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A taste for the unusual. Green, flat pebbles used by late Neanderthals

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ABSTRACT

Neanderthals collected unusual, sometimes colorful mineral materials from different sources. Several green serpentinite smooth pebbles with a flat shape and use modifications were unearthed at Fumane Cave in northern Italy. This study explores cognitive and functional criteria that influenced the selection and use of unique pebbles based on their regional geology, morphology, petrology, use wear, and residues. Besides the attraction for green materials, there is no evidence for the use of soft green and flat pebbles, like those from Fumane Cave, during the Middle Palaeolithic. Moreover, these materials were collected by Neanderthals only from ca. 44 ka cal BP, despite the large availability of green serpentine pebbles in the alluvial beds near the cave. Ultimately, we provide new data to understand the role of aesthetic and technological factors in shaping the human behavioral range in the Middle Paleolithic.

1. Introduction

Over the last 30 years of excavations, nine pebbles with similar green to dark green hues, flat shape, smoothness, and functional modifications were discovered in the late Mousterian and Protoaurignacian layers of Grotta di Fumane (Fumane cave, see S1 in SM section). For a long time, the flat morphology and the unique petrographic nature of the Protoaurignacian green pebbles suggested they could reflect a large-scale circulation of lithic items from the western Ligurian arch seashore. Here, other Anatomically Modern Human (henceforth AMH) groups were settled and had possibly contacts with coeval groups located in the Southern fringe of the Italian Alps (Bertola et al., 2013). The discovery of three pebbles with comparable features (i.e., petrography, color, size, and shape), clearly embedded in one of the most recent Mousterian layers characterized by the Levallois industry and other Neanderthal cultural proxies challenged this interpretation. Therefore, questions arose about the provenance of these further lithologies, their physical properties, function, and potential visual/aesthetic significance. In addition, a revision of the field data of the Protoaurignacian items allowed us to re-evaluate their uncertain attribution to this cultural complex.

We conducted a comprehensive study based on the regional geographic distribution of the serpentinite outcrops and their areal of dispersion, the pebbles' morphology and petrology, and the characterization of the use-wear and residues preserved on their surfaces. Our main aim was to investigate the cognitive and technological criteria that led to collecting and using peculiar pebbles. By exploring some unique expressions of Neanderthal behavior, our multidisciplinary results substantially contribute to understanding the range of human behaviors in the Middle Paleolithic.

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2. Middle-Late Pleistocene geomorphological setting around Fumane cave

Fumane Cave is located at 350 m of elevation at the foot of the western Monti Lessini Plateau in the Venetian Prealps at the northern edge of the Po Plain. The plateau is fan-shaped and characterized by summits reaching 1500–1600 m a.s.l in the north and dipping gently towards the alluvial plain of the Adige River in the south. Its foreland is a large alluvial plain that originated in the Early Pleistocene (Scardia et al., 2015) from the Adige River. Its tributaries originate from the central and eastern Monti Lessini (Fig. 1). Notably, the western sector comprises the apex of the Adige alluvial megafan at the outlet and the lower reach of the deeply incised Adige valley, whose catchment is one of the largest of the Alps and extends to the axial sector of the Alpine chain. The Adige and other minor rivers and streams fed the aggradation of the piedmont sector of the plains and megafans with coarse gravelly deposits. Pebbles and gravels are also the main sedimentary fraction of the glacial tills and fluvioglacial deposits ascribed to the last glacial-interglacial cycle (125–10 ka, see Monegato and Ravazzi, 2018 for a review) and the penultimate glacial maximum (160 to ca. 130 ka). These events severely affected the landscape of the Alps and the piedmont plain, when large glaciers spread out the valley outlets (Monegato et al., 2017; Seguinot et al., 2018), and aggradation of the outwash rivers exceeded 25 m in the lower plain (Fontana et al., 2014). No signs of fluvioglacial or significant aggradation are recorded during the time span of 65 ka from Early to Middle Würm. Major rivers flowed within stable trenched paths, and relatively low sedimentation rates (Monegato et al., 2011; Fontana et al., 2014), recorded in lacustrine and alluvial successions, are related to the stability of the water table.

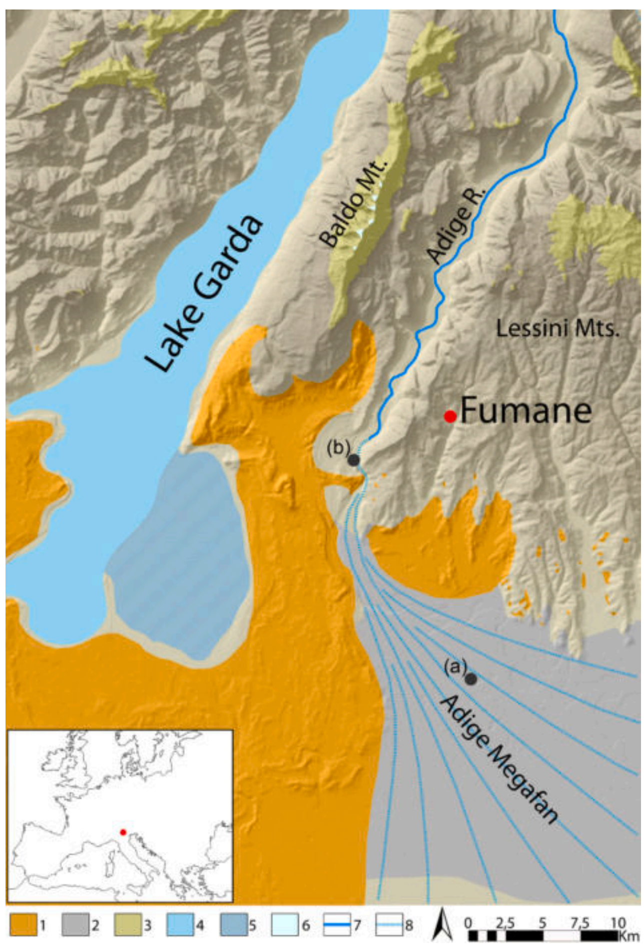

Fig. 1. Paleogeographic map of the Lower Adige Valley, Lake Garda and Lessini Mountains with location of Grotta di Fumane and the main geo-physiographic units. Key: 1. stable surfaces supporting deeply weathered soils and loess. These surfaces belong to the following main physiographic units: ancient, terraced alluvial units; hills emerging from the plain (BH, Berici Hills); karstic plateaux at low elevation; 2. Upper proximal megafan belt; 3. Area above timberlines (Badino et al., 2019); 4. Deep basin of Lake Garda; 5. Shallow basin of Lake Garda; 6. The mountain glaciers (pale blue) are inferred both from simulations (Seguinot et al., 2018; Badino et al., 2019) and ELA calculations; 7. Adige River floodplain; 8. Adige megafan body. Technical note. Coordinate system ETRS89/ UTM zone 32 N (EPSG 25832); Digital Elevation Model (base topography – Copernicus Land Monitoring Service (CLMS), 2019 and General Bathymetric Chart of the Oceans (GEBCO), 2019). Lake Garda morphology (Gasperini et al., 2020). Stable areas (middle and lower Pleistocene alluvial deposits, aeolian sediments, Loess) (Zerboni et al., 2018; Geological Map 1:50.000 Iseo, Bergamo, Vimercate sheets; Geomorphological Map of the Po Plain (Giuliano et al., 1998). Alluvial Adige megafan (Fontana et al., 2014). Gravelly sector of the plain (Castiglioni et al., 1997). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3. Materials and methods

3.1. Materials

Nine green serpentinite pebbles were discovered during the archaeological excavations conducted over an area of 70 m^2 at the entrance and the mouth of the Fumane cave (Table 1, Fig. 2, see also section SM for more details). This assemblage comprises six entire (two of which were sampled in a previous study) and three fragmentary specimens (Table 1). The archaeological material was either directly excavated using a 33x33cm grid or recovered from wet sieving, as in the case of tiny fragments. Entire pebbles are very thin and characterized by an oval shape (Table 1, Fig. 3). Such a unique assemblage was not discovered during a single field campaign. GPb9 was found in 1985 out of context during a restoration campaign carried out by collaborators of the Natural History Museum of Verona. As the Uluzzian-Aurignacian sequence at the top of the section was not exposed at that time, an Upper Paleolithic provenance for this specimen can reasonably be excluded. Thus, its attribution might fall somewhere across the long Mousterian sequence. GPb8 was recovered during the 1990 excavation in a burrowing rodent tunnel filled with sediments produced from the reworking of units A8 (the upper horizon of A9), A9, A7, A6 ÷ A5, A4 (Mousterian), and A3 (Uluzzian); Bartolomei et al., 1992; Peresani et al., 2016). A prolongation of the same tunnel was brought to light in 2006 at the base of A4II and A4V units and, definitely from unit A5BR in sqs. 66 and 67 down to at least A10, as inferred from the present-day state of excavation of this tunnel. Given its size, shape, and direction, a possibility that the burrowing affected units older than A10 cannot be ruled out. GPb7 is a tiny fragment found in the innermost square of the excavated area, where units A9 and A6 look indistinguishable from each other. The extensive excavation of unit A6 conducted in 2001 in the eastern zone of the cave entrance led to the discovery of GPb6 in sq 81a, clearly embedded in the anthropogenic context. GPb5 was recorded during the 2006 excavation well positioned at the edge of unit A6 close to an area lacking its typical brownish-dark anthropogenic sediment. On the base of the field notes, the patterns of the coarse and fine sedimentary fractions in this area allow excluding any type of burrowing animal actions. Another complete Mousterian pebble GPb4 was found during the 2002 excavation campaign at the base of A6 in sq 125e in the cave mouth. The spatial distribution of these pebbles is not related to any specific concentration of anthropogenic remains like bones, knapped stones, and lithic tools in unit A6. Instead, they scatter in the present-day sheltered zone at the periphery of the main concentration of fireplaces and other possibly related anthropogenic features brought to light in the western area (Peresani et al., 2011a) (Fig. 2). Few other pebbles of different lithologies were found in the A5-A6 stratigraphic complex (Peresani et al., 2014). As they were all embedded in unit A6, the ages of these pebbles should range from 47.6 ka cal BP, which is the minimum age of A9 (Peresani et al., 2008), to 44.3 cal ka BP, which is

Table 1
Complete and fragmentary green pebbles from Fumane Cave. Column headings: ID; Identification of Green Pebbles (GPbx) analysed in this study; IG Mibact, National repository number; RF Id, Fumane repository identification number; US, Stratigraphic unit; Grid, square and subsquare; L, length in mm; W, width in mm; T, thickness in mm; Section, shape of mid transverse section; Integrity, state of integrity and notes. Notes: D6 and D3 are Aurignacian layers, A3I Uluzzian, A6 and A6base late Mousterian, A6 ÷ A9 late Mousterian, A3 ÷ A8tana was found in the tunnel of a burrowing animal; GPb4 is affected by post-depositional fissures.

NEW ID	IG Mibact	RF Id	US	Grid	L (mm)	W (mm)	T (mm)	W (g)	Section	Integrity
GPb1	–	–	D6	125 g	–	–	–	–	–	Fragmented
GPb2	–	RF3116	D3 + D6cp	157b	54.0	47.0	10	45	Sub-Oval/Oval	Sampled in 2006
GPb3	–	–	A3I	111	–	–	–	–	–	Fragmented
GPb4	–	RF2149	A6 base	125e	70.0	36.0	15.0	60	Oval/Oval	Complete
GPb5	–	–	A6	97e	75.0	25.0	7.0	43	Elongated Oval/Oval	Complete
GPb6	VR67996	RF336	A6	81a	56.0	46.0	20.0	122	Sub-Circular/Oval	Complete
GPb7	–	–	A6 ÷ A9	168 h	–	–	–	–	–	Fragmented
GPb8	VR35451	–	A3 ÷ A8 Tana	51	67.0	42.0	10.0	75	Oval/Oval	Complete
GPb9	–	–	No context		60.0	40.0	11.0	69	Oval/Oval	Sampled in 2006

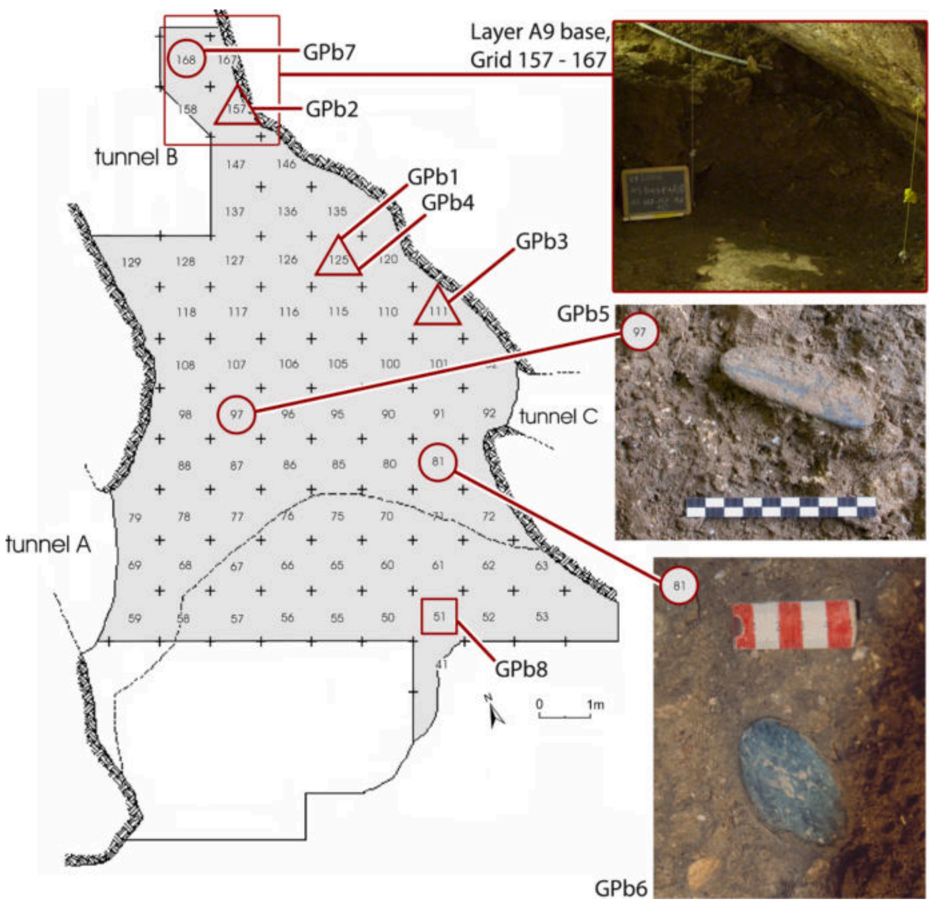

Fig. 2. Plan of unit A6 with positions of all pebbles except GPb9 because it was found in dispersed sediments reworked from unauthorized excavations.

the minimum age of A5 + A6 according to Higham et al. (2009).

GPb3 is a tiny undeterminable fragment of a pebble found in unit A3I (the first spit of unit A3). This item was found in proximity to the left cave wall (Fig. 2), where postdepositional disturbance affected the boundary between units A2 (Aurignacian) and A3 and possibly units underlying (A4 and A5-A6). Accordingly, its attribution to the Uluzzian should be considered cautiously, similarly to a previously published fragment of a human tooth (Benazzi et al., 2014).

The only Protoaurignacian green pebble (GPb2) considered in this work was found during the 2005 excavation of the D3-D6 stratigraphic complex in the cave mouth in proximity to the left wall subsquare 157b. However, our examination of the field notes revealed that sediments in this stratigraphic complex were subjected to compaction and deformation. A thick accumulation of the Mousterian deposits labeled A6 ÷ A9 is documented, featured by a massive structure and no lithological, textural, and structural visible differentiation. Furthermore, the position of the pebble was 40 cm deeper than the two deepest Aurignacian flint artifacts found in the D3 + D6 context, in subsquares 157e and 157f, adjacent to 157b (Fig. 2). Further doubts on the reliable attribution of this pebble to the Upper Paleolithic are raised by the dispersion of Mousterian artifacts in the D3 + D6 sediments (A. Falcucci, pers. Comm.). The second green stone (GPb1) is a tiny fragment found in layer D6 in the cave mouth, in square 125 g. Given the minute size of this specimen and the lack of any similar material to associate within the Upper Paleolithic at Fumane (Caricola et al., 2018; Falcucci and Peresani, 2019; Falcucci et al., 2020), we consider the attribution of GPb1 to the Aurignacian or the Gravettian not reliable (contra Bertola et al., 2009).

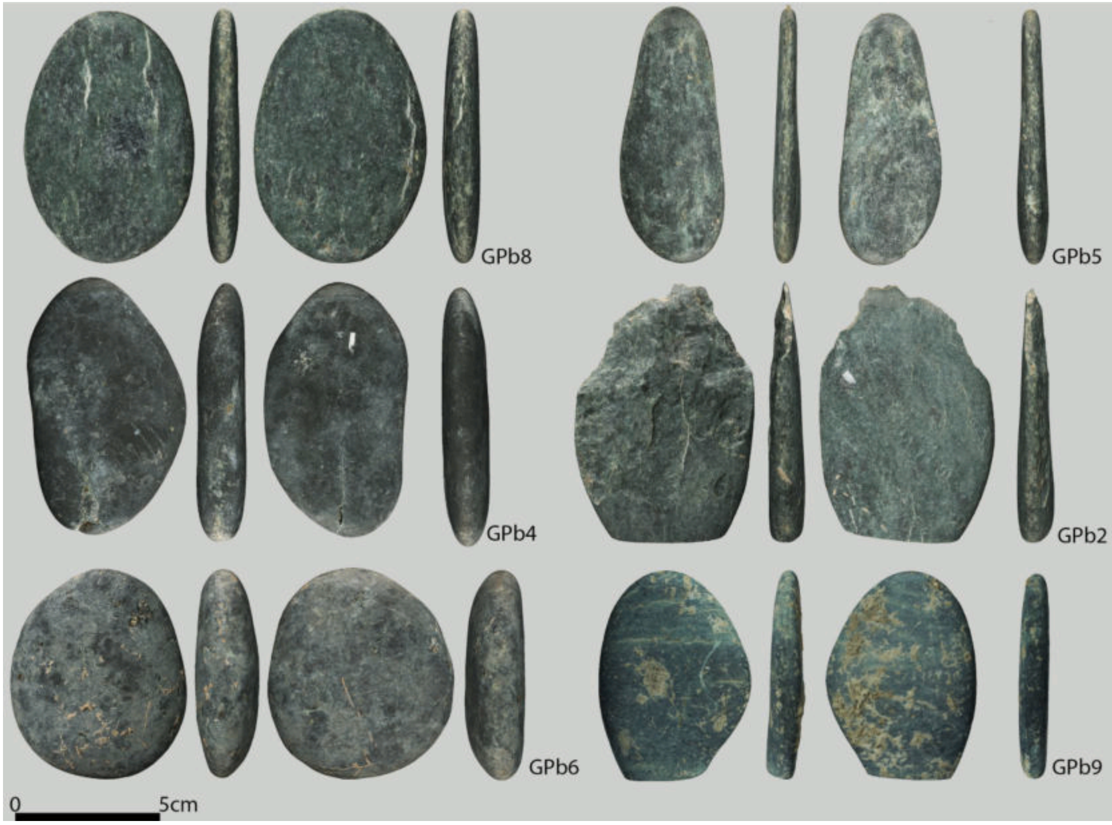

Fig. 3. The archaeological green pebbles found at Fumane Cave. GPb2 (RF157) and GPb9 (RIM) were cut of the petrographic sections before their analysis. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.2. Methods

After their discovery, the Mousterian pebbles were gently washed with water to remove the loose sediment on their surfaces. No brush or other metal tools were used, and tiny concretions were preserved on the stone surfaces. Morphometric determinations, photogrammetry, petrographic and functional analyses were performed on the pebbles (Table 2). Given the unicity of the findings, only non-destructive and non-invasive analytical techniques were applied. At the same time, thin sections resulted from a previous preliminary study focused on the presumed Proto-Aurignacian pebbles (Bertola et al., 2013). Furthermore, we collected pebbles of similar nature, size, and shape in the present-day riverbed and the coarse gravel deposits of the fluvioglacial Adige megafan. We used them as a reference for natural surfaces during

Table 2
Summary of results produced from petrographic and functional analyses of complete and fragmentary green pebbles from Fumane Cave. Column headings see Table 1.

ID	US	Petrographic analyses				Functional analyses			
		MACRO	TS	SEM-EDS	RAMAN	Macro-traces	Use-wear Localisation	Residues	FTIR
GPb1	D6		X						
GPb2	D3 + D6cp	X	X			Long and short striations; elongate overlapping pits	Flat surface and edges	Few patches of amorphous yellowish/ orange glossy residue	Adipocere
GPb3	A3I		X						
GPb4	A6 base	X			X	Striations; small circular pits; macro-striations	Flat surface and edges	Patches of white and glossy residues, sometime smeared over the used surfaces and consistent with animal fat; one collagen fiber packed in a small pit	Adipocere
GPb5	A6	X				Overlapping pits	Opposed short edges	Few patches of amorphous yellowish/ orange glossy residue	Organic residues not diagnostic
GPb6	A6	X				Sporadic striations, non diagnostic	Flat surface	No macroscopic residue	No residues
GPb7	A6 ÷ A9	X	X	X	X				
GPb8	A3 ÷ A8 Tana	X				Overlapping pits; long and oriented striations; linear cracks	Opposed short edges	No macroscopic residue	Adipocere
GPb9	No context	X	X			Sporadic striations, not diagnostic	Flat surface	No macroscopic residue	No residues

our use wear and residue analysis.

3.2.1. Basic morphometrics

The morphometric features of the pebbles were recorded based on standard norms in sedimentology (Bosellini et al., 1989). The complete pebbles' lengths, width, and thickness were measured using a hand caliper on the longest, intermediate, and shortest axis, respectively. Shape, flattening, and elongation were inferred by calculating the rates between the three axes. The Sneed and Folk (1958) formula was used to calculate the sphericity (equidimensionality). Smoothness was estimated using comparative charts (Pettijohn, 1975).

3.2.2. 3D modelling

A detailed representation of the archaeological specimens bearing use wear and residues was obtained by applying Close Range Photogrammetry (CRP), following the methodological framework proposed by Porter et al. (2016) to produce accurate 3D models. Pictures were taken utilizing a Nikon D7200 DSLR camera equipped with a Nikkor Lens AF-S VR 105 mm lens at the DANTE – Diet and ANcient TEchnology laboratory (Sapienza University of Rome). The objects were placed over an automated turntable (Foldio 360), and photos were automatically shot. A whole revolution comprised 24 shots, one every 15°. Images were taken at three different height stages (every 10 cm, starting at object level), and the camera was raised every time the object completed a 360° rotation. After these three steps, the object was flipped over, and pictures of the opposite face were taken from the highest to the lower height. A total of 72 shots were taken for each green pebble, resulting in 144 pictures per object. The sets of images were processed using MetaShape Pro v.1.5 software. Pictures of each face of the pebbles were aligned, and high-definition dense clouds were generated. The two dense clouds were then aligned and merged, thus creating a complete object model, which was then correctly scaled. Finally, a mesh originating from the merged dense cloud was generated.

3.2.3. Petrography

We performed petrographic determinations at the Department of Physics and Earth Sciences and Department of Humanities, Section of Prehistoric and Anthropological Sciences, following a protocol based on macroscopic and microscopic scales of observation for all or part of the specimens (Table 2) (Chiari et al., 1996; Compagnoni et al., 2006; Giustetto et al., 2008). Macroscopic determination followed normalized nomenclature (D'Amico et al., 2004; Klein, 1999). We inspected the pebbles at the naked eye and a multivariable optical stereomicroscope Optika SZ series, 45X with camera Moticam 3 + USB 3, and progressive magnifications ranging from 5X to 20XXx. The color was determined according to the Munsell Soil Color Charts® (Munsell, 2009). For the sake of comparison, we re-examined thin sections of pebbles collected on the Adige River gravel bed (Bertola et al., 2013). We examined thin polished sections of fragmentary specimen GPb7 using optical transmitted light microscope (OTLM) OPLOPTIKA B510 POL-AOS equipped with a MOTICAM 2500 5.0 M pixel webcam operated by Motic Images Plus 2.0 ML software. Nonetheless, such technique alone does not allow for a secure and univocal recognition as different varieties of the serpentine family present themselves in association with each other and with a different appearance from the one expected (Hirauchi et al., 2020).

We performed scanning electron microscopy (SEM) observations on the specimen GPb7 for microstructural characterization and qualitative determination of its chemical composition. A ZEISS EVO MA 15, coupled with an Energy-Dispersive X-ray spectroscopy (EDX) system (Aztec Oxford apparatus, SDD detector, WD 8.5 mm, EHT 20 kV) and a LaB6 filament as the electron source was used. SEM images in back-scattered detector imaging mode were crucial for studying the samples' morphological and topographical features. We also conducted μ-Raman analyses of GPb7 and GPb4 using a LabRam HR800 micro-Raman instrument from Horiba Scientific. The latter was equipped with an air-cooled CCD detector at –70 °C, an Olympus BXFM microscope, a 600 groove/mm grating, and a 10X or 50X objective for collecting the Raman scattering signals. The excitation source was a He-Ne laser (632.8 nm line) with a maximum laser power of 20 mW, and the spectrometer was calibrated with silicon at 520 cm-1.

3.2.4. Residues and use-wear

Residues and use traces were preserved on six pebbles (GPb2, Gpb4, GPb5, GPb6, GPb8, GPb9) (Table 2). They were analyzed at the DANTE laboratory using a Zeiss Axio Zoom V16 binocular stereo microscope with progressive magnifications ranging from 10X to 112X and equipped with a Zeiss Axiocam 305/506 color camera.

We evaluated residue morphological features (e.g., color, appearance, inclusions, consistency, birefringence, etc.) and spatial patterns of their distribution (Lombard and Wadley 2007; Langejans, 2011) following criteria well-known in literature (e.g., Barton et al., 1998; Kealhofer et al., 1999; Lombard, 2005, Lombard and Wadley, 2007; Monnier et al., 2012; Rots et al. 2015; Cnuts and Rots, 2017; Hayes et al., 2017). In addition to this, archaeological residues have also been compared to an experimental reference collection of 70 experimental macro-tools stored at the DANTE laboratory and used in different activities involving thrusting and resting percussion on materials of animal, plant, and mineral origin.

Archaeological residues were further analyzed at the MUSE – Science Museum of Trento (Italy) using a ZEISS EVO 40 XVP, a SEM coupled with an Energy-Dispersive X-ray detector (EDX). This analysis was aimed at characterizing the elemental composition of the residues previously identified with reflected light microscopy. The SEM was operated in variable pressure mode (chamber pressure ~ 14 Pa), enabling backscattered electron images obtained at magnifications between 70X and 500X without applying a conducting layer on the specimen. EDX microanalysis was carried out using an Oxford Instrument X-act PentaFET precision detector and Aztec 3.1 SP1 software.

Archaeological pebbles were analyzed at the Department of Chemistry at Sapienza University, using the micro-Fourier Transform InfraRed (micro-FTIR) technique not requiring a preliminary treatment of the samples. Spectra were collected with a Bruker Optic Alpha-R portable interferometer with an external reflectance head covering a circular area of about 5 mm in diameter. The investigated spectral range was 7500–375 cm^{-1} with a resolution of 4 cm^{-1} cumulating 250 scans or more. Two or three zones were analyzed on each pebble. The analysis was carried out on the unused surface and on the zones with evident use-wear to detect relevant changes in the sample spectra.

Following residue evaluation, the samples were gently washed with ultra-pure water. Macro-traces, primarily consisting of pits and striations, were described at low magnification (up to 168x) using parameters well-established in literature (Hamon, 2006; Adams et al., 2009; Dubreuil et al., 2015; Cristiani and Zupancich, 2020).

3.2.5. 3D morphometric analysis

Following published protocols (Benito-Calvo et al. 2018; Zupancich and Cristiani, 2020), a 360° 3D morphometric analysis was performed on the pebbles of the Fumane cave. At first, convex hulls were created in Meshlab (v.2020.3) for each artifact (Cignoni et al., 2008). These consist of the smallest three-dimensional convex surface containing all the data of the 3D model and are utilized as a reference from which the measure of surface elevation is calculated (Cignoni et al., 2008; Benito-Calvo et al. 2018; Zupancich and Cristiani 2020). 3D meshes and their relative convex hulls were then imported in CloudCompare (v2.10.2) to measure surface depression depths and surface roughness, two parameters that proved helpful in quantifying surface modifications caused by the use (Benito-Calvo et al., 2018; Zupancich and Cristiani, 2020). The depth of surface depression was calculated through the *cloud/mesh distance tool,* which measures the distance occurring between the 3D mesh and its convex hull. Surface roughness values were obtained, calculating the distance between each point of the 3D model and its best-fitting plane applying a 0.5 mm local neighbor radius.

4. Results: The nature of the pebbles

4.1. Shape, size, and macroscopic petrographic features

All the six green-grey pebbles have naturally flat and oval shapes with quite regular morphologies and 10.3 mm average thickness (Figs. 3, 9, and 10; Table 1; section S2 in SM). No technological modifications were identified on them. The edges of all pebbles appear heavily rounded by transport and abrasion processes in high-energy fluvial environments. Their serpentinite rocks are not very hard (3–6 of the Mohs scale, 4.5 average).

4.2. Optical microscopy, SEM-EDX, and Raman analyses

The use of optical microscopy, SEM-EDX, and Raman spectroscopy has proven to be an effective strategy when studying serpentine minerals (Kloprogge et al., 1999; Rinaudo et al., 2003; 2004). The association of optical-morphological and chemical-vibrational information has primarily allowed the complete characterization of the mineral associations present in the rock samples. Above all has allowed the identification of the group's polymorphs.

4.2.1. OTLM thin sections (parallel nicols 5X)

The observation of thin sections by optical microscopy allowed a first assessment of the presence of minerals in this family. It also provided helpful information regarding the attribution of the different varieties. First-order gray-black interference colors characterize the pebble GPb7 in section (Figs. 4 and 5). Among these lamellae, in some cases, more fibrous veins with higher interference colors emerge. These are probably Chrysolite/Lizardite/Antigorite inserts. The visible opaque minerals are crystals of chromium oxides transformed into Haematite/Magnetite. In the fibrous Chrysolite veins, the fiber's direction generally changes by a few degrees going from the walls towards the center, showing rapid variations in thickness. The reaction edge shows the first-order interference colors typical of the lamellar-type coil. There are also opaque minerals. Although the appearance of the section remains homogeneous from a structural point of view, the texture varies from finer to denser. Denser textured zones are also characterized by the presence of brownish fibers flanked by larger whitish veins.

The optical microscopic scrutiny of thin section and XRD GPb2: Fig. 6) previously conducted on the green pebbles found in the Protoaurignacian contexts led to their identification as Serpentinite rock (Bertola et al., 2013). Their mineralogical composition consists of Antigorite with few dispersed granules of Magnetite and Dolomite.

4.2.2. SEM-EDX

Unfortunately, the very nature of the Serpentine minerals did not facilitate the SEM micro-analysis of the different morphologies and the polymorphs characterization. The acquisition of X-ray maps with EDX revealed no substantial variation in the composition. At the same time, SEM images showed no significant structural variations in the section, mainly characterized by the intertwining of Serpentine veins. Analyses showed that GPb7 is primarily constituted by Mg-Si rich minerals, as highlighted by EDX spectra with a grain size variation from the rim to the center. The EDS analysis carried out on the oxides has highlighted the presence of Magnetite and Chromite, type Mg-Al-Chromite (Fig. 7).

4.2.3. Raman

Raman analyses conducted on GPb4 and GPb7 have shown the presence of Serpentine as the main mineral of the specimens (Fig. 8). The spectra obtained at low frequency, very similar to one another, did not distinguish between the Chrysolite-Lizardite varieties. Actinolite amphibole emerges among the most common minerals near the border. The presence of this amphibole derives from the alteration by hydration of the femic minerals such as, in particular, Ortho and Clino-pyroxene.

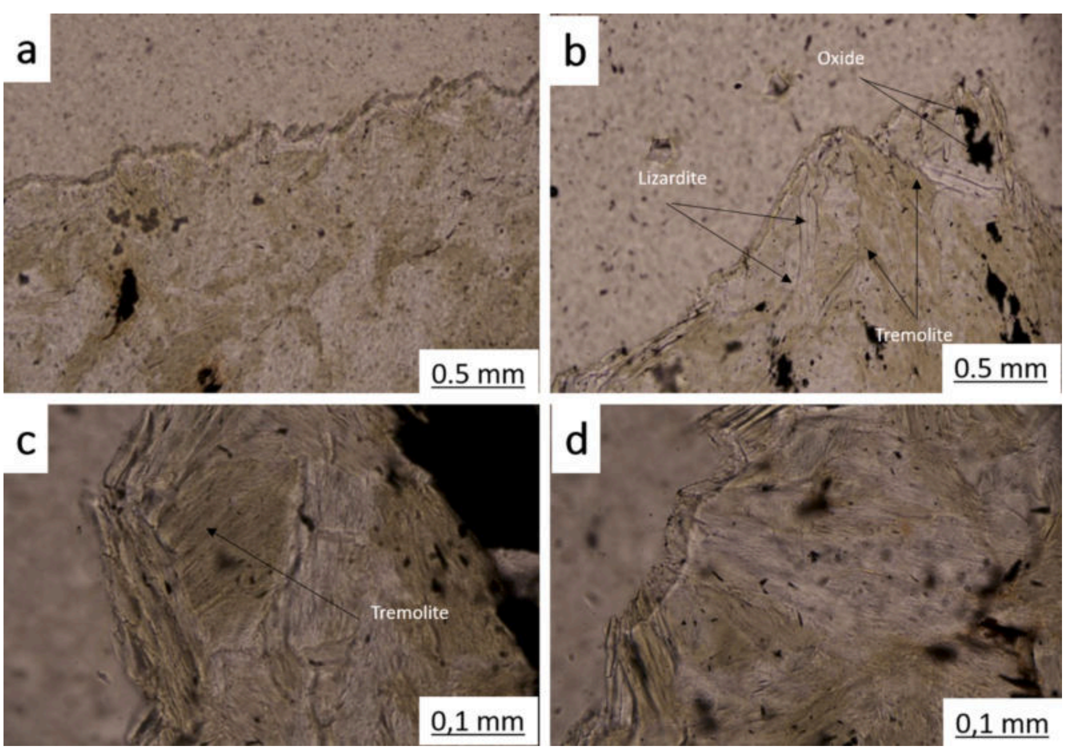

Fig. 4. Photomicrographs polarized light of GPb7. Tremolite is light green colored, and Lizardite very pale green colored. Also, oxides are present related to the alteration of primary minerals due to level of hydration metamorphic grade. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

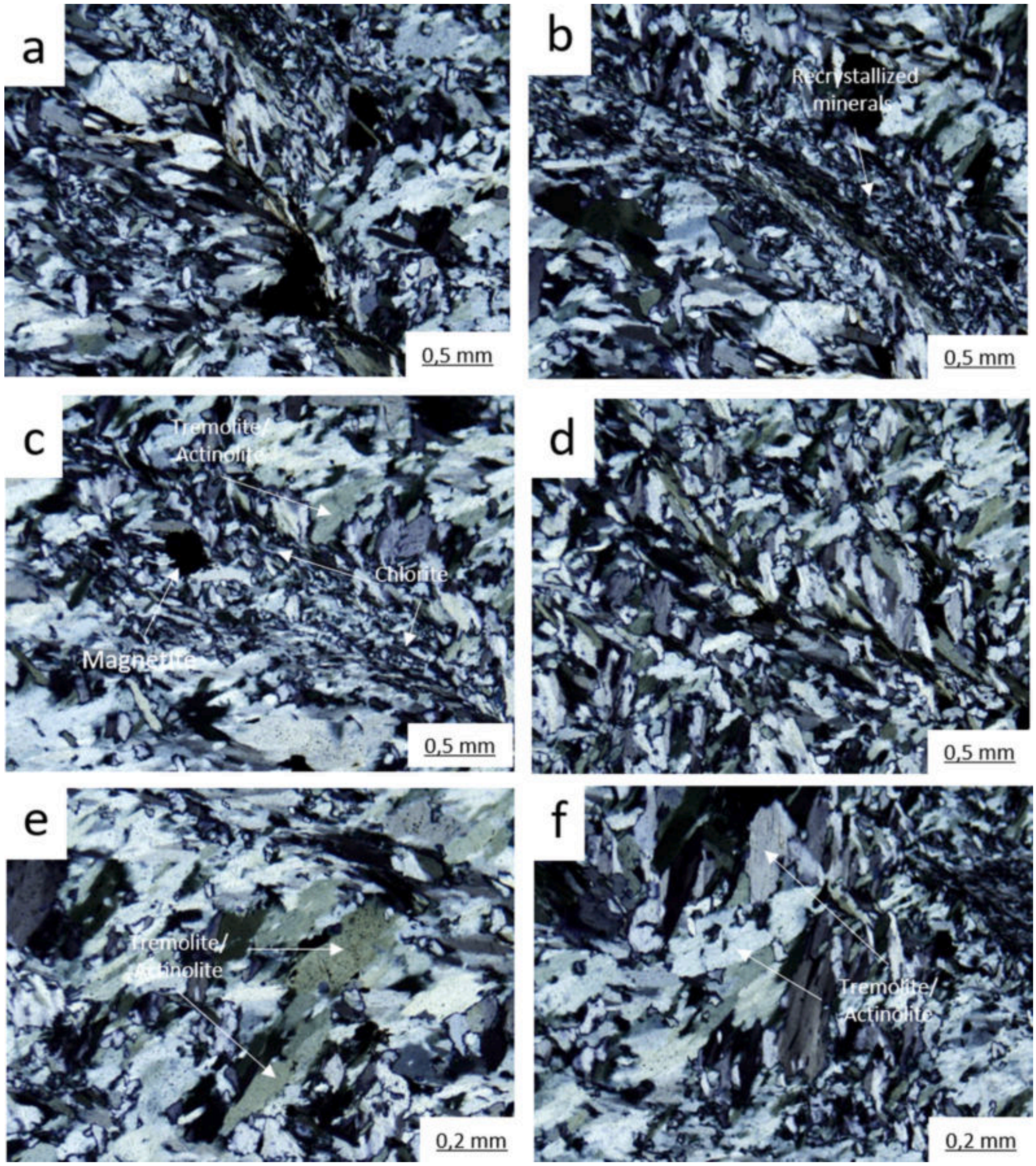

Fig. 5. Photomicrographs crossed-polarized light of GPb7. Polygonal texture, typically occurring within micro-granular with a patchy extinction pattern from a deformed serpentinite.

5. The ensemble of anthropic traces

5.1. Use-Wear

Diagnostic macro-traces were observed on five pebbles, GPb2, GPb4, GPb5, GPb6, GPb8. In detail, we identified different types of macro-striations (i.e., long/shallow or short/deep) localized in specific tools areas, namely across the flat apical surfaces or along with the short and/or long edges (Figs. 9 and 10).

Dense clusters of rounded pits are often documented in association with striations and cracks. Such a combination of traces has experimentally been obtained through different types of thrusting percussion, including ample and short gestures, performed using the pebble's short edges. A detailed description of the use-wear identified on each sample is reported in Table 2. Based on an experimental reference collection of worked pebbles, although of different lithologies than serpentinite, the traces identified on the archaeological pebbles can be attributed to the processing of hard-animal material (Caricola et al., 2018).

5.2. Residues

At the naked eye, a residual film covers the surface of the pebbles. Once observed at higher magnification, spots of abundant amorphous glossy residue and fibers, ranging from white to dark orange, have been identified on GPb2, GPb4, GPb5 (Fig. 10). Like the stone surface, residues are also affected by the patina. On GPb4, patches of white, glossy residues are abundant, either spread across the surface or concentrated inside the functional pits characterizing the distal ends. On the distal end and towards the center of the tool, whitish glossy amorphous residues are also smeared inside functional striations (Fig. 10). The linear distribution of the residue suggests the tool was used in thrusting percussion. Yellowish-orange amorphous residues and fibers have also been identified inside pits and cracks on the tool's edge or trapped under minuscule stone flakes (Fig. 10). Residues' appearance, color, consistency, and inclusions are consistent with experimental animal fat and fresh bone fibers.

All the micro-FTIR spectra of GPb2, GPb4, GPb5, GPb6, GPb7, Gpb9 show intense absorption bands at 1043 and 473 $^{-1}$, medium intense

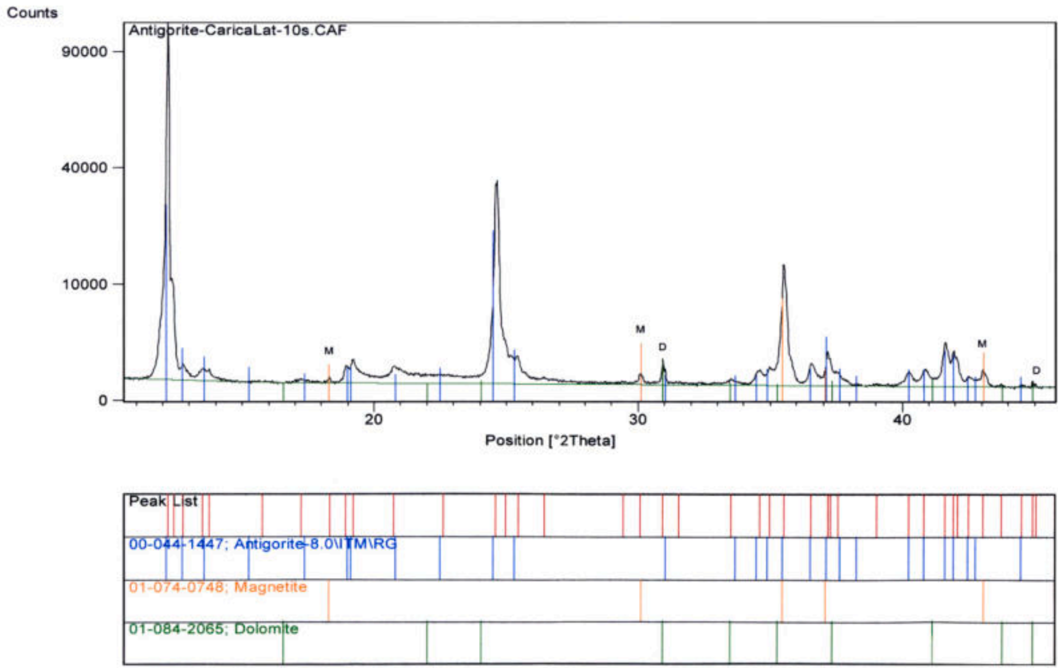

Fig. 6. XRD spectra of GPb2.

peaks at 658 and 642 cm^{-1}, and a very weak peak at 3684 cm^{-1}, confirming serpentine as principal or unique component of the items examined. Weak doublets at 1574\ 1537 and 2915\ 2848 cm^{-1} observed in the spectra of specimens GPb4, GPb5, and GPb8 (SM Fig. 1) suggest the presence of organic residues. In agreement with published data (Solodenko et al., 2015; Monnier, 2018; Venditti et al., 2019), peaks at 1537 and 1574 cm^{-1} observed in artifacts GPb4 and GPb8 can be attributed to fatty acids, probably adipocere. Also referred to as "grave wax," adipocere is an unctuous brownish substance consisting of fatty acids and calcium soaps produced by the chemical decomposition of animal fat and muscles buried for a long time or immersed in moisture. In the case of artifact GPb5, while indicating the presence of some kind of organic residue, the weakness of the identified peaks does not allow for a detailed interpretation.

EDX microanalysis shows small concentrations of calcium and phosphorus on the flat apical surfaces of GPb4 and GPb8. As the bone mineral is composed of Carbonate-Hydroxyapatite with low crystallinity, this evidence sustains the interpretation of archaeological residues as animal fat and collagen EDX maps of the elemental distribution distinctly localize bone residues in small pits, frequently associated with linear striations. Concerning the sample GPb4, EDX spectra from three selected areas (Fig. 11, sampling points S2, S3, S4) show high calcium and phosphorus levels in the surrounding Serpentinite matrix, mainly composed of silicon, magnesium, and oxygen. Remarkably, the highest percentage of hydroxyapatite is recorded in the smaller sample areas, suggesting residues were primarily preserved in the depressions. Smaller peaks of carbon and aluminum are probably associated with environmental contamination from soil and/or handling.

Overall, qualitative and quantitative analyses of residues sustain the interpretation of the use-wear traces stereoscopically identified.

5.3. 3D surface morphometrics

The analysis of surface depression depths and roughness reveals an overall topographic homogeneity of the green pebbles of the Fumane cave (Figs. 12 and 13). Across the pebbles, surface depressions are characterized by a mean depth of −0.098 mm. The higher mean and median (-0.243 and −0.075 mm) values are recorded on artifact GPb2, while the maximum single computed depth (-3.158 mm) is recorded on tool GPb4 (Table 3). The shallowest depressions are observed across pebble GPb8, where the mean and median depths are −0.047 and −0.027, respectively, and the maximum computed depth is −0.64 mm. The mean value recorded within the assemblage for surface roughness is 0.006 mm, indicating an overall low degree of topographic variation. The pebble GPb2 restituted the roughest surface with the mean and median values of 0.014 mm and 0.006 mm, respectively. This tool also returned the highest maximum roughness value (0.216 mm) recorded within the assemblage. It is worth mentioning that the depths and roughness values computed on this tool are not related to its use but instead to the severe post-depositional fracturing affecting one of its surfaces.

When analyzed singularly, the surfaces and the edge of the tools exhibit differences in terms of morphometrics. In general, shallow depressions are present on the edge of the pebbles (mean depth −0.06 mm), while the surfaces of the tools exhibit deeper hollows (mean −0.078 mm) (Table 3; Fig. 13a). Concerning surface roughness, the edge of the tools is rougher compared to the surfaces. Over the edge of the tools, the recorded mean and median roughness values range between 0.014 mm and 0.012 mm, respectively, evidence of a higher topographic variation affecting this specific area of the pebbles (Table 3; Fig. 13b). The only exception to this pattern is given by artifact GPb2 due to the aforementioned post-depositional surface modifications. Based on the use-wear interpretation (see 4.2), such a difference in the morphometric values recorded on the edges and surface of the pebbles can be confidently associated with the use modifications caused by their utilization in percussive activities.

Furthermore, the low variation in roughness values (Fig. 13c) measured over the edge of the tools fits well with the information obtained through use-wear and residues, which suggest that the Fumane pebbles were most likely used in a specific task (i.e., the processing of hard animal materials).

6. Discussion

6.1. Source area and collecting criteria

6.1.1. Petrographic nature of the pebbles

The acquisition of X-ray maps with EDX analysis in specific areas (for

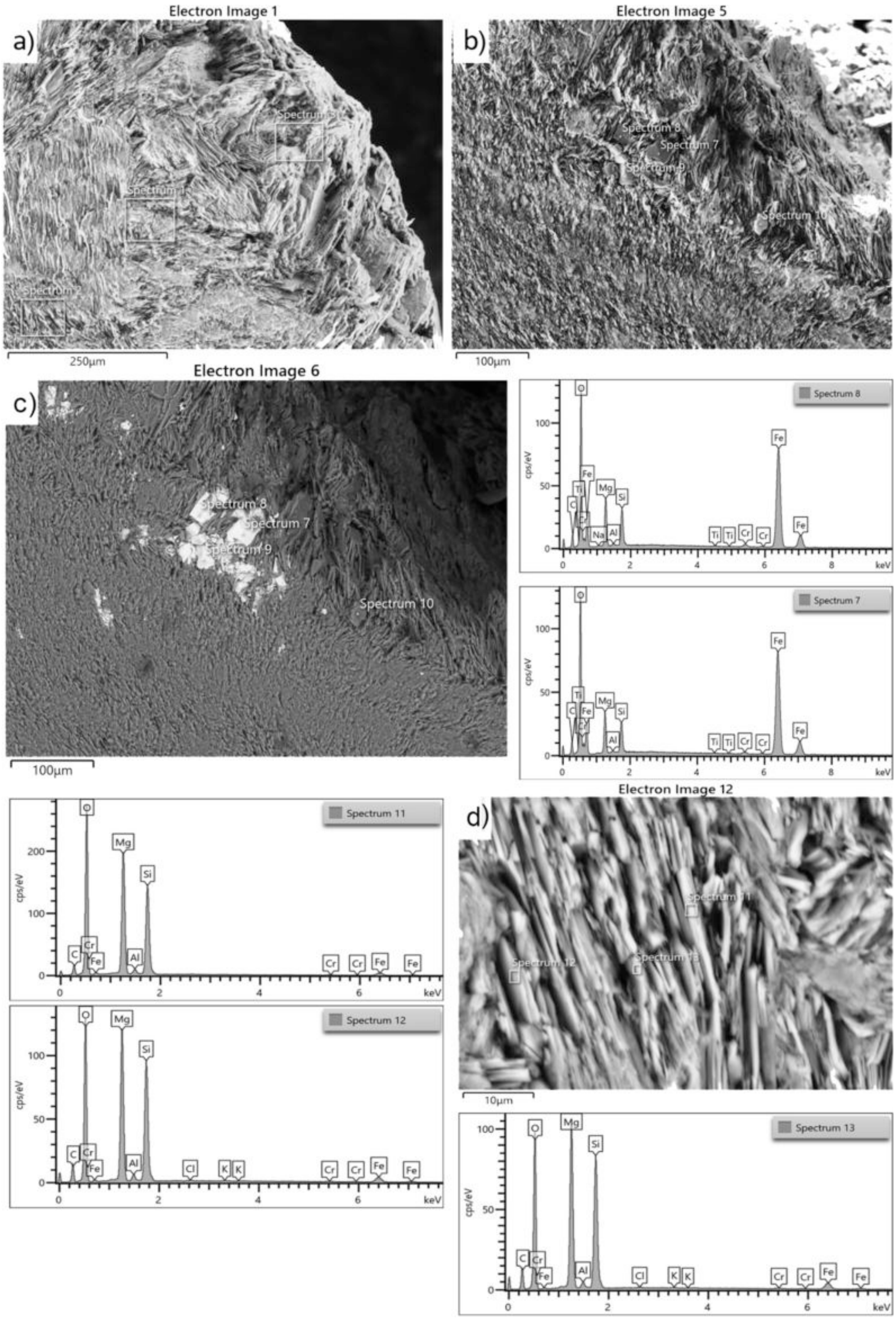

Fig. 7. BSE SEM images of GPb7: a) images showing both tabular and columnar shape; b) image and EDX spectra of Fe oxides due to alteration of femic minerals; c) image and EDX spectra of antigorite. The sample shows a columnar habit; d) image and EDS spectra of lizardite crystals.

example, those characterized by series of different Serpentine veins) revealed no substantial compositional variations in the analyzed samples. Nevertheless, the introduction of Raman spectroscopy was decisive for our study. Despite the apparent similarity of the spectra at low wavenumbers, subtle differences were identified and allowed to distinguish one polymorph from the other (Auzende et al., 2004; Groppo et al., 2006). Raman spectroscopy was also crucial to understand structural relations in the examined samples and verify some secondary minerals and accessories identified through optical microscopy (for example, in Actinolite detected in the outer borders).

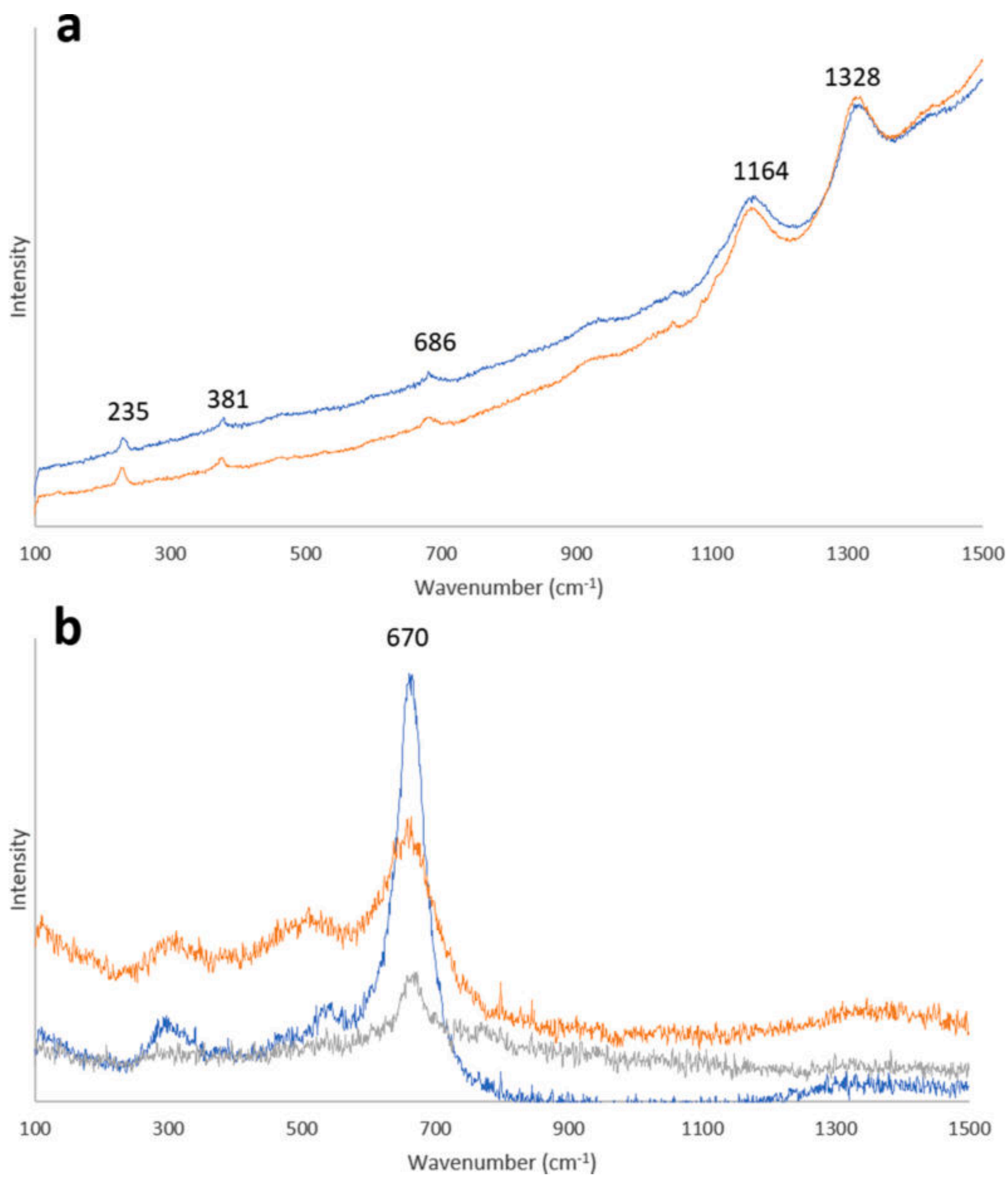

Fig. 8. Results of Raman analyses: a) GPb4, Lizardite/Chrysolite spectra from two sampling points (red and blu); b) GPb7, Hematite/Magnetite spectra from three sampling points. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

6.1.2. Source area

The morphologies of the Serpentinite pebbles from Fumane, with rounded edges, prove they were collected from fluvial deposits and confirmed during our survey (SM Figs. 2 and 3). The extreme flatness is a consequence of the planar anisotropy of schistose rocks. Their size is compatible with distance transport of a few hundred (150–200) kilometers from the source area.

Serpentinites are part of the *meta*-ophiolites, a component of the Pennine basement in the core alpine area and origin from the transformation of upper mantle (Peridotite) rocks due to metamorphic metasomatic effects (Piaz et al., 2003). Present-day primary exposures of Serpentinites are mapped in the river basins of the inner Eastern Alps Mountain range, in our case outcropping in the south-western sector of the Mesozoic window of the Tauern Mountains, currently dissected by the Isarco, Rienza, and Passiria, the main tributary rivers of the upper Adige basin (Fig. 14). The Adige River basin extends 12,000 km2, with a 410 km course from the Alpine watershed to the Adriatic shore. Primary exposures of Serpentinites are located in the upper Adige basin and the Passiria, d'Ultimo, and Sole valleys, the Ridanna, Vizze, and Fundres valleys, the Aurina valleys (Martin et al., 1994). Before sorting out the Alps, the Adige flows the lower Lagarina Valley from the Monte Baldo-Bondone Chain to the West and the Monti Lessini-Piccole Dolomiti-Folgaria plateau to the East. Beyond the Ceraino gorge, the river contributed to the formation of the basal level of the Po Plain. This coarse-gravelly thick deposit currently extends 20 km Southwards until the resurgence belt.

Serpentinite pebbles are contained in the present-day riverbed and in the coarse gravel deposits of the fluvioglacial Adige megafan (De Vecchi and Piccirillo, 1968; De Vecchi and Mezzacasa, 1986) (SM Fig. 2a). The coarse-gravelly Adige plain south-west of Monti Lessini is a megafan originated from outwash rivers from the Rivoli Veronese glacier lobe (Cremaschi, 1990), with significant water and solid discharges that fed the progradation and aggradation of alluvial fans over the plain (Fontana et al., 2014) (Fig. 1). Aggradation phases in the piedmont sector

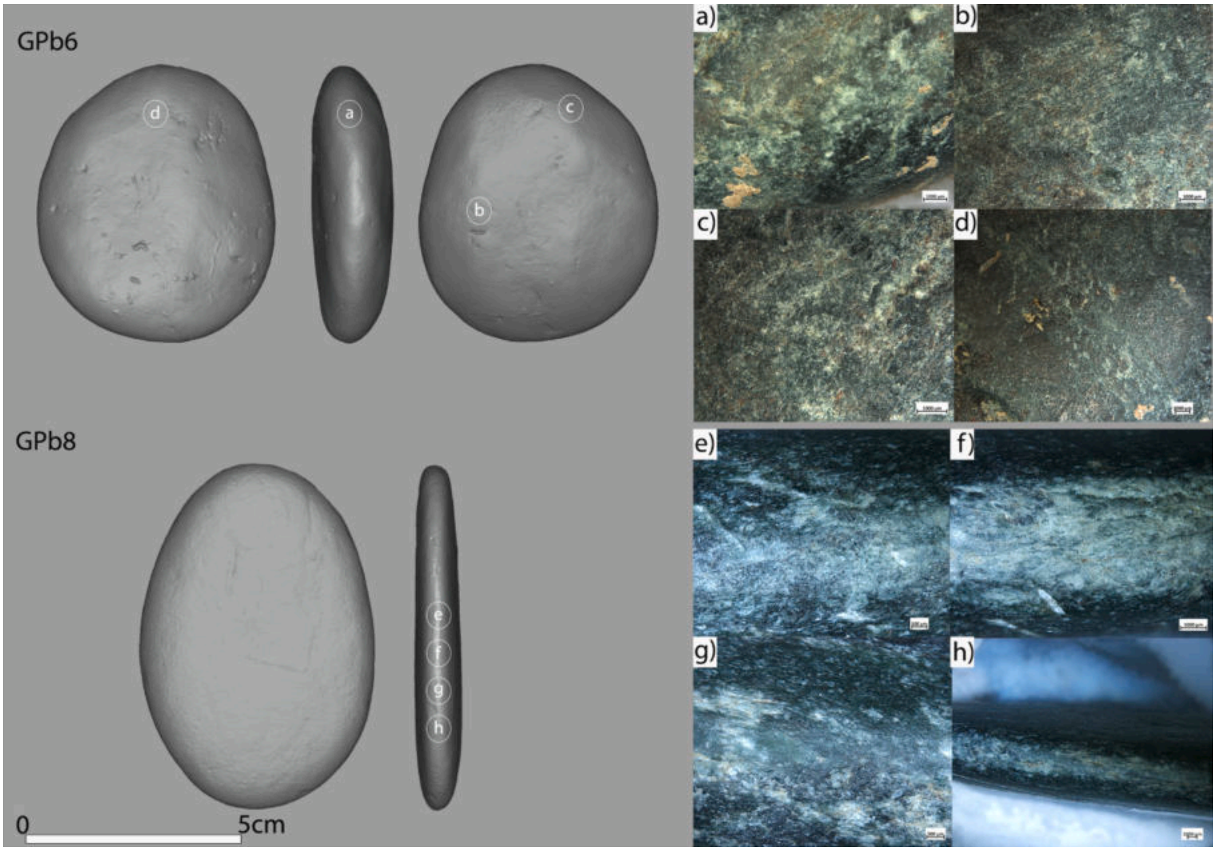

Fig. 9. Use wear identified on pebbles GPb6 (a-d) and GPb8 (e-h): a-d) sporadic striations observed across the flat surface of GPb6; e-h) overlapping pits and long oriented striations identified on the edge of GPb8.

stopped at the onset of glaciers' withdrawal (after 22 ka cal BP, Monegato, et al., 2017) when outwash streams cut the piedmont plains. The Adige megafan is mainly spread to the south-east. Its apex is positioned at the Ceraino gorge (Chiusa di Ceraino-Valle del tasso-Domegliara), where it joins the easternmost moraines of the Rivoli Veronese, and Garda end moraine systems formed during the Last Glacial Maximum (henceforth LGM) (Monegato et al., 2017) (Fig. 1). The northern side of the Adige megafan merges with small fans of the Monti Lessini streams, making the distinction between these structures and the main plain uncertain. Alluvial terraces along the Adige course and the Lessini streams testify dissections during the post-aggradation phases correlated with the postglacial periods.

It has been remarked that before the LGM spread of the glaciers at about 24.7 ka cal BP (Monegato et al., 2017), the outwash stream was concentrated in the Adige River, whose piedmont fan should have been towards the south of Ceraino gorge. In the Lagarina valley and the upper Adige plain, the typical sediments are pebbles, gravel, and coarse sand made of porphyry, gabbro, diorite, gneiss, mica schists, quartzites, dolomite, limestone, marl, sandy marl, and, locally, of silt, clay, and peat. This composition is different from the poorer one characterizing the Monti Lessini streambeds, where pebbles and gravel are made of limestone, marly limestone, and minor basalts. Loamy – clayey sediments are more abundant here than in the Adige plain (De Zanche et al., 1977).

Given this petrographic composition, the Adige alluvial plain appears as a potential source where Neanderthals acquired the green pebbles found at Fumane. Nevertheless, in addition to the post MIS 3 deposits, some limited areas of the present-day geological landscape were excluded from provisioning, like the Lower Pleistocene gravelly-pebble deposits at Sant'Ambrogio di Valpolicella. These are constituted of dolostones, limestones, cherts, and low-grade metamorphic rocks (Scardia et al., 2015), all highly affected by intense weathering, making them unsuitable to be used at Fumane. Also, pre-Würm coarse alluvial exposures cover a vast NW-SE oriented belt and contribute to elevating the Monti Lessini stream valleys (De Zanche et al., 1977), thus limiting inputs to the main plain during the Late Pleistocene. These alluvial deposits are weathered at the top by palaeosoils leading to the dissolution of carbonatic lithologies. Residual silicatic pebbles are affected by differential alteration like in the interglacial palaeosoil developed on the glacial till/fluvioglacial deposits at the base of the Val Sorda sequence (Ferraro, 2009).

Comparably to other multiple Middle Pleistocene glacial advances spread at the southern Alpine border with a piedmontane lobe, also the Garda basin was occupied by glaciers bearing increasing amounts of porphyries and granitoids from the volcanic platforms and the crystalline axial belt of the Alpine chain (Baroni and Cremaschi, 1987; Cremaschi, 1987; Scardia et al., 2015). In the Rivoli Veronese end moraine system, older moraine system remains were mapped (Venzo, 1961; Accorsi et al., 1990). These severely eroded moraines have been attributed to the penultimate glaciation (Accorsi et al., 1990). Traces of weathered till deposits datable to the early Middle Pleistocene and possibly early Pleistocene can be found near Montecchio and Caprino, leaning up against the margin of Mount Belpo (Accorsi et al., 1990).

Based on the data mentioned above, we conducted targeted surveys on the fluvioglacial and fluvial deposits in the proximity of Rivoli Veronese to collect pebbles of lithology and size comparable to the Fumane specimens (SM Fig. 2b and 3). Surprisingly, Serpentinite pebbles were common findings during our surveys. We expected to confirm an ephemeral presence of these materials, given the limited extension of the primary exposures in the Alpine watershed. This *meta*-ophiolite lithologies' input was supported by glacial erosional processes during the Pleistocene when ice caps extended over the Tauern Mounts beyond the

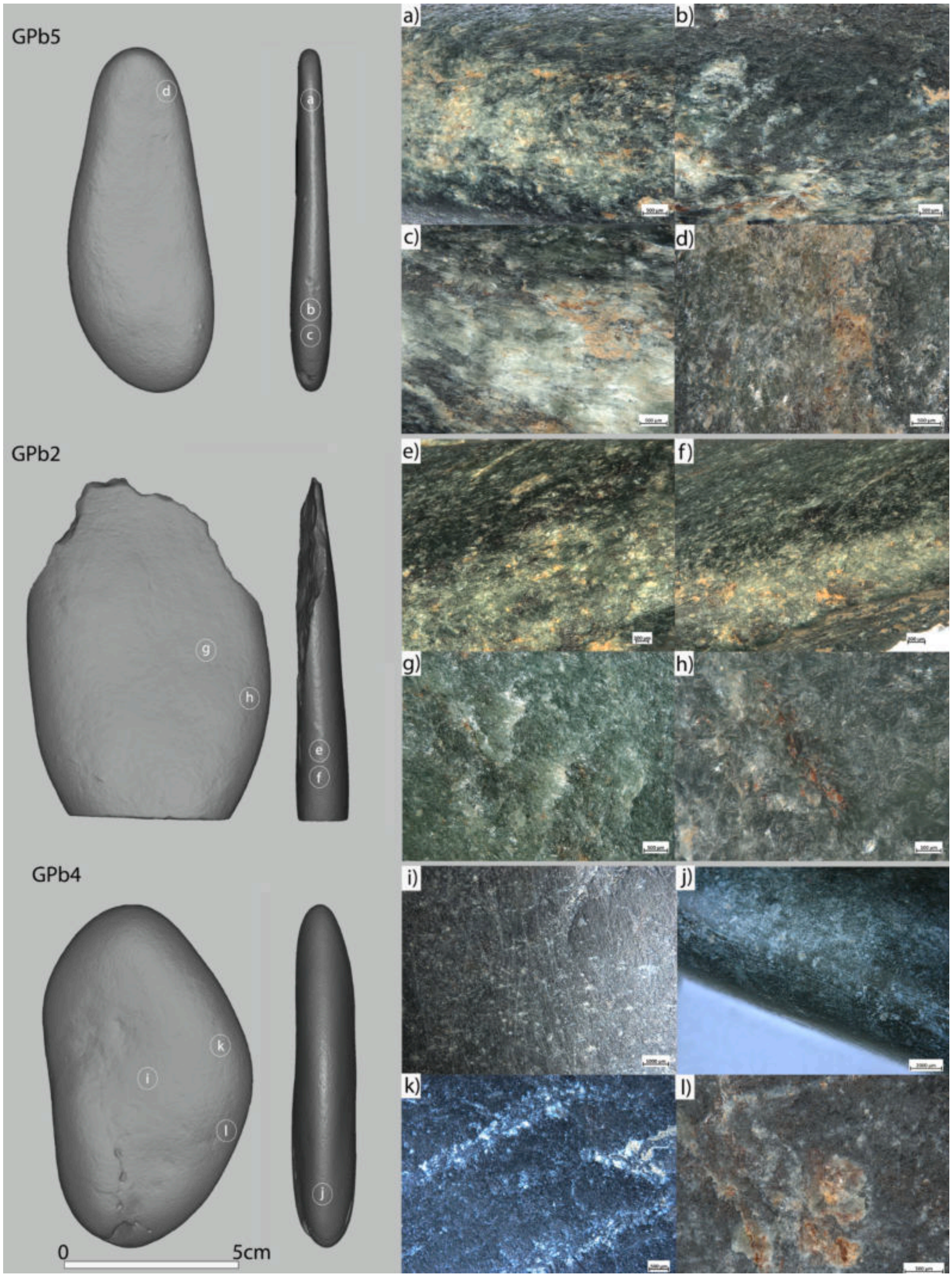

Fig. 10. Use wear and residues identified on pebbles GPb5, GPb2 and GPb4: a-c) overlapping pits identified on the short edge of GPb5; d) reddish patinated residue filling a shallow surface depression; e-g) long and short striations and small rounded pits observed on the surface and the edge of GPb2; h) reddish patinated residue; i-k) striations and circular pits indetified on the surface and the edge of GPb4; l) yellow-reddish residue preserved as a crust on the stone surface. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

present-day watershed and consistently enriched the glacial glacial-fluvioglacial deposits along with the Sarca and Adige River courses (Martin et al., 1994). Most pebbles have sub-spherical or globular uneven, asymmetrical shapes up to 25 cm in diameter and a degree of flatness lower than some of the specimens from Fumane (Table 3). Flat, smoothed regular pebbles were also found, although much less frequent.

6.2. Functional overview

Optical microscopy, FTIR, and EDX analyses revealed evidence of repeated contact between the green pebbles and a greasy matter of animal origin, consistent with bone and animal fat. Possible contacts between stones, bone, and animal fat might have occurred during the archaeological context's sin- and post-depositional evolution. However, the appearance, patination, distribution, and chemical characterization of archaeological residues and a positive correlation with the use-wear

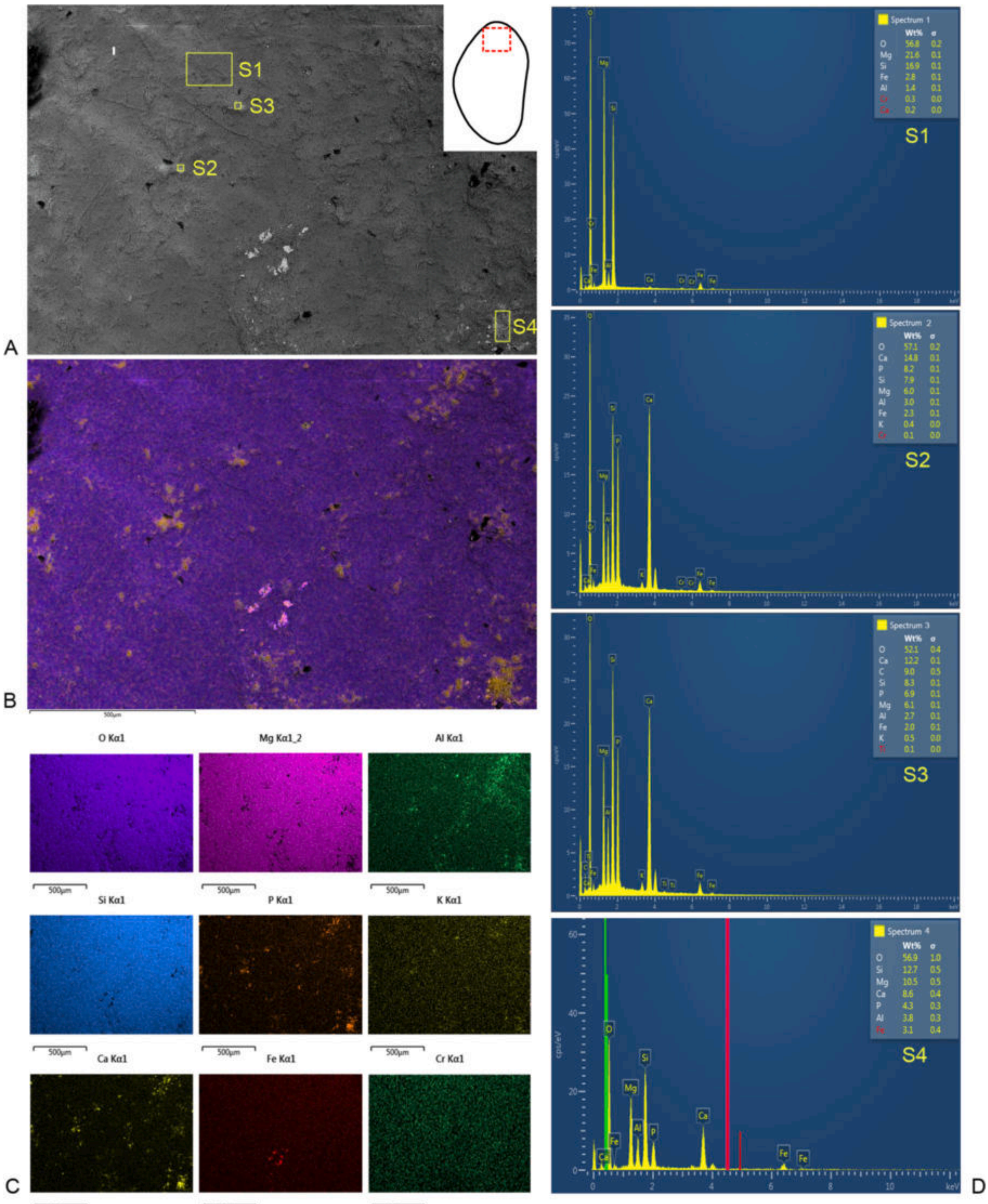

Fig. 11. A: SEM backscattered secondary electron image (BSE) of GPb4 flat apical surface with the location of the four areas analyzed by energy dispersive X-ray spectroscopy (EDX; S1-4); B: BSE images and combined elemental maps shown as false color: oxygen in purple, magnesium in pink, aluminum in green, silicon in light blue, phosphorus in orange, potassium in light green, calcium in yellow, iron in red and chromium in sea green; C: discrete EDX maps of elemental distribution; D: EDX spectra corresponding to the four areas analyzed; the horizontal in axis of the spectrum is the X-ray energy and the vertical axis is the total number of X-rays counted. The peak at zero keV is created by the instrument electronics as a reference. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

traces allow excluding their post-depositional origin. Furthermore, based on the use-wear traces, we suggest the use of the pebbles as bone retouchers. Besides, the occurrence of use modifications on their apical areas (Figs. 9 and 10) and edges suggests green pebbles were turned several times during their use.

Moreover, the localization of macro-traces on green pebbles is similar to what recorded on other stone retouchers from the same site, although belonging to the Aurignacian, suggesting a potential

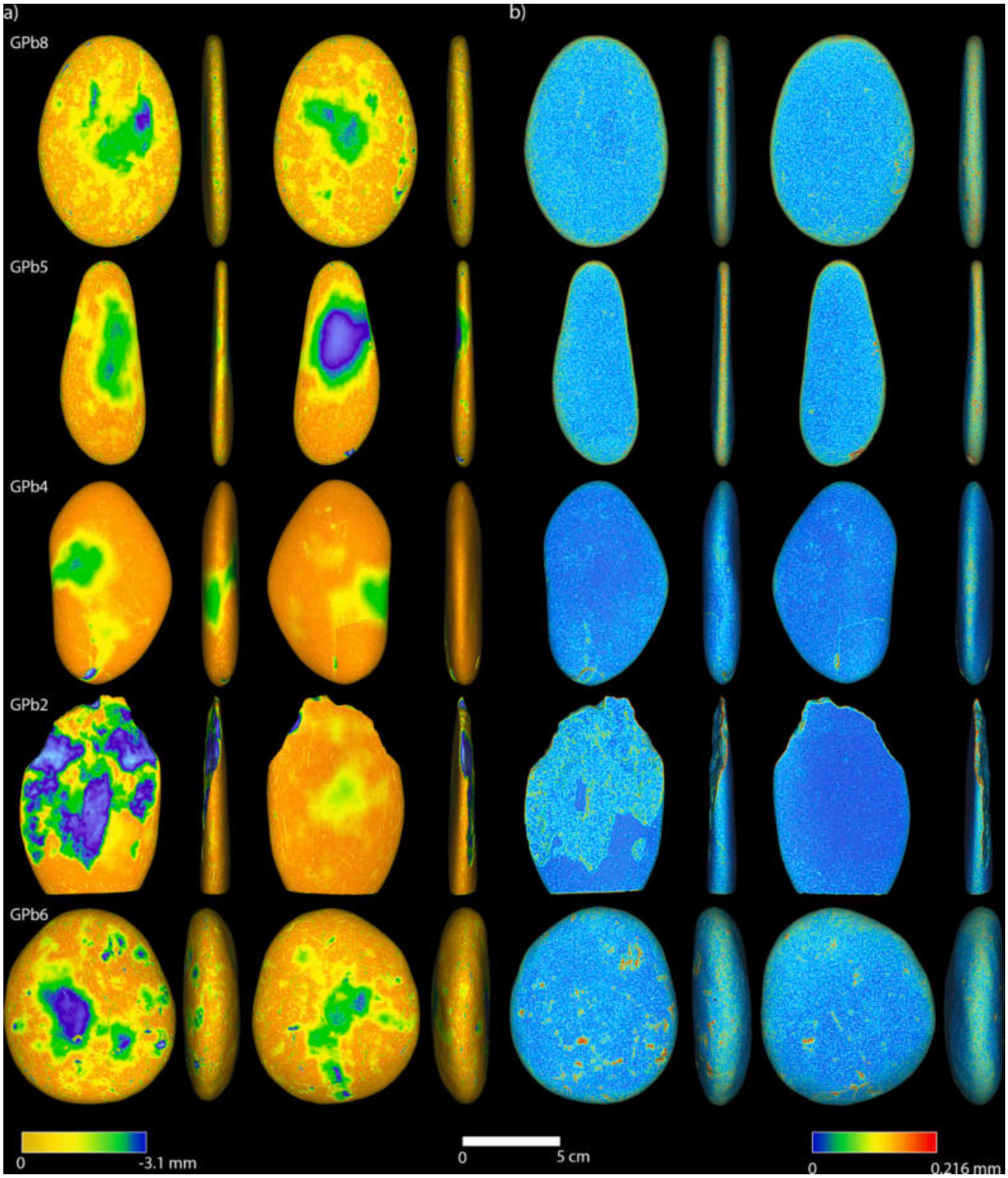

Fig. 12. a) Surface depressions depth and b) surface roughness measured across the green pebbles of Fumane cave. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

uniformity in the technological know-how from the late Mousterian to the Late Protoaurignacian at the cave (Caricola et al., 2018). Finally, we exclude the utilization of the green pebbles as anvils or bases, although a similar function is suggested for the limestone engraved pebbles found in the same A6 context (Peresani et al., 2014). No organic residues were detected on those engraved pebbles.

6.3. Bone technology from the A5-A6 Mousterian complex and comparisons

Retouching of bone has already been documented in the late Mousterian layer A5-A6 stratigraphic context at Fumane. A fresh radius flake of an ungulate was modified by direct percussion on both the surfaces, through a sequence of five detachments on the dorsal face producing a partial modification of the 60°-55° natural angle of the shaft. This artifact was interpreted as a side scraper, possibly used for woodworking (Romandini et al., 2014), albeit post-depositional edge rounding concealed the original use-wear traces on this tool. As comparable archaeological evidence for bone retouching is poorly documented across the whole Middle Paleolithic at Fumane, we cannot exclude that the use of bone tools might have been the result of sporadic Neanderthal technological attempts.

Bone knapping is sporadically documented during the Lower and Middle Paleolithic in Eurasia. Bifaces, choppers, trihedral picks, scrapers, denticulates, and smoothers made on complete or purposely fragmented anatomical elements of proboscideans and big-middle sized ungulates, demonstrate that hominins knapped and/or retouched bone, possibly to overcome limitations in the good quality stone availability in the surroundings of the site (Dobosi, 2001; Gaudzinski et al., 2005; see Rosell et al., 2011; Soressi et al., 2013; Romandini et al., 2014; Zutovski and Barkai, 2016; Villa et al., 2021; Pante et al., 2020 for references). It is also well-known that flake bones were used to retouch stone tools since the mid of the Middle Pleistocene (Blasco et al., 2013; Julien et al., 2015; papers in Hudson et al., 2018 for recent advancements).

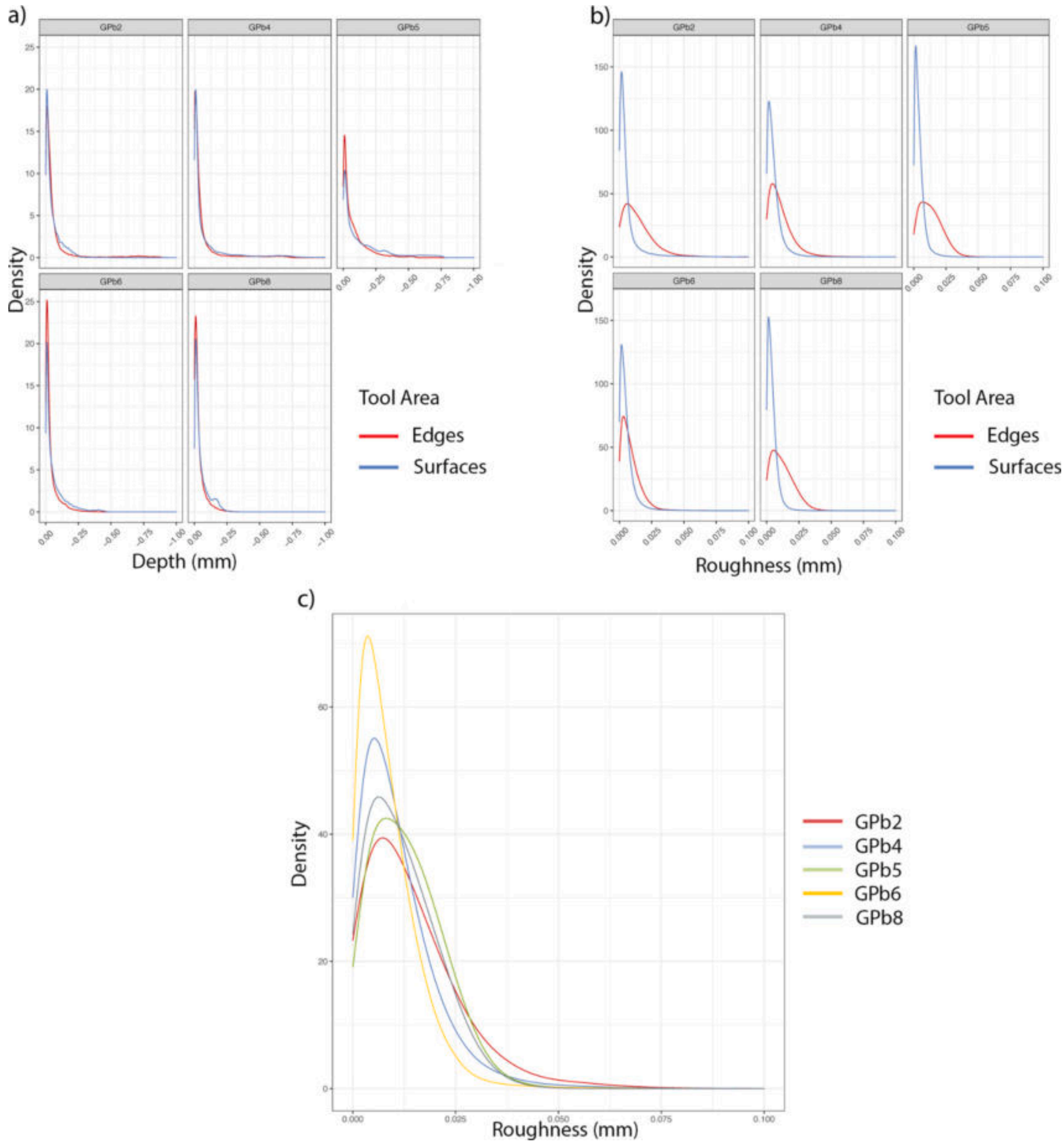

Fig. 13. Density plots comparing the a) surface depression depths and b) surface roughness measured across the surfaces and the edge of the Fumane pebbles; c) density plot comparing the roughness of the edges of the pebbles.

Such sparse evidence can be reasonably related to the taphonomy of bone assemblages, a perishable component of the archaeological record sensitive to post-depositional alterations. Besides, our knowledge about the use of lithic hammers for bone breakage and marrow recovery, splitting, and crushing of spongy tissues is still affected by the limited number of studies performed so far (see Thiébaut et al., 2010 for a review) and the difficulties of integrating multiple set of functional data (Assaf et al. 2020). Yet, functional evidence supports the use of formal Mousterian lithic tools to modify bone (Claud et al., 2012). To use them in knapping tasks, smoothed and rounded cobbles were selected on the basis of the fundamental requirements related to the rock shape, mechanical properties, hardness, and the distribution of provisional sources across the landscape (Inizan et al., 2001). Spheroids and anvils of different lithologies have been known since the earliest phase of the Lower Paleolithic (Barkai and Gopher, 2016; Raynal and Sbihi-Alaoui, 2016; Arroyo and de la Torre, 2017; Assaf et al., 2019; Titton et al. 2018, 2020) and used in stone knapping as well as for processing different materials (De Beaune, 1993). Lower and Middle Paleolithic non-flaked stone technology has undergone morpho-functional analyses, supported by experimental activities (Dibble and Pelcin, 1995; Mourre, 2004; Pelegrin and Texier, 2004; Roussel et al., 2009; Thiébaut et al., 2010; Cristiani and Zupancich, 2021).

Nonetheless, information available on the ability to collect raw materials, transport strategies, complimentary use of tools to produce and maintain tool kits made of organic or inorganic materials is still scanty for Middle Paleolithic hunter-gatherers (Stout and Chaminade, 2012). Pebbles exploited as retouchers are nevertheless widely documented in Europe (A. de Beaune, 1989; Bourguignon, 2001; De Lumley et al., 2004; Raynal et al., 2005; Nicoud, É., 2009-2008). These lithic materials were carefully selected based on their morphological and physical properties like shape, size, weight, and elasticity/density to meet specific requirements. In addition to pebbles, cortical flakes, flakes' ventral surface bulbs, cores, and handaxes were occasionally used for retouching (Thiébaut et al., 2010; Sorensen et al., 2018; Centi et al., 2019).

Table 3
Summary statistics of the values of surface depression depth and roughess measured on the entire tool, its surfaces and edge.

	Tool ID	Area	Min.	Max.	Mean	Median	StDev.
Surface depressions depth (mm)	*GPb2*	edge	−1.301	0	−0.081	−0.030	0.164
		surfaces	−1.020	0	−0.057	−0.030	0.078
		entire tool	−1.740	0	−0.243	−0.075	0.328
	GPb4	edge	−3.158	0	−0.101	−0.026	0.278
		surfaces	−2.901	0	−0.109	−0.028	0.198
		entire tool	−3.158	0	−0.110	−0.028	0.214
	GPb5	edge	−1.165	0	−0.084	−0.044	0.113
		surfaces	−0.773	0	−0.141	−0.068	0.173
		entire tool	−1.166	0	−0.126	−0.057	0.164
	GPb6	edge	−0.790	0	−0.043	−0.021	0.060
		surfaces	−0.790	0	−0.067	−0.033	0.084
		entire tool	−0.790	0	−0.061	−0.029	0.080
	GPb8	edge	−0.426	0	−0.037	−0.022	0.044
		surfaces	−0.436	0	−0.051	−0.030	0.054
		entire tool	−0.641	0	−0.047	−0.027	0.052
Surface roughness (mm)	GPb2	edge	0	0.133	0.014	0.011	0.012
		surfaces	0	0.216	0.006	0.003	0.011
		entire tool	0	0.216	0.011	0.006	0.014
	GPb4	edge	0	0.184	0.011	0.009	0.010
		surfaces	0	0.136	0.006	0.004	0.006
		entire tool	0	0.184	0.006	0.004	0.007
	GPb5	edge	0	0.070	0.013	0.012	0.009
		surfaces	0	0.066	0.004	0.003	0.004
		entire tool	0	0.087	0.006	0.004	0.007
	GPb6	edge	0	0.102	0.009	0.007	0.008
		surfaces	0	0.091	0.005	0.004	0.006
		entire tool	0	0.102	0.006	0.004	0.007
	GPb8	edge	0	0.065	0.012	0.011	0.009
		surfaces	0	0.066	0.004	0.003	0.004
		entire tool	0	0.085	0.006	0.004	0.006

6.4. *Peculiar, colorful green stones among Neanderthals and modern humans*

Since two million years ago, hominins collected different categories of unusual, sometimes colorful mineral materials from various sources distributed at a variable distance from the archeological context where these items were discovered. Many authors had claimed that the attention for “exotic” objects contributed to creating conscious cultural taxonomies and detecting iconicity in the natural world, mainly when these finds were characterized by aesthetic uniqueness. The collection of unique and exotic materials, clearly distinguishable from more utilitarian ones, might have also contributed to the construction of self-awareness (e.g., Leroi-Gourhan, 1967; Oakley, 1981; d’Errico et al., 1989; Enquist and Arak, 1994; Bednarik, 2011; Assaf, 2018). Symbolic behavior has also been suggested to explain Pre-Neanderthal and Neanderthal use of unusually colored or shaped raw materials (Moncel et al., 2012; Radovčić et al., 2016; Cârciumaru and Niţu, 2018). Findings showing noticeable visual characteristics were discovered across Europe. Amongst them are the color-banded biface from Dordogne (White, 2003), the biface and the scraper made on hyaline quartz crystals found in Abri des Merveilles (Delage, 1937), the scrapers and other flint artifacts from Acheulian sites in Britain with fossils embedded and preserved during the shaping process (Oakley 1981; Mithen, 1996; Soressi and d’Errico, 2007). Aesthetic visual features might have also influenced the collection of pebbles, as the small, colorful, flint pebbles discovered at the late Lower Paleolithic site of Qesem Cave in Israel seem to suggest (Assaf, 2018). In these latter cases, the absence of use traces further supports the hypothesis of a non-utilitarian purpose of these unmodified materials collected within the cave surroundings (Assaf, 2018).

Besides quality, size, availability in the home range, other factors can influence the selection of a specific raw material (Braun et al., 2009; Browne and Wilson 2011). For instance, observed in Lower Paleolithic bifaces, symmetry may have fulfilled local aesthetic conventions (Enquist and Arak, 1994; Mithen, 2003). Also, colors played an essential role in human behavior in evolutionary and physiological terms (Ball 1965; Edwards, 1978; Flannery 1993; d’Errico and Stringer, 2011; Roebroeks et al. 2012). Colors convey information about social and individual identity. The archaeological record demonstrates that the red color represented by ocher played a key factor in the origin of symbolism among *Homo sapiens* in Africa (Knight et al., 1995) and the Levant (Hovers et al. 2003), and possibly earlier in South Africa (Watts et al., 2016).

From the Middle to Upper Paleolithic, portable art and ornamental objects made of different types of stones and organic materials document an increase in color variability, which increases with the onset of the Neolithic and the spread of agriculture (Bar-Yosef Mayer and Porat, 2008). Since the Neolithic, the selection of green-colored material has been well documented worldwide (D’Amico et al., 2003; Bar-Yosef Mayer and Porat, 2008) and possibly associated with its positive effect on fertility (Budge, 1978; Darras, 2014). Ethnographically, green beads prevent misfortune, enhance virility (Wickler and Seibt, 1995), women’s health, and fertility (Mershen, 1989).

Nevertheless, green-colored rocks (e.g., steatite) or schistose rocks (e.g., serpentinites, serpentines, and chloritoschists) are known in the Upper Paleolithic record in Eurasia especially in the Aurignacian, Gravettian, post-Gravettian, and other relative cultural complexes. Flat, unmodified green pebbles were part of funerary offerings positioned on the sides and in the deceased’s mouth of the Early Gravettian twin burial from the Grotte des Enfants in the Balzi Rossi in Italy (Verneau, 1906). Chloritoschists, steatite, and other green-colored pebbles and scraped rocks were found in the Gravettian deposits of Laugerie Haute in France (Chiotti et al., 2018). Green-colored metamorphic stones were also sculpted into human figures, beads, or pendants. The most iconic statuette is the Aurignacian anthropomorphic sculpture carved on a small plaquette of Amphibolite schists discovered at Galgenberg near Stratzing/Krems-Rehberg in Lower Austria (Neugebauer-Maresch, 1989). Gravettian venuses made of serpentine and dark green steatite were discovered at Poiana Cireşului in Romania (Cârciumaru and Niţu, 2018) and at the Grimaldi (Balzi Rossi) caves in Italy, where statuettes came to light during excavations in the XIX and XX centuries (White and Bisson, 1999; Fritz et al., 2017). Another figurine is a slender female

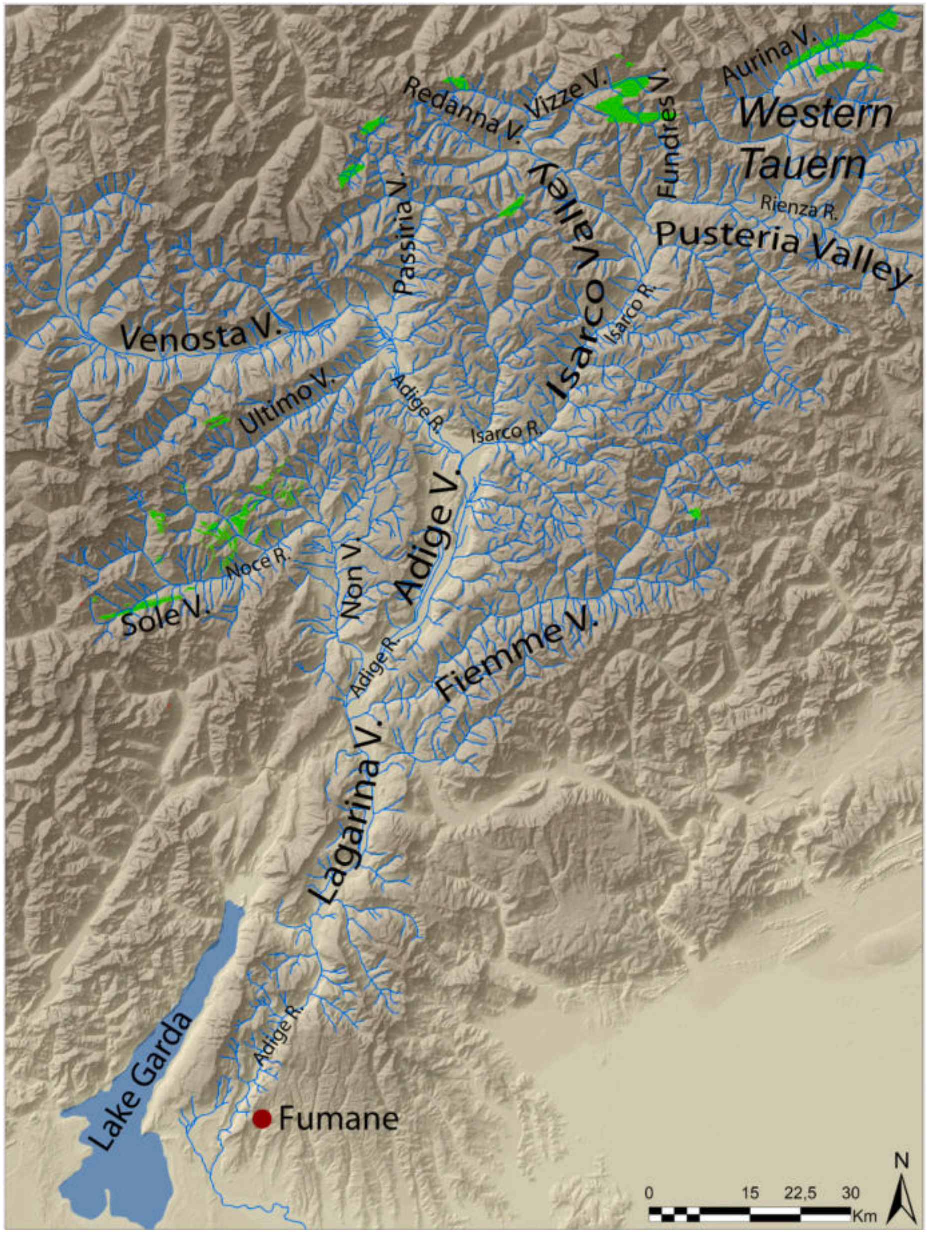

Fig. 14. Digital Elevation Model of the Eastern Italian Alps with present-day primary exposures of Serpentinites (in green) and the idrographic network. The position of Fumane cave is indicated. Notes: DEM (base topography – Copernicus Land Monitoring Service (CLMS), 2019 and General Bathymetric Chart of the Oceans (GEBCO), 2019). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

statuette made of serpentinite, discovered in Siberia at the open-air site of Buret. Dated to 21.190 ± 100 ^{14}C years BP, this artifact was recovered with five buttons carved in their center (Abramova, 1995).

Several lumps also testify to the exploitation of serpentine found dispersed in the archaeological deposits. Beads and personal ornaments made of green stones are also occasionally documented in Eurasia. Pendants, cylindrical washers, and buttons are part of the Gravettian and Magdalenian beads from Afontova Gora II, Korolevo I, and Novosselovo in Romania (Cârciumaru and Niţu, 2018) and Les Espélugues Cave in France (Piette, 1907), respectively. Nephrite, a green-colored rock with a different mineralogical nature than serpentinite, was perforated and carved into a pendant at the Aurignacian site of Krems-Hundessteig, in Lower Austria (Neugebauer-Maresch, 1999), and into a round artifact at Buret (Abramova, 1995). Two serpentine beads come from Kapova, a cave in the Southern Urals, and the rarity of this type of finds in the Paleolithic of Russia has been emphasized (Shchelinsky, 1989). Green schistose material was used with higher frequency by modern humans or, even, by the last Denisovans in Central northern Eurasia. The unique fragmentary chloritolite bracelet was found at Denisova cave in the Altai region (Derevianko et al., 2008) in an Initial Upper Paleolithic context not older than 43–48 ka cal BP (Douka et al., 2019). Furthermore, innovative behaviors and symbolic artifacts are documented in Denisova and at Ust-Karakol and Anui-2 sites in the same area by the production and use of local and imported serpentine-antigorite, serpentine, agalmatolite, and chloritolite to obtain perforated pendants, flat and volumetric beads (Fedorchenko et al., 2020; Shunkov et al., 2020).

Based on the evidence mentioned above, it appears that AMHs perceived the utility of green stones for making beads and portable art across the Upper Paleolithic, although with discontinuity in Eurasia. In recent hunter-gatherer and traditional agricultural societies, stones were actively used to enhance self-aesthetic perception, personal and social identity, courting, and social communication (Conneller, 2012; Assaf, 2018). Stones are also conceived as living entities with their ontology related to each phase of their life history (i.e., the different steps of the process of cobble exploitation, Arthur, 2018), and also play a role in the social and ritually mediated life (Naveh and Bird-David, 2014). Also, ethnographic evidence points at a legacy between sensory aesthetic aspects and technology or other aspects (Graves-Brown, 1995) and the raising of chert color preferences between communities of stone knappers (Arthur, 2018).

Concerning Neanderthals, our perception of their aesthetic sensibility is archaeologically limited to the attractiveness conveyed by distinctive organic and inorganic materials.

Gray-blackish organic materials were part of the Neanderthal symbolic world as the taphonomic evidence from Fumane and caves in Gibraltar: large raptors and other birds were exploited to recover wings or pick up remix feathers (Romandini et al., 2016; Finlayson et al., 2019). The collection of dark-colored bird elements such as the eagle claws (Frayer et al., 2020) also suggests a common symbolic code shared between Neanderthals at Fumane and Rio Secco caves in Italy (Romandini et al., 2014).

As for green colors, attractiveness might be claimed when certain materials were picked up for technological tasks like bone smashing, flint knapping, or other craftwork already in the Lower Paleolithic (Assaf, 2018). So far, there is no evidence for the interest in serpentinite green and flat pebbles, like those from Fumane throughout the whole late Middle Paleolithic in Eurasia. Yet, the use of green chert or magmatic knappable stones is recorded at Fumane and other sites of North-East Italy (Peresani, 2011a,b, 2012; Delpiano and Peresani, 2017). Thus, the possibility that a combination of aesthetic and technological factors might have encouraged the collection of green pebbles cannot be ruled out. Surprisingly, despite the large availability of green serpentine pebbles of variable sizes in the Adige coarse alluvial beds, these materials were collected only by late Neanderthals, possibly before but not later than 44–43 ka cal BP. This behavior is noteworthy considering that the petrographic composition of the Adige River basin in the mountain area remains unchanged from late MIS 5 to the first part of MIS 3. This is the time range of the repeated, although specific, frequentations of the cave and its hunting environments (Fiore et al., 2004; Peresani, 2012). Based on the state of surface preservation, we exclude that Neanderthals picked up pebbles from Middle Pleistocene glacial or fluvioglacial deposits. The latter ones are generally altered by pedogenesis developed during the last interglacials. Accordingly, we suggest that Fumane Neanderthals selected flat green pebbles previously unknown or untargeted in this area in the Adige gravelly bed, following specific functional and aesthetic criteria. Their preference for green in place of different colors is highlighted by the presence of gneiss and hornfels flat pebbles in the Adige gravelly deposits. These lithologies display grey color or greyish with pink, brown, or other colored nuances and mechanical properties comparable to serpentinites. Also, mica schists have greyish color and hardness similar to serpentinites. Still, due to their strongly developed anisotropy and schistosity, pebbles quickly reduce in size after hydrological rolling and are not provisionable for being used as percussion tools. These pebbles in the Late Mousterian context at Fumane thus reflects a specific choice of those who picked them up and shared aesthetic conventions.

Pebbles with a similar morphology come from the excavations of approximately coeval contexts at Riparo Bombrini in Liguria, a region geologically suitable for collecting green serpentine pebbles (F. Negrino, pers. comm.). This recovery further highlights raw cobbles were chosen for their curved contours (Munar et al., 2005) and their color, texture, or brightness (Belfer-Cohen and Goren-Inbar, 1994). Color and tactile qualities of stony materials are thought to have always attracted humans and contributed to developing aesthetic sensibilities providing social benefits in the course of our evolution (Regan et al., 2001; Berleant, 2007; Melin et al., 2014). Despite this, recent past hunter-gatherer stone tool affordance – a term that refers to the properties like value, meaning, distinctive features, and classification of things (Gibson, 1966) might have been different from those of our ancestors.

So far, the analysis of the green pebbles from Fumane suggests that at this site, Neanderthals were aesthetically sensitive to the specific visual properties of these cobbles. Neanderthals settled at Fumane chronologically close to their demise elsewhere in Eurasia (Higham et al., 2014) when *Homo sapiens* arrived in Southern and Central-Eastern Europe. In this scenario, the possible occurrence of acculturation has repeatedly been invoked to explain changes in technology and social behavior among the latest native communities. As a result, there is an interminable debate around the impact of the newcomers on the local bio-cultural substratum (d'Errico and Banks, 2013; Villa et al., 2021; Gravina et al., 2018; Majkić et al., 2018; Hublin et al., 2020; Nielsen et al., 2020, among others). An example of such acculturation in south-eastern and central Europe might be the Châtelperronian (Balzeau et al., 2020), a cultural complex produced by contacts between Neanderthals and the earliest *Homo sapiens* communities of the initial Upper Paleolithic, ca. 48–47 ka BP (Müller et al., 2011; Hublin et al., 2020). Archaic natives should have consequently assimilated know-how in technology, social communication, and hunting behavior.

This scenario has not been documented in Mediterranean Europe so far despite the first *H. sapiens* introgression bearing the Uluzzian culture being recorded not earlier than 46–45 ka BP in the South of the Italian peninsula (Zanchetta et al., 2018). However, the green pebbles from Fumane lie outside of this picture as these materials were selected for purposes different than those recorded throughout the whole Upper Paleolithic. Similar items are not present in the Protoaurignacian sites on the present-day northern Mediterranean Coast and the Southern Alpine foreland. Hence, we believe their selection reflects a Neanderthal autochthonous behavior.

7. Conclusion

Several studies suggest an ancient origin of human aesthetic perceptions and attraction to roundness, brightness, and colorful objects. Our tendency to symmetry, roundness, and interest in specific colors and/or bright shiny objects have also been underlined and traced back to the earliest stages of humankind's history. Colors constantly surrounded humans, and we might expect colors to be charged with different meanings and importance through time. Although sparse, Paleolithic record is characterized by colored stones, ornamental beads, bird feathers, horns, and other material of biological origin, suggesting an eventful preference for pigment use. In this scenario, colored and polished green stones were selected from peculiar locations in the landscape according to the specific Neanderthals' relationship with their surroundings.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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analysis; all authors wrote and edited the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2021.101368.

References

Abramova, Z.A., 1995. L'art Paléolithique d'Europe orientale et de Sibérie. Collection L'Homme des origins, Editions Jérôme Millon, Grenoble.

Accorsi, C.A., Aitken, M.J., Cremaschi, M., Ferraris, M., McElroy, C., Questiaux, D., Van Vliet Lanoe, B., 1990. The loess deposits of the Rivoli Moraine system. In: Cremaschi, M. (Ed.), The loess in Northern and Central Italy: a loess basin between the Alps and the Mediterranean region. Quaderni di Geodinamica Alpina e Quaternaria I, Gutenberg, Milano, pp. 21–39.

Adams, J.L., 2010. Understanding grinding technology through experimentation. In: Ferguson, J.R. (Ed.), Designing Experimental Research in Archaeology; Examining Technology through Production and Use. University Press of Colorado, Boulder, pp. 129–151.

A. de Beaune, S., 1989. Essai d'une classification typologique des galets et plaquettes utilisés au Paléolithique. Gallia Préhistoire 31 (1), 27–64.

Arroyo, A., de la Torre, I., 2018. Pounding tools in HWK EE and EF-HR (Olduvai Gorge, Tanzania): Percussive activities in the Oldowan-Acheulean transition. J. Hum. Evol. 120, 402–421. https://doi.org/10.1016/j.jhevol.2017.10.005.

Assaf, E., 2018. Paleolithic aesthetics: Collecting colorful flint pebbles at Middle Pleistocene Qesem Cave, Israel. Journal of Lithic Studies 5 (1). https://doi.org/10.2218/jls.2616.

Auzende, A.L., Daniel, I., Reynard, B., Lemaire, C., Guyot, F., 2004. High-pressure behavior of serpentine minerals: a Raman spectroscopic study. Phys. Chem. Min. 31, 269–277.

Ball, V.K., 1965. The aesthetics of color: A review of fifty years of experimentation. Journal of Aesthetics and Art Criticism 23, 441-452.

Balzeau, A., Turq, A., Talamo, S., Daujeard, C., Guérin, G., Welker, F., Crevecoeur, I., Fewlass, H., Hublin, J.J., Lahaye, C., Maureille, B., Meyer, M., Schwab, C., Gómez-Olivencia, A., 2020. Pluridisciplinary evidence for burial for the La Ferrassie 8 Neandertal child. Sci. Rep. 10, 21230.

Bar-Yosef Mayer, D.E., Porat, N., 2008. Green stone beads at the dawn of agriculture. Proc. Natl. Acad. Sci. USA 105 (25), 8548–8551. https://doi.org/10.1073/pnas.0709931105.

Barkai, R., Gopher, A., 2016. On anachronism: The curious presence of Spheroids and Polyhedrons at Acheulo-Yabrudian Qesem Cave. Israel. Quat. Int. 398, 118–128. https://doi.org/10.1016/j.quaint.2015.08.005.

Baroni, C., Cremaschi, M., 1987. Geologia e pedostratigrafia della collina di Ciliverghe (Brescia); fasi glaciali, pedogenesi e sedimentazione loessica al margine alpino durante il Pleistocene. Natura Bresciana 23, 55–78.

Bartolomei, G., Broglio, A., Cassoli, P., Cremaschi, M., Giacobini, G., Malerba, G., Maspero, A., Peresani, M., Tagliacozzo, A., 1992. Risultati preliminari delle nuove ricerche al Riparo di Fumane. Annuario storico della Valpolicella 9, 7–8.

Barton, H., Torrence, R., Fullagar, R., 1998. Clues to Stone Tool Function Re-Examined: Comparing Starch Grain Frequencies on Used and Unused Obsidian Artefacts. J. Archaeol. Sci. 25 (12), 1231–1238. https://doi.org/10.1006/jasc.1998.0300.

Bednarik, R.G., 2011. The Human Condition. Developments in Primatology: Progress and Prospects. Springer, New York.

Belfer-Cohen, A., Goren-Inbar, N., 1994. Cognition and communication in the Levantine Lower Palaeolithic. W. Arch. 26 (2), 144–157.

Benazzi, S., Bailey, S.E., Peresani, M., Mannino, M., Romandini, M., Richards, M.P., Hublin, J.J., 2014. Middle Paleolithic and Uluzzian human remains from Fumane Cave. Italy. J. Hum. Evol. 70, 61–68. https://doi.org/10.1016/j.jhevol.2014.03.001.

Benito-Calvo, A., Crittenden, A.N., Livengood, S.V., Sánchez-Romero, L., Martínez-Fernández, A., de la Torre, I., Pante, M., 2018. 3D 360° surface morphometric analysis of pounding stone tools used by Hadza foragers of Tanzania: A new methodological approach for studying percussive stone artefacts. J. Archaeol. Sci. Reports 20, 611–621. https://doi.org/10.1016/j.jasrep.2018.06.003.

Berleant, R., 2007. Paleolithic Flints: Is an aesthetics of stone tools possible? Contemporary Aesthetics, 5: online. http://hdl.handle.net/2027/spo.7523862.0005.006.

Bertola, S., Broglio, A., Cristiani, E., de Stefani, M., Gurioli, F., Negrino, F., Romandini, M., Vanhaeren, M., 2013. La diffusione del primo Aurignaziano a sud dell'arco alpino. Preistoria Alpina 47, 123–152.

Bertola, S., Broglio, A., Gurioli, F., De Vecchi, G., Facciolo, A., Fiore, I., Tagliacozzo, A., Pallecchi, P., 2009. Le territoire des chasseurs aurignaciens dans les Prealpes de la Vénetie: l'exemple de la Grotte de Fumane. In: Djindjian, F., Kozlowski, J., Bicho, N. (Eds.), Le concept de territoire dans le Paléolithique supérieur européen. BAR Int. Series 1938, pp. 167-181.

Blasco, R., Rosell, J., Cuartero, F., Fernández Peris, J., Gopher, A., Barkai, R., Petraglia, M.D., 2013. Using Bones to Shape Stones: MIS 9 Bone Retouchers at Both Edges of the Mediterranean Sea. PLoS One 8 (10), e76780. https://doi.org/10.1371/journal.pone.007678010.1371/journal.pone.0076780.g00110.1371/journal.pone.0076780.g002.

Bosellini, A., Mutti, E., Ricci-Lucchi, F., 1989. Rocce e successioni sedimentarie. UTET, Torino.

Bourguignon, L., 2001. Apports de l'expérimentation et de l'analyse techno-morpho-fonctionnelle à la reconnaissance du processus d'aménagement de la retouche Quina. In: Bourguignon, L., Ortega, I., Frère-Sautot, M.C. (Eds.), Préhistoire et approche expérimentale. Éditions Mergoil, Montagnac, pp. 35–66.

Braun, D.R., Plummer, T., Ferraro, J.V., Ditchfield, P., Bishop, L.C., 2009. Raw material quality and Oldowan hominin tool stone preferences: Evidence from Kanjera South. Kenya. J. Archaeol. Sci. 36 (7), 1605–1614. https://doi.org/10.1016/j.jas.2009.03.025.

Browne, C.L., Wilson, L., 2011. Resource selection of lithic raw materials in the Middle Palaeolithic in southern France. J. Hum. Evol. 61 (5), 597–608. https://doi.org/10.1016/j.jhevol.2011.08.004.

Budge, E.A.W., 1978. Amulets and Superstitions. Dover, New York.

Cârciumaru, M., Nițu, C.E., 2018. Symbolic behaviour and art on the territory of Romania from the Middle Palaeolithic to the Mesolithic (55,000–7,500 B.P.). In: Museum of Human Evolution and Technology in the Palaeolithic, Editura Cetatea de Scaun, p. 423.

Caricola, I., Zupancich, A., Moscone, D., Mutri, G., Falcucci, A., Duches, R., Peresani, M., Cristiani, E., 2018. Exploring Early Upper Palaeolithic Knapping Techniques and Gestures. Use Wear and Spatial Analyses applied to the study of Macro-Lithic Tools. PLoS One 13 (12), e0207773. https://doi.org/10.1371/journal.pone.0207773.

Castiglioni, G.B., Ajassa, R., Baroni, C., Biancotti, A., Bondesan, A., Bondesan, M., Brancucci, G., Castaldini, D., Castellaccio, E., Cavallin, A., Cortemiglia, F., Cortemiglia, G.C., Cremaschi, M., Da Rold, O., Elmi, C., Favero, V., Ferri, R., Gandini, F., Gasperi, G., Giorgi, G., Marchetti, G., Marchetti, M., Marocco, R., Meneghel, M., Motta, M., Nesci, O., Orombelli, G., Paronuzzi, P., Pellegrini, G.B., Pellegrini, L., Rigoni, A., Sommaruga, M., Sorbini, L., Tellini, C., Turrini, M.C., Vaia, F., Vercesi, P.L., Zecchi, R., Zorzin, R., 1997. Carta Geomorfologica della Pianura Padana. 3 Fogli alla scala 1:250.000. S.EL.CA., Firenze.

Centi, L., Groman-Yaroslavski, I., Friedman, N., Oron, M., Prévost, M., Zaidner, Y., Peresani, M., 2019. The bulb retouchers in the Levant: New insights into Middle Palaeolithic retouching techniques and mobile tool-kit composition. PLoS One 14 (7), e0218859. https://doi.org/10.1371/journal.pone.021885910.1371/journal.pone.0218859.g00110.1371/journal.pone.0218859.g00210.1371/journal.pone.0218859.g00310.1371/journal.pone.0218859.g00410.1371/journal.pone.0218859.g00510.1371/journal.pone.0218859.g00610.1371/journal.pone.0218859.g00710.1371/journal.pone.0218859.g00810.1371/journal.pone.0218859.g00910.1371/journal.pone.0218859.g01010.1371/journal.pone.0218859.g01110.1371/journal.pone.0218859.g01210.1371/journal.pone.0218859.g01310.1371/journal.pone.0218859.g01410.1371/journal.pone.0218859.t00110.1371/journal.pone.0218859.t00210.1371/journal.pone.0218859.t00310.1371/journal.pone.0218859.t00410.1371/journal.pone.0218859.t00510.1371/journal.pone.0218859.t00610.1371/journal.pone.0218859.t00710.1371/journal.pone.0218859.s00110.1371/journal.pone.0218859.s00210.1371/journal.pone.0218859.s00310.1371/journal.pone.0218859.s00410.1371/journal.pone.0218859.s00510.1371/journal.pone.0218859.s00610.1371/journal.pone.0218859.s007.

Chiari, G., Compagnoni, R., Giustetto, R., Ricq de Bouard, M., 1996. Metodi archeometrici per lo studio dei manufatti in pietra levigata. In: Venturino Gambari, M. (Ed.), Le vie della pietra verde. L'industria litica levigata nella preistoria dell'Italia settentrionale, Omega Ed., pp. 5-52.

Chiotti, L., Morala, A., Nespoulet, R., 2018. Usages domestiques et symboliques du minéral au Gravettian final. Paléo, n.s., p. 212

Cignoni, P., Callieri, M., Corsini, M., Dellepiane, M., Ganovelli, F., Ranzuglia, G., 2008. Meshlab: an open-source mesh processing tool. In: Scarano, V., De Chiara, R., Erra, U. (Eds.), Eurographics Italian Chapter Conference. The Eurographics Association, Salerno, Italy, pp. 129–136. https://doi.org/10.2312/LocalChapterEvents/ItalChap/ItalianChapConf2008/129-136.

Claud, É., Soressi, M., Jaubert, J., Hublin, J.-J., 2012. Étude tracéologique de l'outillage moustérien de type Quina du bonebed de Chez-Pinaud à Jonzac (Charente-Maritime). Nouveaux éléments en faveur d'un site de boucherie et de traitement des peaux. Gallia Préhistoire 54 (1), 3–32.

Cnuts, D., Rots, V., 2018. Extracting Residues from Stone Tools for Optical Analysis: Towards an Experiment-Based Protocol. Archaeol. Anthropol. Sci. 10 (7), 1717–1736. https://doi.org/10.1007/s12520-017-0484-7.

Compagnoni, R., Giustetto, R., Ricq-de-Bouard, M., Venturino Gambari, M., 2006. Studio archeometrico di reperti neolitici e dell'età del rame in pietra verde levigata: discussione sulle tecniche analitiche ed interpretazione dei risultati. Atti XXXIX Riun. Sc. Ist. It. Preist. Prot., 655–682.

Cremaschi, M., 1987. Paleosols and Vetusols in the Central Po Plain (Northern Italy). Unicopli, Milano.

Cremaschi, M. (Ed.), 1990. The löess in northern Italy: a löess basin between the Alps and the Mediterranean region. Quaderni di Geodinamica Alpina e Quaternaria I, Gutenberg, Milano.

Cristiani, E., Zupancich, A., 2021. Sandstone Ground Stone Technology: A Multi-Level Use Wear and Residue Approach to Investigate the Function of Pounding and Grinding Tools. J. Archaeol. Method Theory. 28 (2), 704–735. https://doi.org/10.1007/s10816-020-09488-1.

D'Amico, C., Innocenti, F., Sassi, F., 2004. Magmatismo e metaformismo. UTET, Torino.

D'Amico, C., Starnini, E., Gasparotto, G., Ghedini, M., 2003. Eclogites, jades and other HP-metaophiolites employed for prehistoric polished stone implements in Italy and Europe. Per. Mineral. 73, 17–42.

d'Errico, F., Banks, W.E., 2013. Identifying Mechanisms behind Middle Paleolithic and Middle Stone Age Cultural Trajectories Current Anthropology Volume 54, Supplement 8, December 2013, S371-S387.

d'Errico, F., Gaillard, C., Misra, V.N., 1989. Collection of non-utilitarian objects by Homo erectus in India. In: Giacobini, G. (Ed.), Hominidae. Proceedings of the Second

International Congress of Human Palaeontology, Torino, Italy. Jaca Book, Milano, pp. 237-239.
d'Errico, F., Stringer, C.B., 2011. Evolution, revolution or saltation scenario for the emergence of modern cultures? Philos. Trans. R. Soc. B. Biol. Sci. 366 (1567), 1060–1069.
Piaz, G.V.D., Bistacchi, A., Massironi, M., 2003. Geological outline of the Alps. Episodes 26 (3), 175–180.
Darras, V., 2014. Ethnohistorical evidence for obsidian's ritual and symbolic uses among the PostClassic Tarascans. In: Levine, M.B., Carballo, D.M. (Eds.), Obsidian Reflections: Symbolic Dimensions of Obsidian in Mesoamerica. University Press of Colorado, Boulder, pp. 45–47.
De Beaune, S., 1993. Nonflint Stone Tools of the Early Upper Paleolithic. CRC Press Inc., Boca Raton, Florida.
De Lumley, H., Echassoux, A., Bailon, S., Cauche, D., De Marchi, M.P., Desclaux, E., El Guennouni, K., Khatib, S., Lacombat, F., Roger, T., Valensi, P., 2004. Le sol d'occupation acheuléen de l'unité archéostratigraphique UA 25 de La Grotte du Lazaret. Nice, Edisud, Aix-en-Provence.
De Vecchi, G., Mezzacasa, G., 1986. The Pennine basement and cover units in the Mesule group (south-western Tauern window). Mem. Sci. Geol. Padova 38, 365–392.
De Vecchi, G., Piccirillo, E.M., 1968. Le ofioliti mesozoiche associate ai calcescisti negli Alti Tauri sud-occidentali (Valli di Vizze e di Fundres - Alto Adige). Mem. Mus. Tridentino Sci. Nat. 24, 99–152.
De Zanche, V., Sorbini, L., Spagna, V., 1977. Geologia del territorio del comune di Verona. II serie, sez. B, Memorie Museo Civico di Storia Naturale di Verona, p. 1.
Delage, F., 1937. L'Abri des Merveilles à Castelmerle (Sergeac, Dordogne). Congrès Préhistorique de France - XIIe Session 9, 578–608.
Derevianko, A.P., Shunkov, M.V., Volkov, P.V., 2008. A palaeolithic bracelet from Denisova cave. Archaeol. Ethnol. Anthropol. Eurasia 34 (2), 13–25. https://doi.org/10.1016/j.aeae.2008.07.002.
Dibble, H.L., Pelcin, A., 1995. The effect of hammer mass and velocity on flake mass. J. Archaeol. Sci. Academic Press 22 (3), 429–439. https://doi.org/10.1006/jasc.1995.0042.
Dobosi, V.T., 2001. In: The World of Elephants, pp. 429–431.
Douka, K., Slon, V., Jacobs, Z., Ramsey, C.B., Shunkov, M.V., Derevianko, A.P., Mafessoni, F., Kozlikin, M.B., Li, B.o., Grün, R., Comeskey, D., Devièse, T., Brown, S., Viola, B., Kinsley, L., Buckley, M., Meyer, M., Roberts, R.G., Pääbo, S., Kelso, J., Higham, T., 2019. Age estimates for hominin fossils and the onset of the Upper Palaeolithic at Denisova Cave. Nature 565 (7741), 640–644. https://doi.org/10.1038/s41586-018-0870-z.
Dubreuil, L., Savage, D., Delgado-Raack, S., Plisson, H., Stephenson, B., de la Torre, I., 2015. Current analytical frameworks for studies of use–wear on ground stone tools. In: Marreiros, J.M., Gibaja Bao, J.F., Ferreira Bicho, N. (Eds.), Use-wear and residue analysis in archaeology. Springer International Publishing, pp. 105–158.
Edwards, S.W., 1978. Nonutilitarian activities in the Lower Paleolithic: A look at the two kinds of evidence. Current Anthropology 19 (1), 135–137.
Enquist, M., Arak, A., 1994. Symmetry, beauty and evolution. Nature 372 (6502), 169–172. https://doi.org/10.1038/372169a0.
Falcucci, A., Conard, N.J., Peresani, M., 2020. Breaking through the Aquitanian frame: a re-evaluation on the significance of regional variants during the Early Upper Paleolithic as seen from a key record in southern Europe. J. Anthr. Sci. 98, 1–42. https://doi.org/10.4436/jass98021.
Falcucci, A., Peresani, M., 2019. A pre-Heinrich Event 3 assemblage at Fumane Cave and its contribution for understanding the beginning of the Gravettian in Italy. Quartär 66, 135–154.
Fedorchenko, A.Y., Belousova, N.E., Kulik, N.A., Shunkov, M.V., 2020. Early Upper Paleolithic serpentine ornaments from Ust-Karakol, northwestern Altai. Archaeol. Ethnol. Anthropol. Eurasia 48 (1), 3–15. https://doi.org/10.17746/1563-0110.2020.48.1.003-015.
Ferraro, F., 2009. Age, sedimentation, and soil formation in the Val Sorda loess sequence, Northern Italy. Quat. Int. 204 (1-2), 54–64. https://doi.org/10.1016/j.quaint.2008.12.002.
Finlayson, S., Finlayson, G., Guzman, F.G., Finlayson, C., 2019. Neanderthals and the cult of the Sun Bird. Quat. Sc. Rev. 217, 217–224.
Fiore, I., Gala, M., Tagliacozzo, A., 2004. Ecology and subsistence strategies in the Eastern Italian Alps during the Middle Palaeolithic. Int. J. Osteoarchaeol. 14 (34), 273–286. https://doi.org/10.1002/(ISSN)1099-121210.1002/oa.v14:3/410.1002/oa.761.
Flannery, M.C., 1993. The biology of aesthetics. The American Biology Teacher 55 (8), 497–500. https://doi.org/10.2307/4449723.
Fontana, A., Mozzi, P., Marchetti, M., 2014. Alluvial fans and megafans along the southern side of the Alps. Sedim. Geol. 301, 150–171. https://doi.org/10.1016/j.sedgeo.2013.09.003.
Frayer, D., Radovčić, J., Radovčić, D., 2020. Krapina and the Case for Neandertal Symbolic Behavior by. Current Anthropology 61 (6), 725–726.
Fritz, C., Tosello, G., Magail, J., 2017. Nouvelle statuette féminine provenant des grottes de Grimaldi. Bulletin Musée Anthropologie Préhistorique Monaco 57, 99–103.
Gasperini, L., Marzocchi, A., Mazza, S., Miele, R., Meli, M., Najjar, H., Michetti, A.M., Polonia, A., 2020. Morphotectonics and late Quaternary seismic stratigraphy of Lake Garda (Northern Italy). Geomorphology 371, 107427. https://doi.org/10.1016/j.geomorph.2020.107427.
Gaudzinski, S., Turner, E., Anzidei, A.P., Àlvarez-Fernández, E., Arroyo-Cabrales, J., Cinq-Mars, J., Villa, P., 2005. The use of Proboscidean remains in every-day Palaeolithic life. Quaternary International 126, 179–194.
Gibson, J.J., 1966. The Senses Considered as Perceptual Systems. Houghton Mifflin, Boston.
Giustetto, R., Chiari, G., Compagnoni, R., 2008. An easy non-invasive X-ray diffraction method to determine the composition of Na-pyroxenes from high-density 'greenstone' implements. Acta Crystallogr. A 64 (1), 161–168.
Gravina, B., Bachellerie, F., Caux, S., Discamps, E., Faivre, J.P., Galland, A., Michel, A., Teyssandier, N., Bordes, J.G., 2018. No Reliable Evidence for a Neanderthal-Châtelperronian Association at La Roche-à-Pierrot. Saint-Césaire. Sci Rep 8, 15134.
Groppo, C., Rinaudo, C., Cairo, S., Gastaldi, D., Compagnoni, R., 2006. Micro-Raman spectroscopy for a quick and reliable identification of serpentine minerals from ultramafics. Eur. J. Mineral. 18 (3), 319–329. https://doi.org/10.1127/0935-1221/2006/0018-0319.
Hamon, C. 2006. Broyage et abrasion au néolithique ancien: caractérisation technique et fonctionnelle de l'outillage en grès du bassin parisien. BAR Int. Ser. 1551. https://doi.org/10.30861/9781841719801.
Hayes, E., Cnuts, D., Lepers, C., Rots, V., 2017. Learning from Blind Tests: Determining the Function of Experimental Grinding Stones through Use-Wear and Residue Analysis. J. Archaeol. Sci. Reports 11, 245–60. https://doi.org/10.1016%2Fj.jasrep.2016.12.001.
Higham, T., Brock, F., Peresani, M., Broglio, A., Wood, R., Douka, K., 2009. Problems with radiocarbon dating the Middle and Upper Palaeolithic transition in Italy. Quat. Sci. Rev. 28, 1257–1267. https://doi.org/10.1016/j.quascirev.2008.12.018.
Higham, T., Douka, K., Wood, R., Ramsey, C.B., Brock, F., Basell, L., Camps, M., Arrizabalaga, A., Baena, J., Barroso-Ruíz, C., Bergman, C., Boitard, C., Boscato, P., Caparrós, M., Conard, N.J., Draily, C., Froment, A., Galván, B., Gambassini, P., Garcia-Moreno, A., Grimaldi, S., Haesaerts, P., Holt, B., Iriarte-Chiapusso, M.-J., Jelinek, A., Jordá Pardo, J.F., Maíllo-Fernández, J.-M., Marom, A., Maroto, J., Menéndez, M., Metz, L., Morin, E., Moroni, A., Negrino, F., Panagopoulou, E., Peresani, M., Pirson, S., de la Rasilla, M., Riel-Salvatore, J., Ronchitelli, A., Santamaria, D., Semal, P., Slimak, L., Soler, J., Soler, N., Villaluenga, A., Pinhasi, R., Jacobi, R., 2014. The timing and spatiotemporal patterning of Neanderthal disappearance. Nature 512 (7514), 306–309. https://doi.org/10.1038/nature13621.
Hirauchi, K.-I., Yamamoto, Y., den Hartog, S.A.M., Niemeijer, A.R., 2020. The role of metasomatic alteration on frictional properties of subduction thrusts: An example from a serpentinite body in the Franciscan Complex. California. Earth and Planetary Science Letters 531, 115967. https://doi.org/10.1016/j.epsl.2019.115967.
Hublin, J.-J., Sirakov, N., Aldeias, V., Bailey, S., Bard, E., Delvigne, V., Endarova, E., Fagault, Y., Fewlass, H., Hajdinjak, M., Kromer, B., Krumov, I., Marreiros, J., Martisius, N.L., Paskulin, L., Sinet-Mathiot, V., Meyer, M., Pääbo, S., Popov, V., Rezek, Z., Sirakova, S., Skinner, M.M., Smith, G.M., Spasov, R., Talamo, S., Tuna, T., Wacker, L., Welker, F., Wilcke, A., Zahariev, N., McPherron, S.P., Tsanova, T., 2020. Initial Upper Palaeolithic Homo sapiens from Bacho Kiro Cave, Bulgaria. Nature 581 (7808), 299–302. https://doi.org/10.1038/s41586-020-2259-z.
Hutson, J.M., García-Moreno, A., Noack, E., Turner, E., Villaluenga, A., Gaudzinski-Windheuser, S. (Eds.), 2018. The Origins of Bone Tool Technologies. Römisch-Germanisches Zentralmuseum – Tagungen. Verlag des Römisch-Germanischen Zentralmuseums, Band 35.
Inizan, M.L., Pelegrin, J., 2002. Débitage par pression et expérimentation: une question de méthodologie. Paléorient 28 (2), 105–108. https://doi.org/10.3406/paleo.2002.4748.
Julien, M.A., Hardy, B., Stahlschmidt, M.C., Urban, B., Serangeli, J., Conard, N.J., 2015. Characterizing the Lower Paleolithic bone industry from Schöningen 12 II: A multi-proxy study. J. Hum. Evol. 89, 264–286. https://doi.org/10.1016/j.jhevol.2015.10.006.
Kealhofer, L., Torrence, R., Fullagar, R., 1999. Integrating Phytoliths within Use-Wear/Residue Studies of Stone Tools. J. Archaeol. Sci. 26 (5), 527–546. https://doi.org/10.1006/jasc.1998.0332.
Klein, C., 1999. Manual of Mineralogy. John Wiley & Sons Inc, New York.
Kloprogge, J.T., Frost, R.L., Rintoul, L., 1999. Single crystal Raman microscopic study of the asbestos mineral Chrysolite. Phys. Chem. Chem. Phys. 1, 2559–2564. https://doi.org/10.1039/A809238I.
Langejans, G.H.J., 2011. Discerning Use-Related Micro-Residues on Tools: Testing the Multi-Stranded Approach for Archaeological Studies. J. Archaeol. Sci. 38 (5), 985–1000. https://doi.org/10.1016/j.jas.2010.11.013.
Leroi-Gourhan, A., 1967. Treasures of Prehistoric Art. Harry N, Abrams, New York.
Lombard, M., Wadley, L., 2007. The Morphological Identification of Micro-Residues on Stone Tools Using Light Microscopy: Progress and Difficulties Based on Blind Tests. J. Archaeol. Sci. 34 (1), 155–165. https://doi.org/10.1016/j.jas.2006.04.008.
Lombard, M., 2005. Evidence of Hunting and Hafting during the Middle Stone Age at Sibidu Cave, KwaZulu-Natal, South Africa: A Multianalytical Approach. J. Hum. Evol. 48 (3), 279–300. https://doi.org/10.1016/j.jhevol.2004.11.006.
Majkić, A., d'Errico, F., Stepanchuk, V. 2018. Assessing the significance of Palaeolithic engraved cortexes. A case study from the Mousterian site of Kiik-Koba, Crimea. PLoS ONE 13(5): e0195049.
Martin, S., Tartarotti, P., Dal Piaz, G., 1994. The Mesozoic ophiolites of the Alps: a review. Bollettino Geofisica Teorica ed Applicata 36, 175–219.
Melin, A.D., Hiramatsu, C., Parr, N.A., Matsushita, Y., Kawamura, S., Fedigan, L.M., 2014. The behavioral ecology of color vision: Considering fruit conspicuity, detection distance and dietary importance. Int. J. Primat. 35 (1), 258–287. https://doi.org/10.1007/s10764-013-9730-8.
Mershen, B., 1989. Amulets and jewelry from Jordan: A study on the function and meaning of recent bead necklaces. Tribus 38, 43–58.
Mithen, S., 1996. On early Palaeolithic "Concept-mediated-marks", mental modularity, and the origins of Art. Curr. Anthropol. 37 (4), 666–670. https://doi.org/10.1086/204541.
Mithen, S., 2003. Handaxes: The first aesthetic artefacts. In: Voland, E., Grammer, K. (Eds.), Evolutionary Aesthetics. Springer-Verlag, Berlin, pp. 261–275.

Moncel, M.H., Chiotti, L., Gaillard, C., Onoratini, G., Pleurdeau, D., 2012. Non-utilitarian lithic objects from the European Paleolithic. Archaeol. Ethnol. Anthropol. Eurasia 40 (1), 24–40. https://doi.org/10.1016/j.aeae.2012.05.004.
Monegato, G., Pini, R., Ravazzi, C., Reimer, P.J., Wick, L., 2011. Correlating Alpine glaciation with Adriatic Sea-level changes through lake and alluvial stratigraphy. J. Quat. Sci. 26 (8), 791–804. https://doi.org/10.1002/jqs.1502.
Monegato, G., Ravazzi, C., 2018. The Late Pleistocene multifold glaciation in the Alps: updates and open questions. Al. Med. Quat. 31, 225–229.
Monegato, G., Scardia, G., Hajdas, I., Rizzini, F., Piccin, A., 2017. The Alpine LGM in the boreal icesheets game. Sci. Rep. 7, 2078. https://doi.org/10.1038/s41598-017-02148-7.
Monnier, G., Frahm, E., Luo, B., Missal, K., 2018. Developing FTIR microspectroscopy for the analysis of animal-tissue residues on stone tools. J. Arch. Met. Th. 25 (1), 1–44. https://doi.org/10.1007/s10816-017-9325-3.
Monnier, G.F., Ladwig, J.L., Porter, S.T., 2012. Swept under the Rug: The Problem of Unacknowledged Ambiguity in Lithic Residue Identification. J. Archaeol. Sci. 39 (10), 3284–3300. https://doi.org/10.1016/j.jas.2012.05.010.
Mourre, V., 2004. Le débitage sur enclume au Paléolithique moyen dans le Sud-Ouest de la France. In: The Middle Palaeolithic, General Sessions and Posters. Acts of the XIVth UISPP Congress, BAR Int. Ser. 1239, pp. 29–38.
Müller, U.C., Pross, J., Tzedakis, P.C., Gamble, C., Kotthoff, U., Schmiedl, G., Wulf, S., Christanis, K., 2011. The role of climate in the spread of modern humans into Europe. Quatern. Sci. Rev. 30 (3-4), 273–279.
Munar, E., Gómez-Puerto, G., Call, J., Nadal, M., Bard, K.A., 2015. Common Visual Preference for Curved Contours in Humans and Great Apes. PloS one 10 (11), e0141106. https://doi.org/10.1371/journal.pone.0141106.
Munsell Soil Color Charts, 2009. Munsell Color.
Neugebauer-Maresch, C., 1989. Zum neufund einer weiblichen statuette bei den rettungsgrabungen an der Aurignacien-station Stratzing/Krems-Rehberg, Niederösterreich. Germania 67, 551–559.
Neugebauer-Maresch, C., 1999. Le Paléolithique en Autriche. L'Homme des Origines, Millon ed., 202 pp.
Nicoud, É., 2009-2010. Les chaînes opératoires sur galets en roches volcaniques et quartz dans l'industrie lithique du gisement Moustérien de champ grand (Saint-Maurice-sur-Loire, Loire). PALEO, Numéro spécial, 107-122. https://doi.org/10.4000/paleo.1937.
Nielsen, M., Langley, M.C., Shipton, C., Kapitány, R., 2020. Homo neanderthalensis and the evolutionary origins of ritual in Homo sapiens. Phil. Trans. R. Soc. B 375 (1805), 20190424. https://doi.org/10.1098/rstb.2019.0424.
Oakley, K.P., 1981. Emergence of Higher Thought 3.0-0.2 Ma B.P. Phil. Trans. R. Soc. Lond., B. Biol. Sci. 292, 205–211. https://doi.org/10.1098/rstb.1981.0029.
Pante, M., Torre, I.de.la., d'Errico, F., Njau, J., Blumenschine, R., 2020. Bone tools from Beds II–IV, Olduvai Gorge, Tanzania, and implications for the origins and evolution of bone technology. J. Hum. Evol. 148, 102885. https://doi.org/10.1016/j.jhevol.2020.102885.
Pelegrin, J., Texier, P.J., 2004. Les techniques de taille de la pierre. Les dossiers d'archeologie 290, 26–33.
Peresani, M., 2012. Fifty thousand years of flint knapping and tool shaping across the Mousterian and Uluzzian sequence of Fumane cave. Quat. Int. 247, 125–150. https://doi.org/10.1016/j.quaint.2011.02.006.
Peresani, Marco, Cremaschi, Mauro, Ferraro, Francesca, Falguères, Christophe, Bahain Jacques, Jean, Gruppioni, Giulia, Sibilia, Emanuela, Quarta, Gianluca, Calcagnile, Lucio, Dolo Michel, Jean, 2008. Age of the final Middle Palaeolithic and Uluzzian levels at Fumane Cave, Northern Italy, using ^{14}C, ESR, ^{234}U/^{230Th} and thermoluminescence methods. Journal of Archaeological Science 35, 2986–2996. https://doi.org/10.1016/j.jas.2008.06.013.
Peresani, M., Cristiani, E., Romandini, M., 2016. The Uluzzian technology of Grotta di Fumane and its implication for reconstructing cultural dynamics in the Middle – Upper Palaeolithic transition of Western Eurasia. J. Hum. Evol. 91, 36–56. https://doi.org/10.1016/j.jhevol.2015.10.012.
Peresani, M., Chravzez, J., Danti, A., De March, M., Duches, R., Gurioli, F., Muratori, S., Romandini, M., Tagliacozzo, A., Trombino, L., 2011a. Fire-places, frequentations and the environmental setting of the final Mousterian at Grotta di Fumane: a report from the 2006–2008 research. Quartär 58, 131–151. https://doi.org/10.7485/QU58_07.
Peresani, M., Fiore, I., Gala, M., Romandini, M., Tagliacozzo, A., 2011b. Late Neandertals and the intentional removal of feathers as evidenced from bird bone taphonomy at Fumane cave 44ky BP. Italy. Proc. Natl. Acad. Sci. USA 108 (10), 3888–3893. https://doi.org/10.1073/pnas.1016212108.
Peresani, M., Dallatorre, S., Astuti, P., Dal Colle, M., Ziggiotti, S., Peretto, C., 2014. Symbolic or utilitarian? Juggling the interpretation of Neanderthal behaviour from symbolic to utilitarian. New inferences from the study of engraved stone surfaces. J. Anthr. Sc. 92, 233–255.
Pettijohn, F.L., 1975. Sedimentary rocks. Harper & Row, New York.
Piette, E., 1907. L'art pendant l'Age du Renne. Masson et Cie, Paris.
Porter, S.T., Huber, N., Hoyer, C., Floss, H., 2016. Portable and low-cost solutions to the imaging of Paleolithic art objects: A comparison of photogrammetry and reflectance transformation imaging. J. Archaeol. Sci. Reports 10, 859–863. https://doi.org/10.1016/j.jasrep.2016.07.013.
Radovčić, D., Japundžić, D., Oros Sršen, A., Radovčić, J., Frayer, D.W., 2016. An interesting rock from Krapina. Comptes Rendu Palevol 15 (8), 988–993. https://doi.org/10.1016/j.crpv.2016.04.013.
Raynal, J.P., Le Corre-Le Beux, M., Santagata, C., Fernandes, P., Guadelli, J.L., Fiore, I., Tagliacozzo, A., Lemorini, C., Rhodes, E.J., Bertran, P., Kieffer, G., Vivent, D., 2005. Paléolithique moyen dans le Sud du Massif central: les données du Velay (Haute-Loire, France). In: Molines, N., Moncel, M.H., Monnier, J.L. (Eds.). Les premiers peuplements en Europe. BAR Int. Ser. 1364, pp. 173-201.
Regan, B.C., Julliot, C., Simmen, B., Vienot, F., Charles-Dominique, P., Mollon, J.D., 2001. Fruits, foliage and the evolution of primate colour vision. Phil. Trans. Royal Soc. London B: Biol. Sci. 356 (1407), 229–283. https://doi.org/10.1098/rstb.2000.0773.
Rinaudo, C., Belluso, E., Gastaldi, D., 2004. Assessment of the use of Raman spectroscopy for the determination of amphibole asbestos. Mineral. Mag. 68 (3), 455–465. https://doi.org/10.1180/0026461046830197.
Rinaudo, C., Gastaldi, D., Belluso, E., 2003. Characterization of Chrysolite, antigorite and lizardite by FT-Raman spectroscopy. Can. Mineral. 41, 883–890. https://doi.org/10.2113/gscanmin.41.4.883.
Roebroeks, W., Sier, M.J., Nielsen, T.K., De Loecker, D., Pares, J.M., Arps, C.E.S., Mucher, H.J., 2012. Use of red ochre by early Neandertals. Proc. Natl. Acad. Sci. USA 109 (6), 1889–1894. https://doi.org/10.1073/pnas.1112261109.
Romandini, M., Peresani, M., Laroulandie, Véronique, Metz, L., Pastoors, A., Vaquero, M., Slimak, L., Petraglia, M.D., 2014. Convergent Evidence of Eagle Talons Used by Late Neanderthals in Europe: a Further Assessment on Symbolism. PLoS ONE 9 (7), e101278.
Romandini, M., Fiore, I., Gala, M., Cestari, M., Tagliacozzo, A., Guida, G., Peresani, M., 2016. Neanderthal scraping and manual handling of vulture wing bones: evidence from Fumane cave. Experimental activities and comparison. Quat. Int. 421, 154–172.
Rosell, J., Blasco, R., Campeny, G., Díez, J.C., Alcalde, R.A., Menéndez, L., Arsuaga, J.L., Bermúdez de Castro, José.M., Carbonell, E., 2011. Bone as a technological raw material at the Gran Dolina site (Sierra de Atapuerca, Burgos, Spain). J. Hum. Evol. 61 (1), 125–131. https://doi.org/10.1016/j.jhevol.2011.02.001.
Rots, V., Hardy, B.L., Serangeli, J., Conard, N.J., 2015. Residue and Microwear Analyses of the Stone Artifacts from Schöningen. J. Hum. Evol. 89, 298–308. https://doi.org/10.1016/j.jhevol.2015.07.005.
Roussel, M., Bourguignon, L., Soressi, M., 2009. Identification par l'expérimentation de la percussion au percuteur de calcaire au Paléolithique moyen: le cas du façonnage des racloirs bifaciaux Quina de Chez Pinaud (Jonzac, Charente-Maritime). Bull. Soc. Préhist. Fr. 106 (2), 219–238. https://doi.org/10.3406/bspf.2009.13846.
Scardia, G., Festa, A., Monegato, G., Pini, R., Rogledi, S., Tremolada, F., Galadini, F., 2015. Evidence for late Alpine tectonics in the Lake Garda area (Northern Italy) and seismogenic implications. GSA Bullettin 127 (1-2), 113–130.
Shchelinsky, V.E., 1989. Some Results of New Investigations at the Kapova Cave in the Southern Urals. Proceedings of the Prehistoric Society 55 (1), 181–191. https://doi.org/10.1017/S0079497X00005387.
Seguinot, J., Ivy-Ochs, S., Jouvet, G., Huss, M., Funk, M., Preusser, F., 2018. Modelling last glacial cycle ice dynamics in the Alps. The Cryosphere 12 (10), 3265–3285.
Shunkov, M.V., Fedorchenko, A.Y., Kozlikin, M.B., Derevianko, A.P., 2020. Initial Upper Palaeolithic ornaments and formal bone tools from the East Chamber of Denisova Cave in the Russian Altai. Quat. Int. 559, 47–67. https://doi.org/10.1016/j.quaint.2020.07.027.
Sneed, E.D., Folk, R.L., 1958. Pebbles in the lower Colorado river, Texas, a study in particle morphogenesis. Journal of Geology 66 (2), 114–150. https://doi.org/10.1086/626490.
Solodenko, N., Zupancich, A., Cesaro, S.N., Marder, O., Lemorini, C., Barkai, R., Petraglia, M.D., 2015. Fat residue and usewear found on Acheulian biface and scraper associated with butchered elephant remains at the site of Revadim. Israel. PLoS ONE 10 (3), e0118572. https://doi.org/10.1371/journal.pone.0118572.
Sorensen, A.C., Claud, E., Soressi, M., 2018. Neandertal fire-making technology inferred from microwear analysis. Sci. Rep. 8, 1–16. https://doi.org/10.1038/s41598-018-28342-9.
Soressi, M., D'Errico, F., 2007. Pigment, gravures, parures: les comportements symboliques controversés des Néandertaliens. In: Vandermeersch, B., Maureille, B. (Eds.), Les Néandertaliens, Biologie et cultures. Éditions du C.T.H.S, Paris, pp. 297–309.
Soressi, M., McPherron, S.P., Lenoir, M., Dogandzic, T., Goldberg, P., Jacobs, Z., Maigrot, Y., Martisius, N.L., Miller, C.E., Rendu, W., Richards, M., Skinner, M.M., Steele, T.E., Talamo, S., Texier, J.-P., 2013. Neandertals made the first specialized bone tools in Europe. Proc. Natl. Acad. Sci. USA 110 (35), 14186–14190. https://doi.org/10.1073/pnas.1302730110.
Stout, D., Chaminade, T., 2012. Stone tools, language and the brain in human evolution. Philos. Trans. R. Soc. B. Biol. Sci. 367 (1585), 75–87. https://doi.org/10.1098/rstb.2011.0099.
Thiébaut, C., Claude, E., Mourre, V., Chacón, M.G., Asselin, G., Brenet, M., Paravel, B., 2010. Le recyclage et la réutilisation de nucléus et de bifaces au Paléolithique moyen Europe occidentale: quelles fonctions et quelles implications culturelles. P@lethnologie, Varia 41, p. https://doi.org/10.4000/palethnologie.588.
Titton, S., Barsky, D., Bargallo, A., Vergès, J.M., Guardiola, M., Solano, José.García., Jimenez Arenas, J.M., Toro-Moyano, I., Sala-Ramos, R., 2018. Active percussion tools from the Oldowan site of Barranco León (Orce, Andalusia, Spain): The fundamental role of pounding activities in hominin lifeways. Journal of Archaeological Science 96, 131–147.
Titton, S., Barsky, D., Bargalló, A., Serrano-Ramos, A., Vergès, J.M., Toro-Moyano, I., Sala-Ramos, R., Solano, José.García., Jimenez Arenas, J.M., Petraglia, M.D., 2020. Subspheroids in the lithic assemblage of Barranco León (Spain): Recognizing the late Oldowan in Europe. PloS one 15 (1), e0228290.
Venditti, F., Cristiani, E., Nunziante-Cesaro, S., Agam, A., Lemorini, C., Barkai, R., 2019. Animal residues found on tiny Lower Paleolithic tools reveal their use in butchery. Sci. Rep. 9, 13031. https://doi.org/10.1038/s41598-019-49650-8.

Venzo, S., 1961. Rilevamento geologico dell'anfiteatro morenico del Garda. Tratto orientale Garda-Adige e anfiteatro atesino di Rivoli Veronese. Memorie Società Italiana Scienze Naturali e Museo Civico Storia Naturale Milano 13, 3–64.
Verneau, R., 1906. Les grottes de Grimaldi (Baoussé-Roussé). Anthropologie.
Villa, P., Boschian, G., Pollarolo, L., Saccà, D., Marra, F., Nomade, S., Pereira, A., Peresani, M., 2021. Elephant bones for the Middle Pleistocene toolmaker. PLoS ONE 16 (8), e0256090. https://doi.org/10.1371/journal.pone.0256090.
White, R., Bisson, M.S., 1998. Imagerie féminine du Paléolithique: l'apport des nouvelles statuettes de Grimaldi. Gallia Préhistoire 40 (1), 95–132. https://doi.org/10.3406/galip.1998.2159.
Wickler, W., Seibt, U., 1995. Syntax and semantics in a Zulu bead colour communication system. Stable url: Anthropos 90, 391–405 http://www.jstor.org/stable/40463187.
Zanchetta, G., Giaccio, B., Bini, M., Sarti, L., 2018. Tephrostratigraphy of Grotta del Cavallo, Southern Italy: Insights on the chronology of Middle to Upper Palaeolithic transition in the Mediterranean. Quat. Sci. Rev. 182, 65–77. https://doi.org/10.1016/j.quascirev.2017.12.014.
Zupancich, A., Cristiani, E., 2020. Functional Analysis of Sandstone Ground Stone Tools: Arguments for a Qualitative and Quantitative Synergetic Approach. Sci. Rep. 10, 15740. https://doi.org/10.1038/s41598-020-72276-0.
Zutovski, K., Barkai, R., 2016. The use of elephant bones for making Acheulian handaxes: A fresh look at old bones. Quat. Int. 406 (B), 227–238. https://doi.org/10.1016/j.quaint.2015.01.033.