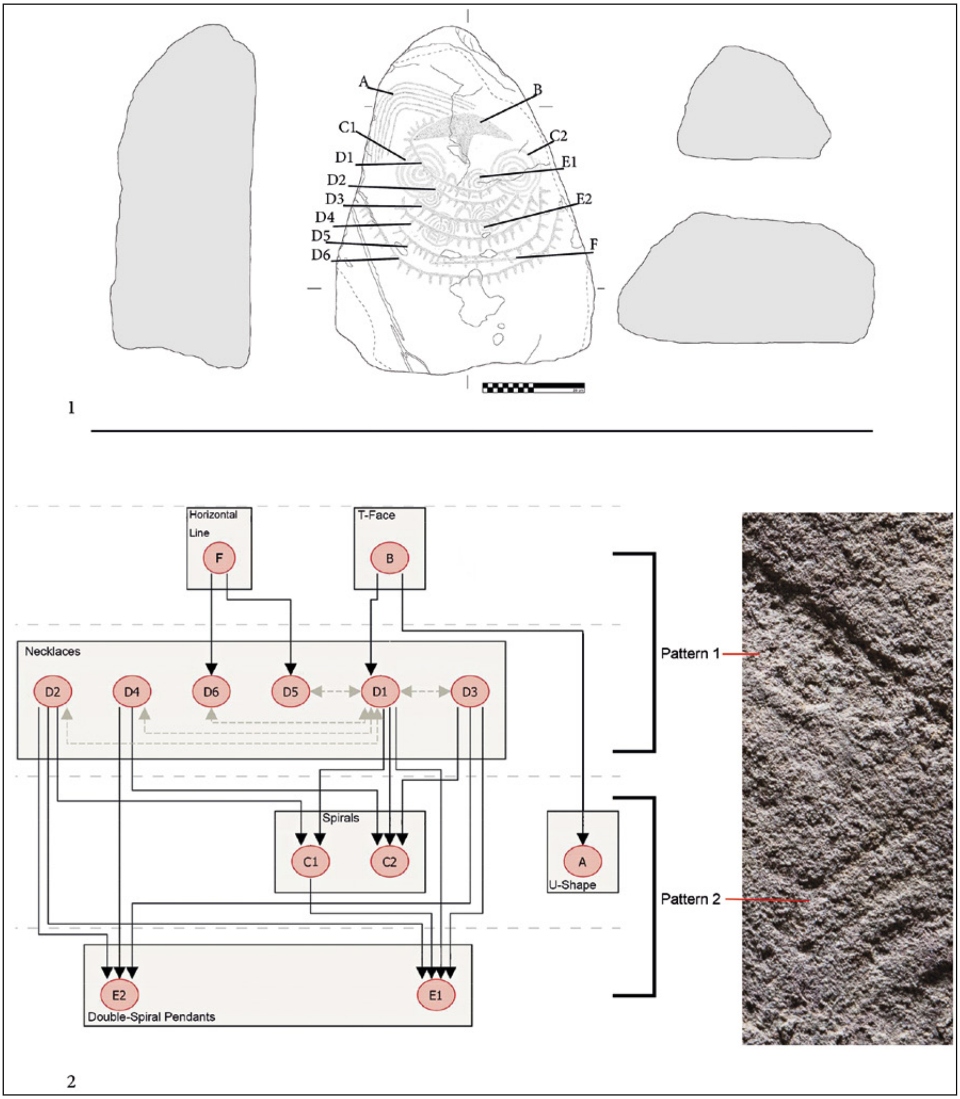


Fig. 7 – Pat n. 23: 1) Identification of the different types of figures on the monolith; 2) Harris matrix sequence of the engravings, cross-referenced with the two different pecking patterns.

F) A horizontal line, probably an incomplete figure. Superimpositions in Pat n. 23 allows the construction of a clear sequence of actions in the creation of this monument (Fig. 7, 2), and the physical relations between the symbols abide by the same set of rules identified for similar cases, as noted in Casini 2008, 6-10.

On the basis of the two different pecking patterns[5], it is possible to divide the sequence in two blocks: the group A-C-E, defined by the "smaller" pattern 2 was probably the first to be engraved, while the group B-D is related to the "bigger" pattern 1 and probably of subsequent execution, while horizontal line F can be removed from consideration for its insubstantiality. Thus, relative chronology of Pat n. 23 appears organized in two main sequential steps (Fig. 7, 2), but it is not possible to suggest further segmentations, let alone any absolute chronological articulation, just on the basis of overlappings between figures.

The closest comparisons for Pat n. 23 are Ossimo n. 10 (Fedele, Fossati 1994, 185-187), Pat n. 5 (Poggiani Keller 2009d, 229), Cemmo n. 10 (Poggiani Keller 2009c, 217). All the engraved figures date Pat n. 23 to the style III A1 (3000-2500 BCE, following the chronology of de Marinis 1994b despite the noted superimpositions, the composition appears harmonic and organically constructed, with a clear anthropomorphic intent, whose garments and ornaments depict a richly dressed feminine figure.

## 6. Discussion

The case study proved a fitting test for the workflow: Pat n. 23 is a boulder of local purplish sandstone that offers a coarse and irregular engraved surface. The visibility of the carvings vary from average to poor, due both to execution features and low surface quality, but the use of night photographs, paired with Depthmap analysis, along with the three versions of the rubbings, led to a clear identification of the symbols. Digital Rocks workflow is efficient both on big rock surfaces as well as small boulders, thanks to its modularity that allows choice, on the basis of different needs, whether to perform every step or only certain ones.

The benefits of native vector tracing are manifold. The use of different size brushes, as well as the possibility to zoom in on the digitized rubbing at 100% resolution for the most delicate details, assure the highest possible accuracy. Moreover, it allows organization of the figures in separate layers, maintaining full control over even very complex compositions, and assuring the absolute editability of every single aspect of the drawing (Fig. 8).

In addition, the final quality of native vector drawings, especially regarding the definition of the single hits and the different pecking patterns, is far superior than the one offered by traditional contact tracing, whose nylon sheets, in order to be vectorized, need to undergo a secondary digitalization,

[5] Patterns have been identified both on the basis of measurements made on the rubbing, and confirmed by analyses of the 3D model. Pattern 1 has irregular shaped hits, 3 to 5 mm wide and average 2-3 mm deep. Pattern 2 has mostly circular hits, average 2 mm wide and 1mm deep.

Fig. 8 – Vector tracing on different layouts.

with an inevitable quality loss. Most importantly, vector tracing allows for observation and tracing of rock engravings in an integrated and multi-source workspace, free from the constraints of time and circumstance otherwise inherent to the traditional contact tracing. This fact assures the reliability and further verifiability of the tracings, both by fully exploiting the capabilities of all the technological tools at hand and by allowing verification and modification of the drawing whenever needed, using the multiple sources of documentation such as night-time photography, 3D mesh manipulations, edited versions of the rubbing, etc.

The final appearance of the tracing (Fig. 6) has been chosen to establish coherence to the scientific studies already existing on the subject. Nonetheless, the digital nature of this documentation gives way to many other possible graphic outcomes, like the integration with a photographic basis or other textured layouts (Fig. 8), also useful for dissemination and fruition purposes.

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## ABSTRACT

This paper addresses the different methods of recording prehistoric rock art, with specific focus on the northern Italian area (Valle Camonica, UNESCO Site n. 94), and presents a new integrated way of recording and tracing engravings. This method combines different sources of data, both traditional, as an "enhanced" way of rubbing, and technological. The active use of Structure from Motion photogrammetry and the subsequent mesh manipulation, as well as the implementation of digital macrophotography with artificial oblique lighting, are among the methods used for the recognition of the correct features of the carvings, while the tracing of the engraved figures, executed in vector graphics, is structured on layers. Combining the benefits of the digitally enhanced visibility of the figures with the precision and versatility of digital vector drawing, this method produces state of the art tracings of rock art, for a better comprehension of the symbols carved on the stone. All steps of this method are demonstrated using, as a selected case study, the unpublished monolith n. 23 from the Copper Age Sanctuary of Ossimo, Pat (BS) in Valle Camonica, Northern Italy.