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New data related to the MIS 3 deposit of the Cava I.E.C.M.E. (Bologna, Italy)

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ABSTRACT - A major project was launched in 2018 to enhance the sites of geo-paleontological interest in the karst area of the "Gessi Bolognesi" (Messinian Bolognese gypsum outcrops), within the framework of the "Gessi Bolognesi" regional park. New chronological and paleo-environmental sequences dating back to a more recent phase of the Late Pleistocene could thus be acquired. Findings come from several relict paleokarst caves of various extension and erosional genesis - corresponding to MIS 3-2 - emerging at a short distance from each other along the north to SE ridge between the Savena and Zena streams. The study focuses on the *Cava I.E.C.M.E.* deposit (Monte Croara - 283 m a.s.l.), which was already investigated in 1972-73 by the Institute of Geology of the University of Ferrara and preliminarily ascribed to an intermediate phase of the Last Glacial Period. The review of the context, supplemented by additional unpublished findings, has led to a rather detailed reconstruction of the paleoecology of the first Apennine margin in the phases preceding the Last Glacial Maximum (LGM). Materials come from the Lower Unit sediments of three different relict caves having a sub-vertical orientation, linked to a single formation episode, which occurred rapidly and massively, where it was possible to collect samples for pollen, fauna and lithic industry dating from the Middle Paleolithic. A bone-derived radiometric date attributes the formation of these sediments to a central stage of MIS 3, around 44,000-43,000 cal BPY. Cold taxa forests (*Pinus sylvestris* and *Pinus mugo)* prevailed, interspersed with grasslands populated by large herbivores: *Bison priscus*, *Bos primigenius*, *Megaloceros giganteus, Equus* sp. The faunal list also includes *Alectoris graeca*, further evidence of rocky outcrops on the border between coniferous forests and grass clearings covered with low shrubs and herbaceous plants. The last groups of Middle Paleolithic hunters-gatherers used to occupy the gypsum outcrops, in a phase of full karst evolution, being still covered, at least partially, by Middle-Lower Pleistocene formations rich in small pebbles, which were used to manufacture artifacts. The adoption of specific knapping techniques, as well as the Levallois débitage method, enabled them to fully exploit this lithological resource potential, to obtain cutting products/by-products (splinters-scrapers). The re-examination of the deposit proved to be essential for a better understanding of some techno-typological aspects of the lithic context, thanks to the relationship between the absolute chronology and paleoecological data. It also allowed for the first time to document the presence of human populations in the late Middle Paleolithic, in the Emilia-Romagna territory. This study also provides evidence of their close connection with some specific ecosystems of the Apennine margin, characterized by a faunal association with large herbivores which occupied the belt facing the opposite vast Adriatic plain and its macrosystems.

Keywords: Bolognese Apennines; Upper Pleistocene; Final Middle Paleolithic; paleo-karst structures; macrofaunas.

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1. INTRODUCTION

The knowledge of Middle Paleolithic hunter-gatherer groups in the Emilia-Romagna area is still partial and incomplete, but not without a few interesting insights, due to their widespread presence. The best-documented phase refers to the Early Pleniglacial (MIS 4) coinciding with arid-cold continental climatic conditions: the anthropogenic attendance model, widespread on a regional scale, is oriented towards the exploitation of the resources available in the sub-flat areas of the Apennine margin, then buried, by large stretches, by thin *loess* layers. In the western Emilia district, a series of TL and OSL datings on stratigraphic sections, sediments, and artifacts place the findings in a rather coherent although not broad chronological range, between 73±11 ka and 61±9 ka (Ghiardello, Cave del Ghiardo, Cremaschi et al., 2017). The characters of the lithic assemblages, well-circumscribed in the Ghiardo Cave deposit, are characterized by the adoption of *chaînes opératoires de débitage* (operational sequences) according to the Levallois technique, with a wide production of flakes, rare blades, and points and rather low support transformation indexes, with a prevailing amount of scrapers. Few or no Acheulean traditional *façonnage* specimens are available.

Similar findings also seem to concern the eastern Po Valley area (Bologna-Imola area), with a series of deposits reported on terraces (average altitude 120-130 m a.s.l.), pending geochronological investigations, by stratigraphic position and typological characteristics of the industry, referred to the medium-recent phases of the Middle Paleolithic (e.g., Bellaria Cantiere, Peverella-Palazzina series1, Calanco series CA3) (Lenzi and Nenzioni, 1996; Fontana and Peretto, 2017; Lenzi, 2018; Nenzioni and Onorevoli, 2021; Nenzioni and Tortolani, 2022).

This work was developed within the framework of a complex project dedicated to the enhancement of sites of geo-paleontological interest of the Gessi Bolognesi Regional Park. The project was launched in 2008 and it led to the acquisition of new chronological and paleo-environmental sequences dating back to a more recent phase of the Late Pleistocene (Nenzioni and Lenzi, 2018; Nenzioni et al., 2019).

The Cava I.E.C.M.E. deposit is a site of interest that was identified in 1972-73 following the investigations on the Monte Croara cave. The deposit consisted of an articulated series of fossil karst morphologies, mostly demolished by gypsum mining works. The research was then carried out by the Institute of Geology of the University of Ferrara, with the identification of three sinkholes, where it was possible to collect samples for pollen analysis, fauna, and lithic industry dating from the Middle Paleolithic, ascribing them in the first study to an intermediate phase of the Last Glacial Period (Bisi et al., 1977).

This contribution is intended to provide an update on the study of the Late-Mousterian lithic industry of the deposit, largely composed of a body of unpublished materials, complementing it with a brief summary of the related palynological and paleontological data and placing it in the contemporary national and European scene.

The review of this context, now attributable to the Final Middle Paleolithic, on a radiometric basis supplemented by additional unpublished findings, has led to a rather detailed reconstruction of the paleoecology of the first Apennine margin in the phases preceding the Last Glacial Maximum (LGM) and in relationship with the ecosystems characterized by the presence of the last Neanderthals.

2. DESCRIPTION OF THE AREA

2.1. LOCATION

The area covered by this study extends along the Messinian gypsum outcrops belt being part of the

Fig. 1 - Location of the Cava I.E.C.M.E. deposit - (I) Municipality of San Lazzaro di Savena (BO), loc. Croara (44°26’33.0”N 11°22’46.2”E).

geological unit known as the Gessoso-solfifera Formation (Vai and Ricci Lucchi, 1977) between the Savena and Zena streams, southeast of the city of Bologna (Fig. 1).

The stratigraphic architecture of the evaporite sequence consists of about 12 depositional cycles, interspersed with clayey-marl interlayers, which may reach a maximum thickness of over 250 meters (Roveri et al., 2003; Montanari et al., 2007). The entire area features significant epigenetic karst phenomena, which according to recent studies (to which reference can be made for further information), are aligned with the two main structuring directions of the Apennine range (NW-SE and NE-SW) (Pisani et al., 2018; De Waele et al., 2018). Further surface karst mesoforms dot the entire sub-outcropping gypsum ridge, resulting from cyclical and intense erosion phenomena that were particularly active during the MIS 3, strengthened by the gypsums high solubility. The sites of greatest prehistoric interest are located on the overall monocline line extending from the north to the SE. This sector includes the morphological highlands of Monte Castello (256 m a.s.l.), Monte Croara (283 m a.s.l.), and, to the east, the Budriolo-risorgente Osteriola system, characterized by a considerable plunging inclination of the selenite banks to the NE.

2.2. STRUCTURAL ASSETS AND SEDIMENTS

The set of data comes from three different relict sub-vertical caves featuring various morphological traits, demolished in three different sections by the quarry mining activity active since the mid-fifties of the last century.

This is what remains of paleo-karst formations (paleo sinkholes) which, in the absence of a dominant primary collector, drained the southern slope of Monte Croara through an epigean network, today partly fossil (Grotta del Ragno), and hypogean (Rio Croara) afferent to the main catchment area (Rio Acquafredda).

The high solubility of gypsum and its high vulnerability to erosion due to channeled flows favored the rapid development of these small sub-vertical secondary drainage basins, further accentuated by micro-faults, caused by contact between the gypsum and the clay-marly layers. As soon as they were no longer crossed by direct water flows, they tended to dry out and were sealed by the accumulation of external physical deposits.

The three explored cavities, named sinkholes A, B, and C, share the same karst amphitheater. Two of them (A, C) are located in the upper part of the quarry, and the third (B), lies at about 100 m. south of the previous ones, opens in the lower level, longtime abandoned (Fig. 2). All the structures, deeply and transversally sectioned, denote paleokarst fillings: two of them (sinkholes A, B) presented in a pronounced discontinuity with two main formation phases (Fig. 3):

- Upper Unit: sinkhole A is composed of soil that presents quarrying debris (layer 1); sinkhole B is filled with Holocene silts containing ashes and charcoals (layer A[1]) and sandy loam sediments with thin structures and rows of pebbles and charcoals in an inclined stratification (layer Y). Their thickness varies from 4 to 5 m. This Unity is absent in sinkhole C.

- Lower Unit (*sinkhole* A layer 4; *sinkhole* B layer 5-6;

Fig. 2 - Cava I.E.C.M.E. deposit - The three sinkholes (A, B, C) brought to light by the mining works along the southern slope of Monte Croara are highlighted in the picture, as they appeared in the mid-eighties of the last century.

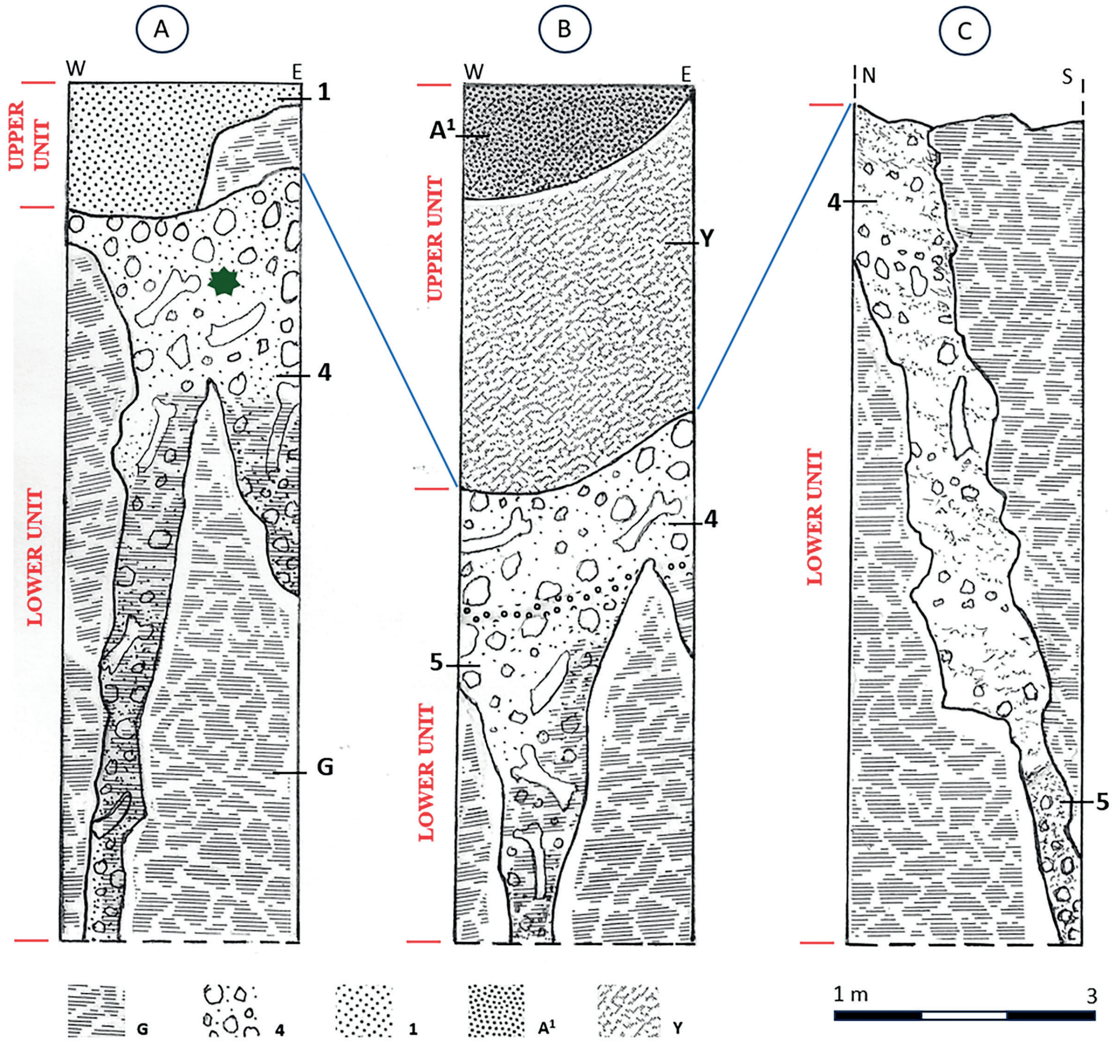

Fig. 3 - Cava I.E.C.M.E. deposit, sinkholes A, B, C. Stratigraphic sections: G - Gypsum; 4 - pebble deposit with lithic industry, fauna, pollens (the asterisk indicates pollinic sampling); 5 - soil with idromorphic level; 1- soil with quarrying debris; A1 - hydrological erosion filled with silts containing ashes and charcoals; Y - marly-clay silt with pebble and charcoal inclusions. Modified from Cremaschi in Bisi et al., 1977.

sinkhole C layer 4) refers to the Late Pleistocene fill, which all the anthropic and naturalistic materials presented here come from, although to a different extent.

This Unit, described by Cremaschi (in Bisi et al., 1977), partly eroded due to the reactivation of the caves, was preserved in contact with the gypsum blades modeled by the karst action with thickness ranging between 4,80 m (*sinkhole* B) and 9 m circa (*sinkhole* C). The sediment featured a sandy loam texture, a polyhedral structure with an abundant skeleton - largely made up of pebbles, gypsum fragments, and calcium carbonate concretions - tended to cement towards the bottom of the deposit. Unchecked particle size distribution indicates rapid sedimentation by mass transport.

All the components come from the dismantling of the formations present on the Monte Croara ridge: sandy fraction and siliceous pebbles from the Sabbie Gialle di Imola (Yellow Sands of Imola) (IMO of the Emilia-Romagna Regional Cartography); fine silts-clays from the gypsum interlayer marls; pebbly skeleton from Continental Deposits and Quaternary Gravels alias Qc (Amorosi and Pavesi 2010) alias AES (Gunderson et al., 2014).

In sinkholes B-C (layer 5) this Unit is composed of a hydromorphic level produced by the scarcity of drainage. This layer presents mottling and thin layers of pebbles altered (sandstone and siltstone) rich in iron oxide and decarbonated.

The absolute correspondence of the sedimentary component, as demonstrated by the analyses of the lower unit of the three sinkholes, links them to a single formation process, which took place rapidly and massively, and determined the remobilization of the soils in close contact, or in the immediate vicinity, of the karst system where they were located.

The soil parameters that have been examined (organic carbon and phosphoric anhydride) rule out that the deposits are directly related to a settlement.

3. MATERIALS AND METHODS

The materials of the Cava I.E.C.M.E. deposit are kept at the Museum of Prehistory "Luigi Donini" in San Lazzaro di Savena (BO), which oversaw the typological study of the lithic industry and promoted the detailed analysis of the paleontological remains. These were the subject of the master's degree thesis by A. Massarenti (University of Ferrara, academic year 2016-2017), then merged into a subsequent work dedicated to the geopaleontology of the Bolognese gypsum /Gessi Bolognesi (Massarenti et al., 2018).

At the same time, steps were taken to carry out dating to ^{14}C, while a pollen analysis was carried out at the Palynology and Archaeobotany Laboratory of the "G. Nicoli" Archeological and Environmental Center of San Giovanni in Persiceto (BO) on a sample of sediment from the prospecting from the Seventies, still preserved in the laboratory.

Conversely, it was not possible to carry out a new sedimentological analysis of the deposit, as following the abandonment of the quarry and the subsequent renaturalization of the site, sinkholes A, B, and C became inaccessible.

3.1. STRATIGRAPHY

The homogeneity of the contexts and materials has enabled an overall presentation of the data relating to the three sedimentary units. The paleo-karst structure A (alias sinkhole A), being the subject of more in-depth investigations, is the main point of reference of this report (pollen series, radiocarbon dating, lithic industry). The research program envisages a forthcoming assessment of the state of conservation of the sedimentary structures and geo-stratigraphic and radiometric investigations in unit B (alias sinkhole B), which is well preserved.

3.2. RADIOCARBON ANALYSIS

A ^{14}C analysis was performed (Centre for Isotope Research, Faculty of Science and Engineering, University of Groningen - sample GrA-52969) on *Bison priscus* bone from sinkhole A-layer 4. The calibration 2σ was executed by P. Paronuzzi with CALIB Radiocarbon Calibration (Stuiver and Reimer, 1993).

3.3. POLLEN ANALYSIS

The pollen spectrum was obtained through only a sample collected from the sinkhole A, stratum 4 - top series (Marchesini et al., 2018).

Palynological analyses were carried out applying a methodology already tested for pollen substrates with some minor modifications (Lowe et al., 1996). The method includes the following phases: about 8-10 g was treated in 10% Na-pyrophosphate to deflocculate the sediment matrix. A Lycopodium spores tablet was added to calculate pollen concentration (expressed as pollen grains per gram=p/g). The sediment residue was subsequently washed through 7-micron sieves and then resuspended in HCl 10% to remove calcareous material and subjected to Erdtman acetolysis; the heavy liquid separation method was then introduced using Na-metatungstate hydrate of s.g. 2.0 and centrifugation at 2000 rpm for 20 min. Following this procedure, the retained fractions were treated with 40% HF for 24 h and then the sediment residue was washed previously in distilled water and in ethanol with glycerol; the final residue was desiccated and mounted on slides by glycerol jelly and finally sealed with paraffin. This method preserves the slides for many years after preparation and therefore it is suitable for pollen extractions from geological and archeological samples. Identification of the samples was performed at 1000 light microscope magnification (ocular ×10 and objective ×100). Determination of the pollen grains was based on the Palinoteca of our laboratory, atlases, and a vast amount of specific morpho-palynological bibliography. Names of the families, genus, and species of plants conform to the classifications of Italian Flora proposal by Pignatti (2017) and European Flora (Tutin et al., 1964-1993). The pollen terminology is based on Berglund and Ralska-Jasiewiczowa (1986), Faegri and Iversen (1989), and Moore et al. (1991) with slight modifications that tend to simplify the nomenclature of plants. Identified pollen groups have been expressed as percentages of the total (usually between 300 and 400 grains).

3.4. FAUNAL ANALYSIS

The paleontological record is rather scarce: 131 finds, of which a low percentage can be determined due to the state of fragmentation. The first faunal list drawn up by Sala (in Bisi et al., 1977) was supplemented by a second lot, acquired thanks to subsequent research, for the specific determination of which reference is made by Massarenti et al. (2018).

Any traces of anthropic interaction on bone surfaces will be the subject of future investigations. The determined taxa are summarized in the following table in taxonomic order.

3.5. LITHIC INDUSTRY ANALYSIS

The lithic industry study took into consideration all the artifacts (246 units). The determination of the raw material was carried out through macroscopic recognition of the textural, granulometric, and chromatic characters on the basis of the detailed study relating to lithic complexes known in the literature, with particular reference to the Bel Poggio (BO) Paleolithic lithocomplex. In this site the lithotypes that are superimposable on those used in the Cava I.E.C.M.E. deposit, with specific reference to the components obtained from tertiary siliceous pebbles and from the middle-upper Eocene (Benedetti and Ghedini, 1996; Fontana and Peretto, 1996).

The essential technological and typological data of the finds have been entered into a database created by means of Microsoft Access, with the product relative placement within the *chaîne opératoire* (operational sequences) by technological stage. As for cores, the distinction was made on the *débitage* method, which took into consideration the number/relationship of the striking platforms and the lithic débitage surface/reduction phase (Boëda, 2013). The concept defined by E. Boëda (1993, 1994) was used for the attribution of the Levallois *débitage* methods, while for the discoid *débitage*, which was very weakly attested, and for some products generically comparable to centripetal *débitage*, reference was made to Peresani (2003) and Mourre (2003).

The SSDA *débitage*, as codified by H. Forestier (1993), was attributed the opportunistic variants, developed on siliceous pebbles, and limited to the more complex forms. The breakdown of the instrumental component, oriented towards the production of scrapers, follows the typological list developed by F. Bordes (1961).

Interpreting factors were then applied to the categories of greatest diagnostic difficulty (intermediate phase products of the predetermined *chaînes opératoires* / operational sequences of fragmented products) seeking, wherever possible, their placement within the technical context in which the site is included and in the production sequences.

4. RESULTS

The integrated analysis of the data has made it possible to ascertain the age of the deposit, to better understand the nature of the site and the relationship between the anthropic evidence and the territorial context, and to circumscribe more precisely the techno-typological characteristics of the lithic industry.

4.1. RADIOMETRIC DATE

A *Bison priscus* long bone has been radio dated (GrA-52969 sample) to 39720±360 BP Later calibration provided the date 44412-43100 cal 2σ BP, placing the deposit in the central phases of MIS 3.

4.2. PALYNOLOGICAL DATA

In general pollen concentration was not high, ranging from 10^2 to 10^3 grains/g; all pollen types were recorded with different degrees of preservation, from good to bad, in the same sample. Deterioration mainly consisted in folding of the grains and degradation with various degrees of thinning of the exines. Pollen flora consisted of 21 types (10 trees and shrubs and 11 herbs).

The pollen spectrum was dominated by taxa typical of cold woods prevail (53%), especially conifers, with numerous pine grains (45.6%: *Pinus sylvestris* and *Pinus mugo*) followed by *Alnus* and *Salix* in the primary pollen component, contextual to the deposit. Traces of *Carpinus betulus* and *Ostrya carpinifolia/Carpinus orientalis* and *Tilia* (7%) could be detected in the background.

Cold grasslands account for 24% and are characterized by Poaceae and in the suborder by Cichorioideae and Asteroideae (Fig. 4).

The results confirmed the infiltration of pollen grains in secondary deposition (*Tsuga, Carya, Pterocarya, Juglans*, etc.) into the sinkhole, deriving from the remobilization of Lower-Middle Pleistocene sedimentary members of a humid-temperate environment. They feature the typical residual appearance, which is very different from the vegetation of a cold environment contemporary with the emplacement of the sediments in the karst conduits.

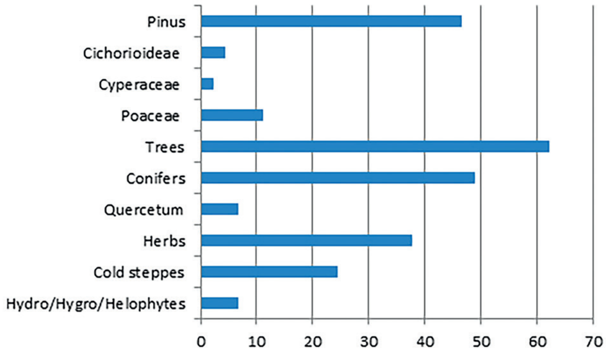

Fig. 4 - Cava I.E.C.M.E. deposit, sinkhole A: pollens in primary deposition. Main taxa and groups (%) of the pollen spectrum.

4.3. FAUNAL DATA

The faunal remains present in the sedimentary context amount to 131 units, of which 39 are referable to determinable species (Tab. 1). The latter are in a good state of conservation and without corrosion on the external surfaces. Cracks, fractures, and loss of portions are due to compressive movements of the ground and to factors connected with their subsequent emplacement. The irregular margins and the polygonal pattern of some fractures indicate that a series of finds underwent fragmentation in the post-depositional phase, following burial in the karst cavity.

Among the faunal remains, bovids prevail (76.9% of the identifiable specimens), represented by *Bison priscus* and *Bos primigenius*. The bison features an imposing neurocranium with perfectly preserved horn cores (CA.IEC 026), with the two hemi-mandibles (CA.IEC 027, CA.IEC 028) complete with all the jugal teeth, except P_2 and interrupted anteriorly in the diastematic portion. *Bos primigenius* remains are less frequent, represented by a left M_3, a right M_3 and a left radio-ulna connected to each other. *Megaloceros giganteus* remains (15.4% of the identifiable ones) follow, in order of abundance, among which three elements stand out (CA.IEC 055a/b/c) forming the large palmated portion of one antler and two left mandibular fragments (CA.IEC 053 and 054), referable to two different adults, with a circular section of the ramus and a robustness index of 75.4 and 71, respectively (Sala in Bisi et al., 1977). The picture is completed by a tibio-tarsus fragment (CA.IEC 01) of *Alectoris graeca* (Fig. 5).

Tab. 1 - Cava I.E.C.M.E. deposit - Faunal remains.

FAMILY	GENUS	FINDS
Equidae	*Equus sp.*	left P^2, fr. molar
Bovidae	*Bos primigenius*	left M_3; right M_3; radio-ulna in connection;
Bovidae	*Bison priscus*	Neurocranium with horn cores; 2 hemi-mandibles (right and left); right talus; frs. distal right humerus; right trapezoid
Bovidae	*Bos vel Bison*	right humerus; right humerus diaphysis; right radius diaphysis; fr. distal left humerus; left tibial diaphysis; dorsal vertebra; fr. distal right scapula; fr. left metatarsal; left cu-bonavicular, left trapezoid; I and III phalanx; fr. mandible with set of teeth; left M_2 l; left M_1; right M_2; right I_3; right M^2; left M^2; left M^2; right M^3
Cervidae	*Megaloceros giganteus*	3 antler frs.; 2 frs. left mandibles with M_2-M_3 e P_2-M_2; left P^2; fr. distal left humerus; II phalanx of the IV toe
Phasianidae	*Alectoris graeca*	fr. right tibio-tarsus
Indeterminate ungulates		3 frr. pelvis; 6 frs. ribs
Indeterminate		83 frs. various

4.4. LITHIC INDUSTRY: RAW MATERIALS AND PRODUCTION SYSTEMS

The lithic assemblage, albeit numerically limited (246 artifacts), allows us to grasp some lines of technical behavior that characterized the industry.

Lithotypes in use are of local origin, resulting from the erosion and dismantling of the formations that once covered the Gessi Bolognesi area. They mainly consist of flint-type pebbles of the Umbro-Marche Series (included in the Imola-IMO Yellow Sands) and other pebbles of Apennine origin present in the bodies of fluvial terraces of the Middle Pleistocene still outcropping in the deposit area during the phases preceding the Last Maximum Glacial (Cremaschi 1985). The use of silicified silt (54.6%) is predominant in the form of pebbles of various sizes (80-120 mm), with an opaque gray-blackish color and, in modest percentages, of other Apennine rocks: lutites, quartzarenites, calcarenites (6.8%). Flint (38.5%), present in medium-small pebbles (mm<60) has favoured the adoption of poorly processed and opportunistic methods (Tab. 2).

Artifacts feature a homogeneous physical state, with sharp edges and light or no patina and are attributable, with highly variable percentages, to the different phases of the operational sequence. In the overall production, *débitage* contemporary fractures can be observed, related to the not always optimal quality of the raw material. The set also includes two flint strikers, bearing traces of use at one end only.

For the definition of the different *débitage* methods, data deriving from the morphotechnical analysis of cores was assessed in comparison with those relating to the various artifacts (Tab. 3).

The adaptability to the raw material has favored diversified technical methodological approaches to the support core (Fig. 6). Unidirectional débitage, with a single prepared platform core prevailing over the other categories (38.8%), was mainly used for processing medium-small sub-spherical flint pebbles. The knapping technique consisted of the removal of a first cortical flake on an orthogonal plane against the major axis of the core and subsequent knapping of the *débitage* surface by short series of adjacent unidirectional detachments. The flaking angle ranged between 90°-45°/30°.

The objective products with plain butt, closely connected with the core morphology/size, were largely made up of flakes with cutting edges opposite to a lateral or latero-distal cortical back.

The Levallois *débitage* technique was the second most widely used method (32.6%) and it was mostly performed on silt cores, more suitable in terms of size. It was performed in the following way:

- recurrent unipolar with small finds (6.1%) in cores at the end of production, but documented by flakes with unidirectional adjacent arris and parallel cutting edges. This set also includes some blade/bladelets with two/three unidirectional removal negatives characterized by a high incidence of fractures.
- recurrent centripetal, well represented (20.4%) by well-crafted cores, some of which overexploited, but poorly documented in the group of flakes. Debitage objectives are flat sub-quadrangular flakes with peripheral cutting edges.

In addition to these two main categories, the orthogonal method was less frequently applied on debitage products, and very rarely documented by multifacial cores.

The Unipolar convergent method is exclusively attested by flakes and by two Levallois points.

The discoid debitage method, the SSDA system, and the flake cores (Kombewa) were more rarely applied in the production of artifacts. Many specimens show that the exploitation led to a remarkable reduction of the core before dismissal.

In the context of debitage products (Tab. 4), cortical flakes (42.8%) are attributable both to the pebble initialization/fragmentation phases (first flakes with partial or total cortex), and in the preparation of the surface of debitage (flakes with distal, lateral, dorsal cortex) exploiting the natural convexity of the raw material.

The rock size is reflected in the typology of artifacts,

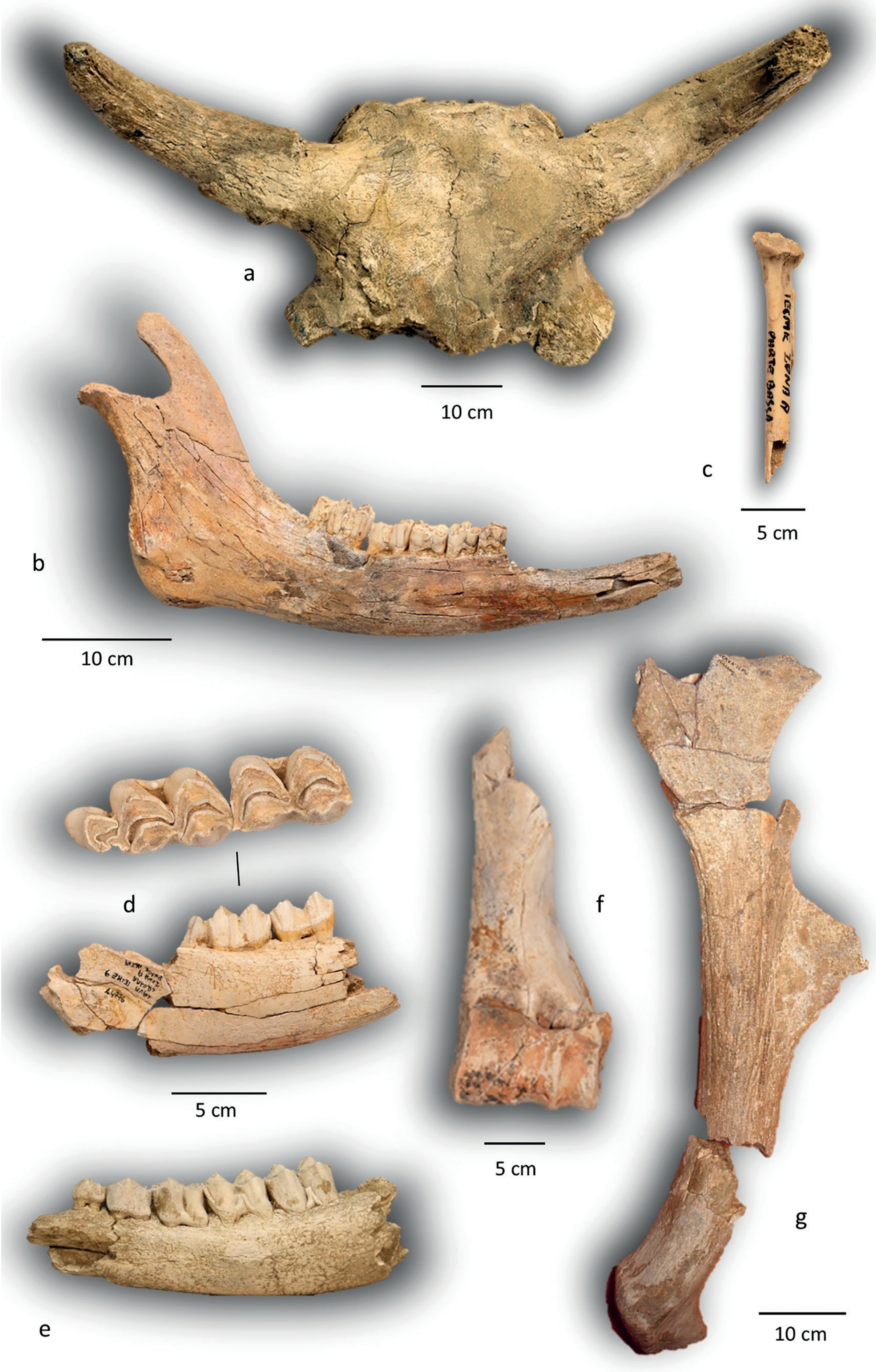

Fig. 5 - Cava I.E.C.M.E. deposit - *Bison priscus*: a) neurocranium in frontal view, b) right hemi-mandible in labial view; *Alectoris graeca*: c) right tibio-tarsus in plantar view; *Megaloceros giganteus*: d) fr. of left mandible with M2-M3 in occlusal (above) and lingual (below) view, e) fr. of left mandible with P2-M2 in labial view, f) left humerus in cranial view, g) antler fragments.

Tab. 2 - Cava I.E.C.M.E. deposit - Raw material and composition of lithic assemblage.

Raw material	no.	%	Technological categories	no.	%
Silicified siltstone	134	54.4			
Flint	95	38.6	Cores	49	19.9
Calcare sensu stricto	2	0.8	Flakes	182	73.9
Calcarenite	7	2.8	Retouched tools	13	5.3
Other raw materials	8	3.2	Strikers	2	0.8
Total	246	100.0	Total	246	100.0

Tab. 3 - Cava I.E.C.M.E. deposit - Main concepts of *débitage* divided by raw material.

Main concepts of débitage	A. Silicified siltstone and other raw materials	B. Flint	A + B
Single prepared platform core	2	17	19
Levallois group	11	5	16
unipolar	3	-	3
bipolar	-	1	1
centripetal	7	3	10
orthogonal	1	1	2
Discoid	2	-	2
Kombewa	2	-	2
S.S.D.A.	1	4	5
Indeterminable	3	2	5
Total	21	28	49

mainly distributed in the categories of *small flakes/micro flakes/micro blades* (65.3%), followed by *flakes/blades (*mm 60-100=31.4%) and finally, to a much lower extent, by *large flakes/blades* (3.2%). With reference to butts, a prevalence of plains is recorded (30.9%) on facettes and dihedrals (Ifl 16.4%) and naturals (8.2%). High proximal fragmentation of flakes can also be observed (non determinated butts 25.7%).

Contrary to the case of cores, in the flakes/blades group the Levallois unipolar method prevails in siltstone flakes, while flint artifacts show a more balanced distribution.

Plein débitage objects feature from three to five removal negatives in the dorsal face.

The unipolar variants parallel to the direction of knapping, which can give rise to even small-sized laminar products, feature on average two/three removal negatives. The removal negatives tend to take on crossed/centripetal shape when the progressive rotation of the striking platform perimeter takes place. Cortical flakes and predetermining flakes derive from the core reduction sequence to an equivalent extent, including some *débordant* flakes which restore the proximal convexity of the flake.

Only 5.2% of flakes are retouched. Medium-large flakes (>60-110 mm) with silicified silt (8 ex.) plain butt were mostly used.

Three retouched flakes are part of the Levallois modules. Convex side scrapers with simple (2 samples) or deep (3 samples) retouch have been identified. One of them, obtained from an oblong and flat calcarenite pebble, with a conventional orientation on the major axis, features a scaled retouch. The denticulate group includes two specimens. One Mousterian elongated point with deep retouch is also included.

An evident typometric and technical dichotomy characterizes the tools obtained from medium-small sized flint pebbles (<45 mm). They were obtained from cortical flakes (débordants flakes, segments, cortical first flakes) and include a transversal scraper with deep retouch, two convex side-scrapers, a denticulate tool, and sub-rectilinear side-scraper obtained from thick cortical flakes. (Fig. 7).

5. DISCUSSION

The pollen spectrum indicates an association with Pine with the constant presence of grassland areas, in which Poaceae clearly prevailed, alternating with deciduous riparian zones. Chronologically referring to a radiocarbonic base to the middle phase of MIS 3, the vegetation assemblage fits into the framework of the climatic oscillations of GS 12/11 (Greenland Stadial) NGRIP (North Greenland Ice Core Project: Rasmussen et al., 2014; Hublin, 2015). The presence of some oak species might be residually linked to the temperate phases between the two stadials.

The vegetational landscape that emerged from the analyzed sample shows results that are completely similar to those that emerged from the analysis of a sample carried out by L. Cattani (Bisi et al., 1977).

The overlapping of the pollen values of the two samples confirms that it is a homogeneous and monophasic filling.

Despite the very few samples available, the association of large ungulates, *Bison priscus*, *Bos primigenius*, *Megaloceros giganteus*, *Equus* sp., is a good indicator of an environment featuring grassland interspersed with scattered woodlands. The common rock partridge (*Alectoris graeca*) suggests the presence of rocky clearances, on the border between coniferous woodlands and open grasslands

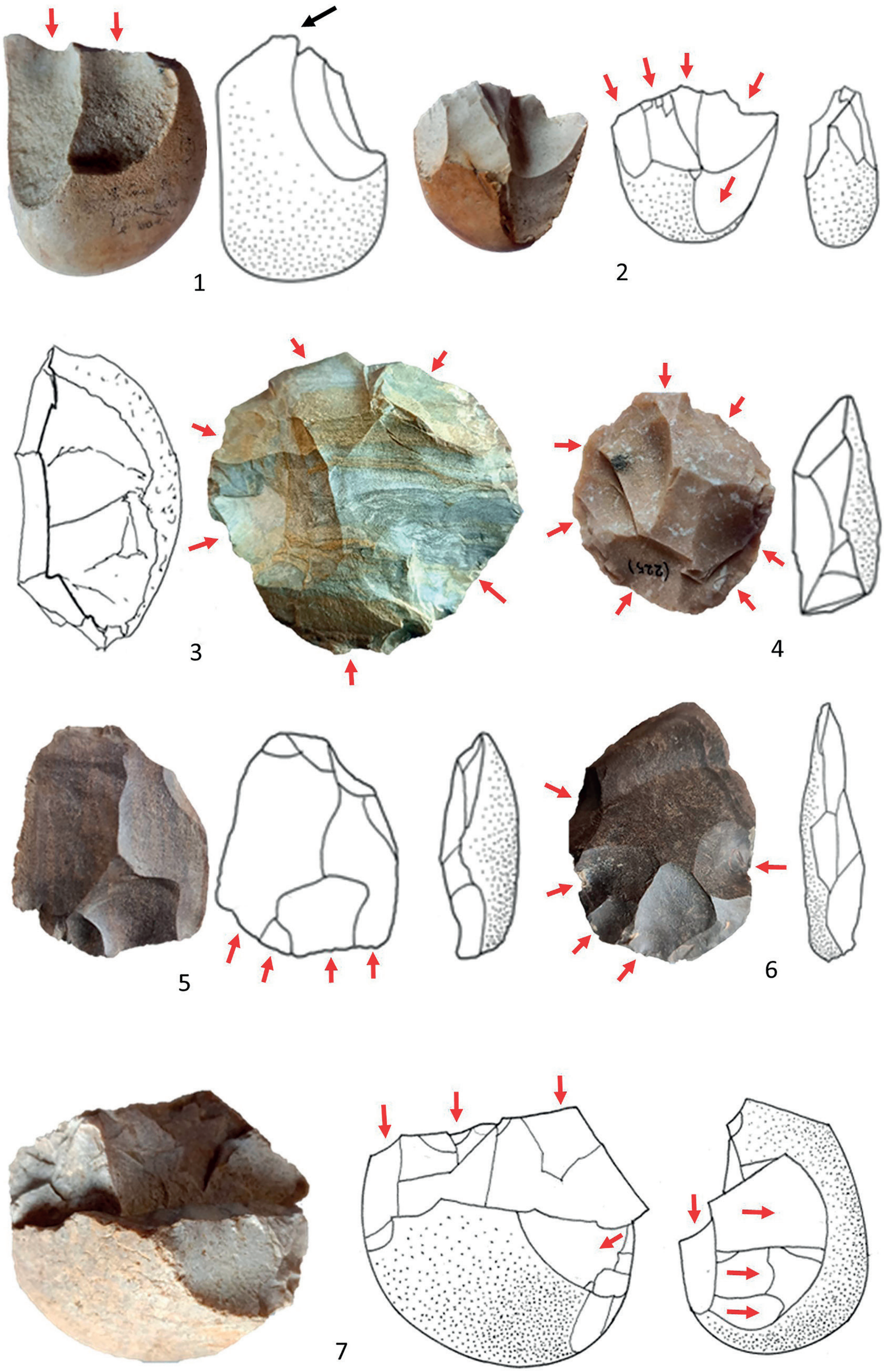

Fig. 6 - Cava I.E.C.M.E. deposit - Single prepared platform core 1-2; Recurrent centripetal core 3-4; Recurrent unipolar core 5; Kombewa core 6; S.S.D.A. core 7 (scale 2/3).

Tab. 4 - Cava I.E.C.M.E. deposit - Technological categories divided by raw material.

Technological categories	A. Silicified siltstone and other raw material	B. Flint	A + B
Levallois flake/blade	28	10	38
unipolar	16	5	21
centripetal	9	5	14
convergent	3	-	3
Levallois point	2	-	2
Predetermined flake	7	2	9
Cortical flake (<50%)	27	22	49
Cortical flake (>50%)	19	12	29
Flake s.l.	39	12	51
Rejuvenation core flake	-	2	2
Total	122	60	182

covered with low shrubs and herbaceous plants. *Alectoris graeca* remains, for example, were found in the level A9 archeological record of Grotta di Fumane (VR), dated 47.6-45 ka cal BP (Fiore et al., 2016) in association with large ungulates adapted to open spaces - *Bos primigenius, Bison priscus* and *Megaloceros giganteus* (Romandini et al., 2014).The two latter species were also found in the Late Mousterian SU 11 of the Broion Cave, together with the horse (Romandini and Peresani, 2019) and in the San Bernardino Cave - Unit II (Terlato et al., 2021).

The Cava I.E.C.M.E. lithic complex provides sufficient elements for a few considerations. Its main characteristics are summarized here below:

- débitage techniques with short and opportunistic operational sequences calibrated on the on-site available raw material
- application of the Levallois method (unipolar/centripetal débitage) for the crafting of sub-quadrangular/rectangular products
- sporadic laminar/lamellar productions
- core over-exploitation
- low flakes modification, mainly oriented towards the production of side scrapers.

The lithic industry analysis (quantitative index/typological dispersion) points out the fragmentary character of the operational sequences and asymmetries in the distribution of the various product categories. This phenomenon was partly connected with the non-optimal quality of the raw material available on site and with the erosive dispersions of materials. Information on the industry technical rate is provided by the coexistence of the unipolar and centripetal Levallois methods, accompanied by a non-Levallois débitage with short unipolar sequences and a scarce orientation towards discoid reduction schemes.

The Cava I.E.C.M.E. deposit allows to broaden the knowledge on the geographical distribution of the final Mousterian groups and their technological expertise, including their further penetration in the wider territory of northern Italy. The site fits consistently into the context of a series of lithic techno-complexes during this phase, starting from the radiometric comparison with the Monte Netto-BS deposit (44.4±4.5 ka: Delpiano et al., 2019a). The sites located in the foothills of western Lessinia and the Berici Hills constitute an essential reference: Riparo Tagliente (Arzarello and Peretto, 2004, 2005), Grotta di Fumane, Grotta di San Bernardino, Grotta e Riparo del Broion (Del Piano et al., 2018, 2019b; Del Piano and Peresani, 2017; Peresani, 1996, 2001, 2010, 2011, 2012; Peresani et al., 2011 a,b; Peresani and Porraz, 2004; Peresani and Romandini, 2019; Porraz and Peresani, 2006; Terlato et al., 2021) and in the Carnic Pre-Alps: Grotta del Rio Secco (Peresani et al., 2014; Talamo et al., 2014).

For the Eastern Adriatic side, sites have been reported on the Croatian coast and hinterland (Mujina Pećina: Karavanić et al., 2008; Vindija Cave: Devièse et al., 2017).

On the Tyrrhenian coast, isotopic or radiometric-based correlations can be established with various sites in the Ligurian arc: Ripari Mochi and Bombrini, Grotta del Principe, Madonna dell'Arma, Arma delle Manie (Cauche, 2007; Douka et al., 2012; Frouin et al., 2016; Grimaldi and Santariello, 2014; Negrino and Riel-Salvatore, 2018; Riel-Salvatore and Negrino, 2018; Rossoni-Notter et al., 2017), while for Tuscany some caves in the Apuan Alps are involved: Tecchia di Equi (43,700±1,900 BP and 44,000±2,200 BP, uncalibrated), Grotta all'Onda, Buca del Tasso, Grotta del Capriolo and Buca della Iena (Bigagli et al., 2018; Dini and Koehler, 2009).

In the Central and Southern area of the Italian Peninsula, a further series of sites falls in the time interval between 45,000 and 40,000 anni BP: Grotta Reali (IS) (Arzarello et al., 2004; Peretto, 2012); Castelcivita (SA) (Gambassini, 1997); Oscurusciuto (Ginosa-TA) (Boscato et al., 2011; Ronchitelli et al., 2011; Ranaldo et al., 2017); Grotta del Cavallo (Nardò-LE) (Carmignani, 2010).

The in-depth studies carried out over the past few decades on these lithic complexes, their absolute chronology, and the various technological aspects have led to a significant summary report (Marciani et al., 2020 and references therein). This comprehensive work provides a significant overview of this crucial transition between two Paleolithic phases, with their relative specificities and variability in terms of the débitage conception and objectives of the individual industries.

A European look at the manifestations attributable to the final Middle-Paleolithic highlights a varied framework from a chronological and techno-cultural point of view. Sites with phases of frequentation parallel to Cava I.E.C.M.E. are found in the Franco-Cantabrian area and on the Pyrenees (Maíllo-Fernández et al., 2004;

Fig. 7 - Cava I.E.C.M.E. deposit - Levallois flake/blade 1-7; Levallois point 8; Blade 9-10; Rejuvenation core flake 11; Denticulate tool 12-13; Retouched elongated point 14, Side-scrapers 15-18.

Thiébaut et al., 2012).

In France, several technocomplexes are located both in the country's western district (Jaubert et al., 2011), and in the area of the Massif Central and the Rhone Valley (Slimak, 2008; Szmidt et al., 2010; Richard et al., 2021) present chronological sequences within which the episode of Cava I.E.C.M.E. is also placed.

Finally, for Central Europe reference should be made to the recent synthesis work by Jöris et al. (2022).

6. CONCLUSIONS

The Cava I.E.C.M.E. karst deposits have yielded the only evidence in the region on the paleoecology of the Eastern Apennine margin of the Po Valley during the last phases of the presence of the late Neanderthal groups. The emplacement of these deposits took place rapidly and massively, under the isotopic stage 3 climate conditions. It led to rapid remobilization of soils containing lithic artifacts, faunal remains, and plant species, in close contact with the karst outcrops.

This framework is fundamentally consistent with a previous pollen analysis performed on a sample from sinkhole A, 4-base series, that highlighted a relation to Pinus, with rare Alnus and Salix, to be referred to as a dry-cold climate (Cattani in Bisi et al., 1977).

It is a very special site. Although not a "primary" deposition, it provides clear evidence of the close relationship between late Mousterian humans and the fauna characterized by large animals on Monte Croara karst plateau, at a short distance from the place of discovery.

While awaiting further insights on lithotechnics (use-wear traces analysis) and on bone remains (anthropic impact traces), with the aim of establishing more dynamic relationships between these findings, it is already possible to highlight a few aspects emerging from this research, although still at a preliminary stage.

The site can therefore be interpreted as having a "low anthropic impact", with traces resulting from single and distinct moments of anthropic presence, during a limited period of time in an area adjacent to active karst conduits capable of generating rich biodiversity conditions. Similar traces seem to extend to the neighbouring karst areas as well, as proven by the ongoing research (Nenzioni et al., 2019) at the Cava Fiorini site (Levallois lithotechnics associated with *Bison priscus* remains) and in the Serafino Calindri Cave. The complex evolutionary genesis of this phenomenon gave rise to the formation of three distinct paleo-karst levels of tectonic origin, characterized by powerful physical fillings, which have been attributed to the radiocarbon date 38160-36605 cal BP in the basal unit of the intermediate branch (RM-US 4b). The upper branch fillings (RS), of more ancient genesis, from which the *Bison priscus* remains and the Levallois technique artifacts originate, are currently being ascertained.

The chronological context and the structural articulation of the Cava I.E.C.M.E. lithic industry, together with the flake size in the various knapping phases, differentiate this deposit from the previous ones and numerous sites with Levallois débitage complexes, buried in the Apennine foothill loess, attributable to MIS 6-4 on a geomorphological basis.

In summary, the deposit documents a more widespread presence of the late Neanderthal groups ranging from the primary sites of the fluvial terraces of the Apennine margin to the first intra-Apennine karst belt. This expansion was directly motivated by the search for ecosystems generated by the Messinian gypsum outcrops: karst plateaus with steppe grassland characterized by the presence of large ungulates, wetter riparian zones with oak woods, water resources, and springs.

This model is further characterized by the great adaptability of the last Middle Paleolithic hunter groups to the local petrographic resources, at a time of full karst evolution, when the whole area was still covered by Lower and Middle Pleistocene formations rich in pebbles used for manufacturing artifacts.

The substantial scarcity of reports relating to Final Mousterian contexts can also be partly due to the absence of extensive investigations on the foothill interconoid systems (from alluvial plain to marshy-continental environment) and on the intravalley terraced surfaces of the valley floor, corresponding to unit b_3 under the structural and geometric profile (chrono-isotopic correlation MIS 3 *sensu* Farabegoli and Onorevoli (1996, 1998).

Significant potential signs of these territorial segments come from the Villa Bignami deposit (S. Lazzaro di Savena - BO), where typological elements dating from the final Middle Paleolithic (discoid cores and Levallois recurrent centripetal associated with Levallois lithotechnics), come from a paleosurface covered by pedogenized silts.

In a broader view, these deposits probably represent the remains of a more complex settlement system in which the gypsum micro-area and the neighboring areas were placed on the margins of major macro-ecosystems, generated by the opposite large Adriatic plain and, more to the South-East, by the Apennine terraced borders rich in petrographic resources.

Highly adaptable human groups occupied and shared this vast territorial district adjusting, from time to time, not only to the physical characteristics of the places but even to their extremely diversified geo-environmental conditions.

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