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Assessing Neanderthal land use and lithic raw material management in Discoid technology

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Summary - *Neanderthal groups developed different models of mobility and exploitation of resources across their territory: these differences can be linked to various knapping methods and are probably related to adaptative strategies and responses at many ecological and cultural levels. Neanderthals associated with Discoid knapping are known to depend on an opportunistic exploitation of lithic raw materials for daily food procurement and be more mobile than others using different technologies. However, we have no defined data for most of the geographical contexts where this technocomplex was found. This study analyzes the southern Alpine site of Grotta di Fumane, where the final Mousterian is characterized by the succession of well defined cultural entities. Unit A9 presents with entirely Discoid technology and is embedded between fully Levallois levels. The level was recently extensively investigated for almost 68m^2 on 9,000 lithic pieces. To study the lithic assemblage of Unit A9 we applied a techno-economical analysis designed to infer the spatial fragmentation of the reduction sequences, and results were corroborated through the characterization of cortex and raw materials based on geological surveys and experimental comparisons. Results show that raw materials collected within a radius of 5km, by far the most frequently used, exhibit complete and ordinary reduction sequences, which were further attested by multiple refittings. Beyond this area, semi-local raw materials (5-10 km) are introduced to perform specific tasks, and are reduced according to their different physical qualities. These data, combined with the presence of lithotypes and fossils collected from longer distances (ten to hundreds of kilometers), and to the recycling of old patinated artifacts, indicate a complex and diversified behavior encompassing both: a) opportunistic and daily residential exploitation within a local territory; b) logistical planning of the economical organization in the semi-local to exotic territory according to quality and distance of available raw materials sources.*

Keywords - *Knapped stone, Economy, Territory, Mobility, Late Middle Palaeolithic, Italy.*

Discoid Neanderthal mobility in the context of late Mousterian

The contribution of lithic technology and economy to the reconstruction of Neanderthal land-use patterns has been expressed in a large number of studies focused on Western Eurasia. These studies demonstrate the existing variability in exploitation and circulation of lithic materials by Neanderthals within their respective landscapes, equipped with different sets of cores, flakes, and tools, as expressed by complete or fragmented reduction sequences. In the southwest of France, especially, territorial patterns of circulation and use were derived from information regarding resource utilization, including knappable rocks and their transport (Turq *et al.*, 2017). Regions with contrasted landscape and ecological scenarios, such as mountain chains, are of particular interest for detecting this variability in human behavior (Adler & Tushabramishvili, 2004; Bernard-Guelle, 2002; Biagi *et al.,* 2016; Jaubert & Bismuth, 1996; Meignen & Brugal, 2001; Terradas & Rueda, 1998; Tillet, 2001). The Alps, which are comprised of diverse contexts at different elevations, including plateaus, ridges, slopes, and valleys, therefore represent a particularly suitable context for such studies (Bona *et al.*, 2007; Tillet, 2001).

Neanderthal mobility to and from the Alpine fringe has been investigated in various regions. Despite the diversity of contexts in which lithic technological studies have been carried out (such as in the Vercors; Bernard-Guelle, 2002), the latter have always focused on Levallois technology. The Levallois is notable for its clear dichotomy between objectives and by-products (cortical flakes, maintenance flakes, exhausted cores) as well as its flexibility, made possible by the versatility in the application of diverse methods, always under the control of an elevated conceptual elaboration. The techno-economic analyses of a Levallois assemblage could thus produce descriptive comparisons for reconstructing planning depth, specialized activities, and determinations of ephemeral as opposed to prolonged site occupation.

In contrast, studies and models of the way in which Neanderthal groups using Discoid technology organized their economy and land-use are sparse in Europe. For instance, cyclical and seasonal residential movements were inferred in southwestern France from data on the exploitation of migratory ungulates like bison and horse. These faunal remains showed different patterns from those associated with Levallois systems, which were more targeted on the exploitation of less migratory species (Delagnes & Rendu, 2011). In the Alps, data of this kind are even scantier.

Across Europe, Discoid technology was noted to be less predetermined but more prolific and versatile/flexible than the Levallois for several reasons, the foremost being the recurrent nature of its reductive and productive concept which allows the maker to obtain a full series of products by concatenating the exploitation of surfaces and facilitating the detachment of both predetermining and predetermined pieces without alternating phases of shaping. Moreover, its greater versatility translates into its applicability to a quantitatively larger range of raw materials than Levallois and laminar technologies. This would make it less restricted by ecological constraints, as in the case of contexts devoid of high-quality raw materials, and more inclined to the interchangeable exploitation of local raw materials (Turq *et al.,* 2017).

In this regard, some western European sites offer emblematic examples, such as Scladina Cave in Belgium (level 5, OIS 5) (Moncel *et al.,* 1998), Coudoulous I (OIS 6), Les Fieux and La Borde (OIS 6) (Jaubert & Farizy, 1995; Jaubert & Mourre, 1996), Champ Grand and La Baume Neron (Slimak, 1999), and Combe Grenal (Faivre *et al.,* 2014) in France. In these sites, both Discoid and Levallois reduction techniques are present in the same occupation levels, but the two technologies are applied to different raw materials. The Levallois is generally associated with higher quality and occasionally allochtonous raw materials, whereas the Discoid is associated with strictly local materials, regardless of quality. In these cases, the Discoid seems to represent a technology through which the exploitation of local resources is maximized, whereas final reductions to meet different objectives are only secondary. This type of behavior is also attested in the Iberian Peninsula (Carrión *et al.,* 2008), where Discoid and Quina were both manufactured from quartzite and flint, while the Levallois was often made only of raw materials of the highest quality. In contexts that are geographically closer to Grotta di Fumane, the Mousterian lithic assemblages of the Alpine arc include the undatable open-air site of Monte Cason (where Levallois is on allochtonous raw materials, and Discoid on local) (Bertola & Peresani, 2000), and Ciota Ciara cave (Daffara *et al.,* 2014). This behavior is also recorded in Liguria at Barma Grande, Riparo Mochi, and Riparo Bombrini in the Balzi Rossi, and in Arma de Le Manie (Peresani, 2003; Negrino, 2002; Bietti & Negrino, 2007), although new studies suggest a gradual decrease of the Levallois concept between OIS 4 and OIS 3 in favor of the Discoid that accompanies a different territorial network of raw material supply (Rossoni-Notter *et al.,* 2017).

However, at some sites and levels in the European record, the Discoid method is also present as an "exclusive" technology, and is thus not only a "supporting" procedure for the maximization of production and the exploitation of local resources. Apparently, this reduction system does not seem to be indicative of planning depth, but of a place-provisioning strategy, aimed at short-term exploitation. In these cases, as already investigated by Delagnes & Rendu (2011), the bearers of this technology would be characterized by increased seasonal mobility in which lithic production, being internally diverse and well ramified, yields a high potential for adaptation to immediate needs.

Discoid "planning" in the use of resources can be interpreted from this perspective as a totally opportunistic method. Its advantage seems to reside in the possibility of maintaining a high potential for adaptation and renewal through the adoption of strategies that are less subjected to environmental constraints. This behavior can, in these contexts, be interpreted as a rational and planned response. In contrast, the broad technological flexibility of the Discoid has never been linked to a diversification in the use of resources or to a systematic fragmentation in the operative chain.

Aiming to generate new evidence on land-use patterns for future comparisons between the Levallois and Discoid technological systems, a complete study of nearly 9,000 flaked stones comprising the Discoid assemblage of the A9 stratigraphic complex at Grotta di Fumane, a key site in the north of Italy (Peresani, 1998; Delpiano, 2014), was carried out. Unit A9 represents a suitable context for obtaining this type of information, because it consists of a palimpsest of numerous and repeated occupations over time, as it is testified by overlapping combustion structures and an elevated density of lithic artifacts and faunal remains. Within this unit the Discoid flaking method is presented as a well-defined tradition, clearly distinct from the other technological traditions ascribable to the Levallois method that were adopted both before and after by Neanderthal groups at the same site (Peresani, 2012).

The environmental and archaeological context of Grotta di Fumane, Unit A9

The eastern Italian Alps represent a physical and environmental barrier where in the late Middle Palaeolithic ice fields and Alpine glaciers developed during cold stages, and vegetation recovered during warm interglacial periods. The southernmost fringe, the pre-Alps, which separates the Alps from the alluvial plain, is a succession of short chains and mountain groups, whose elevation exceeds 2000m and karstic high plateaus reaching 1000-1600m. The pre-Alps are cut by gorges, large valleys, and wide basins, which are crossed by rivers or occupied by glacial Alpine lakes such as Lago di Garda, in proximity to Grotta di Fumane. The Alpine foreland is a large alluvial plain that originated primarily during the Middle and Late Pleistocene from the region's main rivers: Po, Adige, and the rivers of the Friulian-Venetian plain (Fontana *et al.,* 2008; Monegato *et al.,* 2011). This region also includes hills of different origins, such as the Berici karst-plateau and the cone-shaped volcanic reliefs of the Euganean Hills, which are separated by the Brenta paleo-river alluvial plain.

Grotta di Fumane is located in the Veneto pre-Alps, at 350m of elevation in the western part of the Monti Lessini, a fan-shaped plateau dipping gently towards the alluvial plain of the Adige River in the south, with summits reaching 1500-1600m a.s.l in the north. To the west of Fumane, the plateau ends at the Adige Valley, a long and deeply incised valley connecting the inner Alpine region with the Po Plain. The immediate surroundings of the cave are composed of several morphotectonic terraces connected to the bottom of the Fumane valley by steep slopes and rock walls that include many caves and shelters. The cave is strategically placed due to its geographic setting, which may have facilitated human penetration to the highlands (Fig. 1).

Excavated over a surface of 68m², Unit A9 is part of the Late Middle Paleolithic deposits and consists of numerous thin to very thin parallel levels and lenses with dense archaeological remains and human teeth (Benazzi *et al.,* 2014). Layer A8,

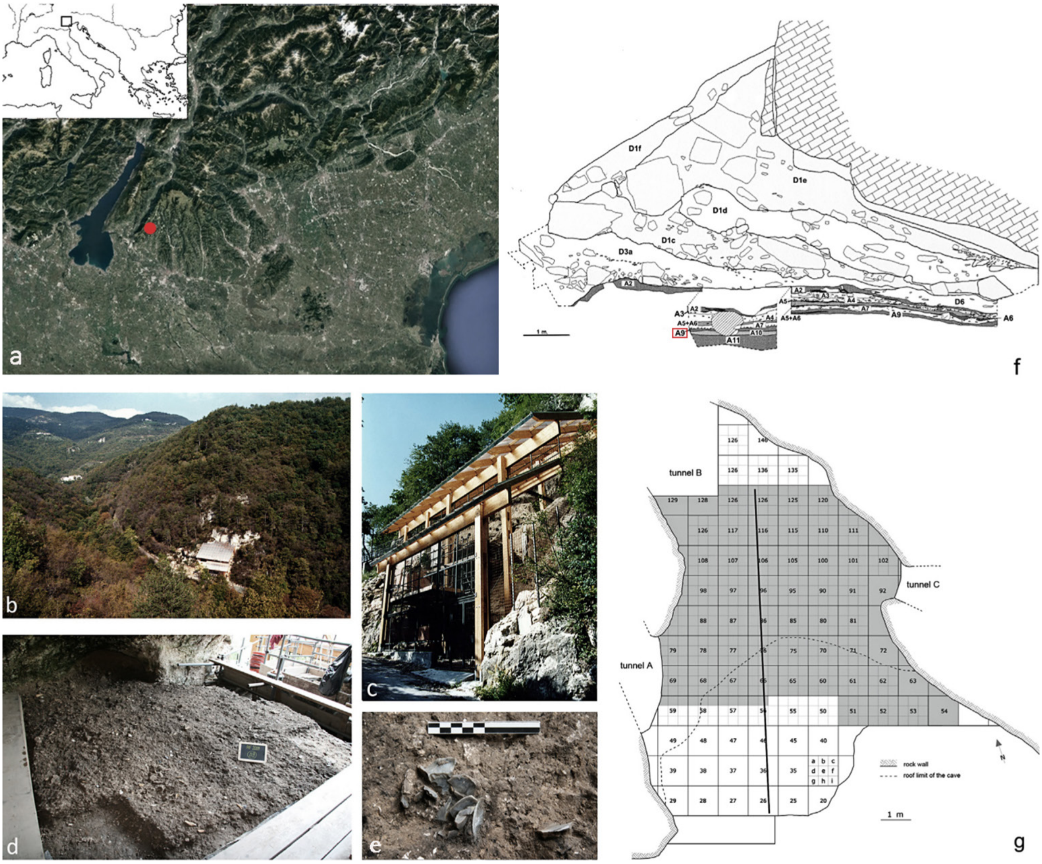


Fig. 1 - The northern Adriatic region with the location of Grotta di Fumane (red) (a); Vajo di Manune view (b); the site (c); level A9 during the 2009 excavation (d); the lithic concentration of structure A9II_SXLII (e); sketch of sagittal section of the cave with evidence of the late Mousterian (A11-A5), Uluzzian (A4-A3) and earliest Aurignacian layers (A2) and of their variable content in archaeological remains (increasing from light gray to dark gray and black) (by M. Cremaschi & M. Peresani) (f); plan of the cave with zone of origin of the materials in gray and position of the section above (g). The colour version of this figure is available at the JASs website.

only present in an area outside the cave (Bartolomei *et al.,* 1992), is considered to be a facies of Unit A9.

Different sources of data have contributed to reconstructions of the ecological framework of this late Mousterian sequence. The micro-mammal and large-mammal data show temperate and relatively moist conditions and an expansion of woodland and forested habitats from A11 to A9, as evidenced by the abundance of the ungulate species, red deer and European roe deer (Fiore *et al.,* 2004; Romandini *et al.,* 2014; López-García *et al.,* 2015). The ecological framework shown from the avifaunal assemblage reflects diverse environments, including rock cliffs and Alpine meadows, mountainous zones and ponds, high mountain woodlands, and sub-Alpine forests (Fiore *et al.*, 2016). Additionally, an anthracological investigation carried out on A9 attests to the presence of larch, spruce, pine and birch species (Basile *et al.,* 2014). The associated faunal remains are dominated by cervids (*Cervus*, *Megalocerus,* and *Capreolus*), followed by bovids and caprids (*Rupicapra* and *Ibex*). Hunting focused on adult and old individuals (Romandini *et al.,* 2014). Results show that hunting activity was not specialized to target one or several selected taxa, but was rather shaped by the game availability in the western Lessini, and that well-established, cost-effective patterns were used in carcass processing. Considering the ^{14}C ages obtained from overlying units, known biases due to sample contamination in this age range, and the ESR result, it is probable that the oldest of six ^{14}C dates (47.6 ky cal BP) is the most reliable minimum age for Unit A9 (Peresani *et al.,* 2008).

Unit A9 also yielded a fragmentary Miocene-Pliocene fossil marine shell, *Aspa marginata*. According to palaeontological and taphonomic data, it has been ascertained that the shell was collected by Neanderthals at a fossil exposure probably located at more than 110km from the site, from Miocene and Pliocene exposures south of the Po Valley. The closest fossil *Aspa marginata* shells are also reported as occasional findings in the Veneto region, near Cornuda and Anzano di Vittorio Veneto, and the Lombardy region. Traces of ochre, striations present on the inner lip, and other aspects suggest that the shell was modified and suspended by a 'thread' for visual display as a pendant (Peresani *et al.,* 2013).

Previous studies on the A9 lithic industry

Previous studies of the flaked stone assemblage of Unit A9 have highlighted the technological variability of Discoid Mousterian, revealing that the technological system was structured in two reduction sequences: the most common involved the reduction of blocks, whilst the second, less productive approach, entailed the exploitation of flake-cores (Fig. 2). The common goal of both sequences was to produce short, strong, and sometimes pointed implements such as pseudo-Levallois points, backed flakes, and sub-circular, squared, or triangular flakes (Peresani, 1998). The main reduction sequence exploited blocks, slabs, and nodules, whereas the secondary used flake-cores originated either from by-products (cortical flakes) or flakes introduced directly onto the site. The cores began to yield usable blanks right from the initial steps, with their outlines gradually changing from unidirectional to Discoid. The flakes thus became shorter and simple schemes

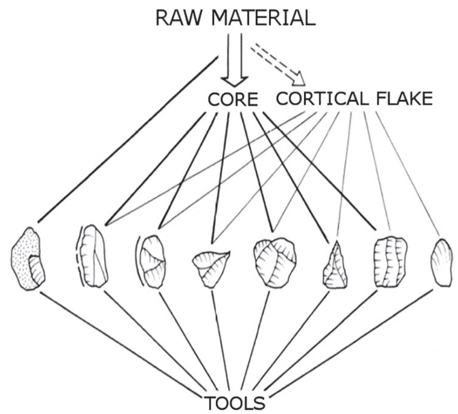


Fig. 2 - The Discoidal reduction strategy at Fumane (by Peresani, 1998). Ramification of the Discoid lithic production in A9; the reduction sequences are organized along two parallel or divergent axis: the main one on blocks and nodules and aimed at the production of thick flakes; the secondary one on flake-cores, obtained directly at flint sources or in the first stages of the main reduction sequence (From Peresani, 2008).

with one or two parallel or convergent detachments were replaced by centripetal schemes. There are also modifications in the morphological and functional arrangements and core face convexities, whose outline can become polyhedral. According to Meignen *et al.* (2006), the reasons for this "changeable" nature of Discoid reduction sequences can also be justified as economic choices. However, such a kind of organizational planning of operative chains could lead to the obtainment of a range of blanks, all of which fulfill a broader range of needs.

Data achieved from a functional study on specimens from A9 Unit, however, show that - although with some exceptions - different types of motion and action are randomly distributed across the sample. Furthermore, the different kinds of blanks- both retouched and unretouched - were used in similar ways in the processing of hard to moderately-hard more than hard to very-hard material. The motions are variable, with transverse being more frequent than longitudinal, unidirectional, and bidirectional. Given the considerable thickness of the sample of analyzed blanks (mean

Tab. 1 - Total count (N and %) of the A9 lithic assemblage, composed of 8,860 pieces. Artifacts are grouped on the basis of raw materials (Bi, SR, SVA, Ool, Eoc, and Other/Exotic) and listed according to the techno-economical categories belonging to the reduction sequence phases. Ind =indeterminate; TOT= total.

	OOLITIC		BIANCONE		S. VARIEGATA		S. ROSSA		EOCENIC		OTHER/ EXOTIC		IND.	TOT.
STAGE	N°	%	N°	%	N°	%	N°	%	N°	%	N°	%	N°	
Block/Pre-core	0	0.0	8	0.2	0		0		0					
Cortical (>50%)	7	4.7	643	12.5	113	11.9	149	10.7	9	3.7				
Semi-cortical (<50%)	8	5.4	794	15.4	113	11.9	204	14.7	17	6.9				
Cortical fragment	14	9.5	409	7.9	82	8.6	135	9.7	16	6.5				
Scale	0	0.0	119	2.3	18	1.9	42	3.0	0	0.0				
Debordant cortical fl.	0	0.0	67	1.3	10	1.1	17	1.2	4	1.6				
Undifferentiated flake	9	6.1	431	8.4	80	8.4	119	8.6	41	16.7				
Natural backed fl.	3	2.0	200	3.9	28	2.9	37	2.7	9	3.7				
Pseudo-Levallois point	3	2.0	180	3.5	39	4.1	37	2.7	17	6.9				
Débordant fl.	7	4.7	325	6.3	41	4.3	91	6.6	18	7.3				
Centripetal fl.	10	6.8	429	8.3	75	7.9	93	6.7	17	6.9				
Centripetal overshoot fl.	1	0.7	26	0.5	5	0.5	8	0.6	1	0.4				
Unipolar fl.	7	4.7	9	0.2	4	0.4	5	0.4	8	3.3				
Kombewa-type fl.	22	14.9	390	7.6	66	6.9	87	6.3	28	11.4				
Crest removal fl.	3	2.0	58	1.1	14	1.5	15	1.1	4	1.6				
Repair fl.	2	1.4	71	1.4	12	1.3	29	2.1	4	1.6				
Core	1	0.7	102	2.0	18	1.9	32	2.3	4	1.6				
Core fragment	0	0.0	21	0.4	5	0.5	14	1.0	0	0.0				
Core-on-flake	5	3.4	158	3.1	36	3.8	43	3.1	5	2.0				
Knapping mistake	3	2.0	286	5.5	49	5.1	54	3.9	9	3.7				
Syret accident	1	0.7	39	0.8	9	0.9	11	0.8	2	0.8				
Levallois piece	1	0.7	31	0.6	12	1.2	4	0.3	0	0.0				
Indet. Retouched piece	0	0.0	9	0.2	1	0.1	4	0.3	0	0.0				
Retouch flake	0	0.0	0	0.0	1	0.1	3	0.2	0	0.0				
Indet. fragment	42	28.4	379	7.4	133	14.0	158	11.4	32	13.1				
Other	0	0.0	1	0.0	0	0.0	0	0.0	0	0.0				
Double patina			32	0.6	11	1.1	20	1.4						
Limestone flakes											2			
Alloctonous pieces											32			
TOTAL	149	1.7	5185	58.5	964	10.9	1391	15.7	245	2.8	34	0.4	892	**8860**
% of determinable		1.9		65.1		12.1		17.5		3.1		0.4		

value=11mm), the interpretation of the Discoid artifacts- although biased from partial alteration of the potentially workable edges- is that of “strong” blanks, suitable for the processing hard and very-hard materials (Lemorini *et al.*, 2003).

From these data, a complete analysis to a much larger assemblage, composed of the artifacts extracted in the excavation campaigns between 2009-2013, has been carried out following a techno-economical approach which takes into account the development of the reduction sequences for every exploited raw material, and the GIS localization of their primary and secondary sources.

Materials and methods

The conceptual and analytical approach was inspired by E. Boëda (1993), with a widening of the basic criteria used to define this flaking method (see papers in Peresani, 2003). To reconstruct the reduction sequences, diacritic, morpho-technical, and morphometric analyses were conducted on the cores, complete (and fragmentary unless indeterminable) Discoid blanks, by-products deemed to have had a significant role in production, and some refitted pieces. The analysis was limited to artifacts of dimensions (length + width) greater than 4cm, including all fragments. The lithic assemblage therefore amounts to 8,860 pieces, of which 892 (10.1%) were not taken into account, as they are considered indeterminable from a lithological and techno-economic point of view due to heavy patination or thermal alteration. Amongst the 7,968 products for which analysis was possible, the primary and secondary products number 7,516; cores and residual core fragments total 444, and shaped cobbles number 8 (Tab. 1).

The reduction sequences were replicated with a stepwise experimental testing method. Certain types of exploitation, such as the reduction focused on the ventral faces of large cortical flakes, have been termed ‘Kombewa-type,’ with reference to the adaptation of the Kombewa technology to the Levallois concept (Dauvois, 1981).

Reduction sequences have been broadly reconstructed for each group of flint using artifact techno-typological categories that possess economic value within the sequence; this characterization was based on features related to supply (cortex presence and quantification), management (preparation/restoration or technical purpose), full production (usable blanks and presence of retouch) and abandonment/recycle stages.

Cortical analyses were undertaken in addition to the lithological and techno-economic analyses in order to determine provisioning from primary outcrops or secondary sources (streams, palaeosols, recycled old patinated artifacts) and the form of the exploited raw materials (block, slab, nodule, cobble). The cortical analyses were conducted on a sample of cortical flakes (>50% and >20% cortex), cortical fragments, cores, and cores-on-flakes, which together represent 16.4% of the assemblage and nearly 40.0% of the cortical assemblage. The raw materials were differently sampled: Scaglia Rossa, Scaglia Variegata, Eocene (Tertiary) and Oolitic (Tenno Formation) cortical assemblages were analyzed at between 90 to 100%; Biancone flint cortical assemblage was analyzed at 25%, including the totality of cortical cores, core fragments, and cores-on-flakes, but only 20% of cortical flakes. However, as Biancone is so highly represented (65%) in the assemblage, the number of analyzed pieces (n=419) is relevant and comparable to both Scaglia Rossa (n=481) and Scaglia Variegata (n=518). Tools were classified using general typological groups that include blanks shaped at variable level of retouching and some specific unretouched products like pseudo-Levallois points bearing traces of use.

The economic context: distribution of the exploitable lithic sources

The macroscopic features (texture, structure, color, and morphoscopy of cortical surfaces) of the exploited flint vary according to their associated carbonatic formations, which, in the western Monti Lessini, are dated from the Upper Jurassic to the middle Eocene (Fig. 3). The oldest flint formations outcrop at the surface at higher altitudes,

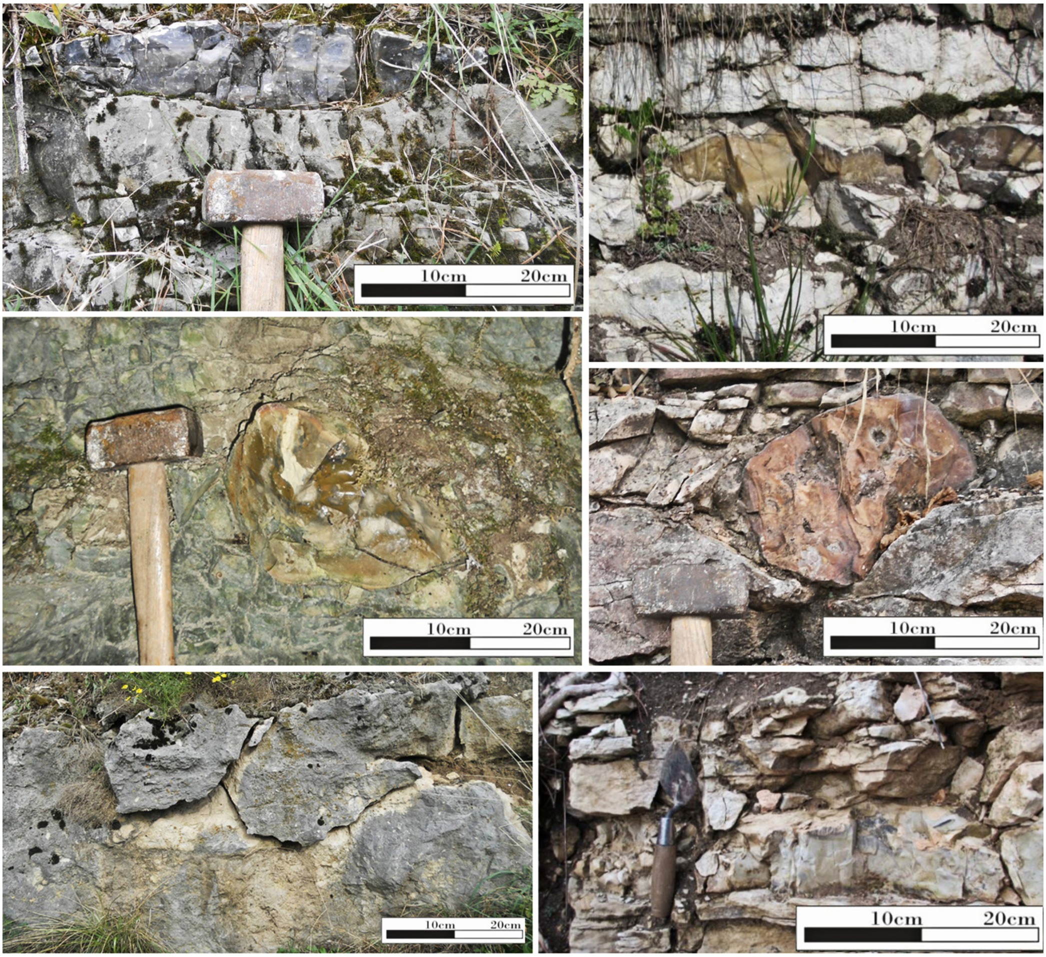


Fig. 3 - Lithic prospection of primary exposures in Western Lessini area: Bi grey (a) and Bi yellow (b) flint slabs; green-yellow SVA flint nodule (c); SR flint nodule (d); Oolitic sandstones of Tenno Formation (exposure lacking in flint (e); Eoc flint slab (f). The colour version of this figure is available at the JASs website.

towards the high reliefs of the Monti Lessini, while the more recent outcrops (except few very limited exposures on the plateau over the Fumane Valley) are found below, making contact with the Quaternary plain. This stratigraphic "inversion" is due to the pronounced incline of the above-mentioned formations, which is greater than the gradient of the slopes. The most widespread flint types are the Biancone (Bi) and its varieties, and the Scaglia Rossa (SR) and Scaglia Variegata Alpina (SVA). Conversely, flint from other formations like Tertiary sandstones (Pietra Gallina and Pietra d'Avesa; Eoc) and Oolitic limestone (Tenno Formation; Ool) is rare (Fig. 4). The associations reflect the lithological variability of the Valpolicella, an area rich in easily provisionable knappable rocks within a range of 5-10km from the site, where the flint is also available loose in fluvial and stream deposits and in deposits on the slopes and in the soils. Most of the raw material introduced onto the site is provisionable at not less than one linear kilometer from the cave (Bi, SVA, and SR flints). Other raw materials (Eoc, Ool) outcrop from 5 to 10 km as the crow-flies from the site, whereby they've been defined as "semi-local". Also to be noted is the use of older patinated artifacts, recovered elsewhere and exploited as cores or retouched tools (Peresani *et al.*, 2015).

The Ool flints originate from marly limestone, marls, and calcarenites in the Jurassic Tenno formation, which outcrops 5km away in the upper Valpantena and Adige valleys. Within the Bi micritic limestone formation, which thickens out from the western to the eastern fringe of Monti Lessini, several flint varieties are found. Dark yellowish and gray flint outcrops extensively in the western series and in the Fumane valley, is abundant in stream gravels, and is highly valued because of its excellent quality. The colors often vary from light to dark gray, sometimes with colour variations within the same nodule. There are various types of flint distributed randomly in the SVA marly limestone. The gray-green (SVA-g) type has excellent flaking properties, but nodules are rare. The gray-blackish (SVA-gb) type is concentrated at the top of the formation in dark gray, thin layers, but its use is hampered by its poor quality (intense fissuring) and small slab size. The dark-reddish flints from the SR marly limestone are of excellent quality and, although not frequently provisionable in the immediate site surroundings, are present in the form of nodules along the western watershed of the Fumane basin. The succession ends with the middle Eocene calcarenites (Eoc). Again, the flint nodules are scarce, and present at least at 5 km linear distance from the site. They are gray or brown in color with *Nummulites* and *Discocyclines*, with the coarse texture of the parent rock (Bertola, 2001).

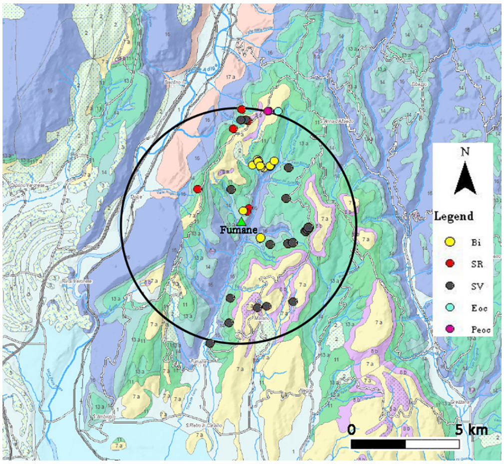


Fig. 4 - All primary flint outcrops identified during lithic prospection in 5km crow flies radius from the site overlying the geological map of the Western Lessini area, showing relevant late Jurassic through Eocene limestone formations (source: Antonelli* et al.*, 1990, Carta Geologica del Veneto). The colour version of this figure is available at the JASs website.

Results: techno-economic characterization of the lithic assemblage

The lithic assemblage shows a technology that represents the large spectrum of variability associated with the Discoid reduction concept and results in a number of technical options adopted in the course of the operational sequence. These data are broadly in agreement with what has already been established in the course of previous analysis (Peresani, 1998), with the development of two operational chains. The first involved the exploitation of medium-sized (10cm width) blocks of flint, in which primary products may have been obtained at the earliest stages, which are aimed at decortication and the creation of the crest delimiting the two core surfaces around which the entire production is arranged. The secondary reduction sequence is developed through the exploitation of large flakes as cores according to a Kombewa-type reduction that in several aspects aligns with the Discoid. In this case the crest is represented by the plane of intersection between the two flake faces, while taking advantage of the bulb as the volume of greatest convexity. The exploitation is mostly unifacial and located on the ventral surface. The development of the two sequences occurs in two different ways: a divergent one, through the exploitation of a flake-core produced during the initial stage of the main operational chain; a parallel one,

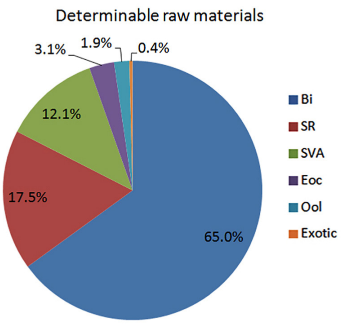


Fig. 5 - Proportions of determinable lithic raw materials in A9; local flints (0-5 km) are 94.6% of the total; semi-local flints 4.0%, and exotic 0.4%. The colour version of this figure is available at the JASs website.

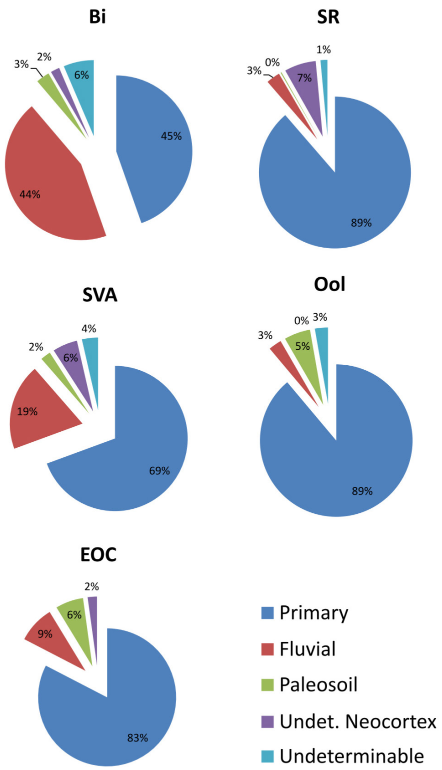


Fig. 6 - Cortex analysis and characterization of the different lithotypes, indicating the source exploited for every raw material. The colour version of this figure is available at the JASs website.

avoiding any shared technological phase during or just following the provisioning phase (Fig. 2).

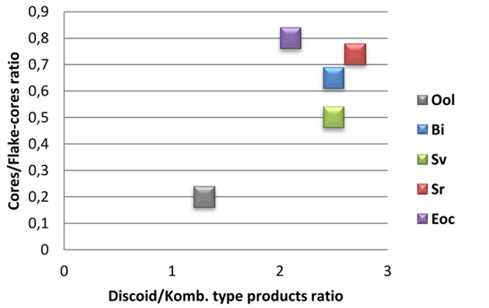
The Bi flint, which with 5,185 pieces represents almost two-thirds (65%) of the whole lithic assemblage (Figs. 5 and 8), perfectly summarizes the wide range of recognized techno-economic strategies. The large amount of intact cortical products (35% of the total pieces) suggests that the first preparation of cores occurred mostly inside the cave (Tab. 1). The splitting of the Discoid production into the two operational sequences was arranged in comparable proportions- as testified by the relatively high number of Kombewa-type flakes (390; 8.0%) and cores resulting from flake blanks (158; 56.2% of the total Bi cores). The main production is aimed at obtaining a range of typical Discoid blanks: these include 429 (8.8%) centripetal flakes, 325 (6.7%) core-edge removal flakes (*éclats débordants*), and 180 (3.7%) pseudo-Levallois points. The production, however, is interspersed by several readjustments and core preparations, resulting in a high number of by-products (586; 12%), which is proportional to the frequency of flaking errors (325; 6.7%).

Bi flint is widely dispersed in the landscape, in both primary outcrops and secondary sources in stream beds and palaeosols. The cortex analyses indicate that the provisioning of this raw material occurred at both primary and secondary sources in nearly equal measure (47.6% and 46.7%, respectively) (Fig. 6). The nearest primary outcrops are located a few kilometers to the north of Grotta di Fumane and contain blocks, slabs, and nodules of gray flint. Each of these forms was exploited for technical operations. Secondary sources are predominantly from stream beds, which include the small streams and ravines that flank the Fumane landform and surrounding area. A small percentage (2.6%) was provisioned from palaeosols in the form of blocks and undifferentiated block/slabs, and 3.1% of the analyzed assemblage shows the presence of indeterminable neocortical surfaces.

SR and SVA are respectively the second (17.5%) and third (12.1%) most used knappable stones in A9 (Fig. 5 and 8). Their complete reduction sequences attest behaviors that are comparable to those observed on Bi flint. The determined proximity of the provisioning sources (within 5km) is reflected in the overall high representation of products related to the first phases of core preparation: cortical flakes, in fact, amount to 31.4% (SR) and 29.6% (SVA) of the total lithic industries (Table 1). Production was arranged in a sequence similar to that adopted for Bi flint, with a relative predominance of the primary reduction sequence over the secondary one, and a substantial balance between chordal and centripetal products. Similar frequencies of pseudo-Levallois points are registered: 2.7% in SR flint and 4.0% in SVA. Tools, including pseudo-Levallois points and other pieces with traces of use, represent 6.9% of the SR assemblage, and 12% of the SVA assemblage. Like tool frequency, the amount of scrapers and denticulates and notches are somewhat elevated in SVA.

Detailed cortical analysis of SR artifacts reveals a preferential recovery from primary outcrops, mostly in the form of blocks and slabs (90.2%; Fig. 6). Viable outcrops containing high quality blocks, slabs, and nodules are found to the west and southwest. Lower-quality outcrops can be found within a few hundred meters of the site. The flint derived from this source, however, is not viable for knapping due to intense internal fissure network. Secondary source procurement is limited and contributes to 10.8% of the determinable sample. Whilst seldom used in this particular assemblage (3.2%), SR can be sourced in fluvial cobbles in the western stream beds that dissect the hilly local landscape. In addition, blocks and slabs from palaeosols (0.5%) only represent limited procurement sources, while 7.3% of the pieces show presence of neocortex.

Exploitation from primary outcrops is quantified as 71.7% of the analyzed cortical SVA assemblage (Fig. 6). While outcrop nature was largely indeterminable (70%), among the determinable fraction, blocks and slabs exceed the nodules four to one. Outcrops of SVA are located to the north, east, and south-east of the site, with varied abundance and quality. High quality blocks, slabs, and nodules can be found a few kilometers to the north of the site, within a few hundred meters of the nearest Bi outcrops. To the east, high quality outcrops are located at the top of the Lessini Plateau. While the plateau only dists a kilometer from Grotta di Fumane as-the-crow-flies, access



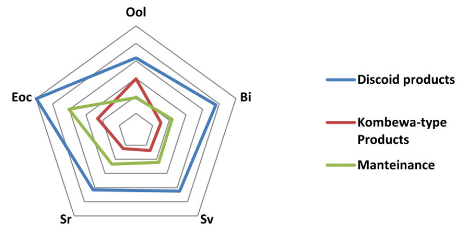


Fig. 7 - Diagram representing the ratio between main and Kombewa-type reduction sequences for each raw material: Ool lithic assemblage differs in preferential use of the secondary sequence (a); representation of the productivity rate estimated for group type of flint: the primary reduction sequence appears highly productive in Eoc, while secondary in Ool, due to planned supply, transportation, and reduction (b). The colour version of this figure is available at the JASs website.

to this landform is limited for it is surrounded by steep limestone cliffs that represent a physical impediment. To the East of the site outcrops of gray-blackish SVA (SVA-gb) can also be reached. This material is quite abundant, although it is highly fissured and thus unsuitable for knapping (Figs. 3 and 4). Secondary sources are represented by fluvial cobbles, comprising both rough cobbles (14.5%) from small stream beds in the immediate surroundings of the site, elaborated cobbles (5.5%) from more developed water courses, blocks, slabs, undifferentiated block/slabs from palaeosols (2.2%), and neocortical surfaces (6.1%).

The fourth most represented raw material in the Unit A9 lithic assemblage is microcrystalline flint from the Tertiary Eocene formations (3.1%; Figs. 5 and 9). In this case, the different ratio between techno-typological

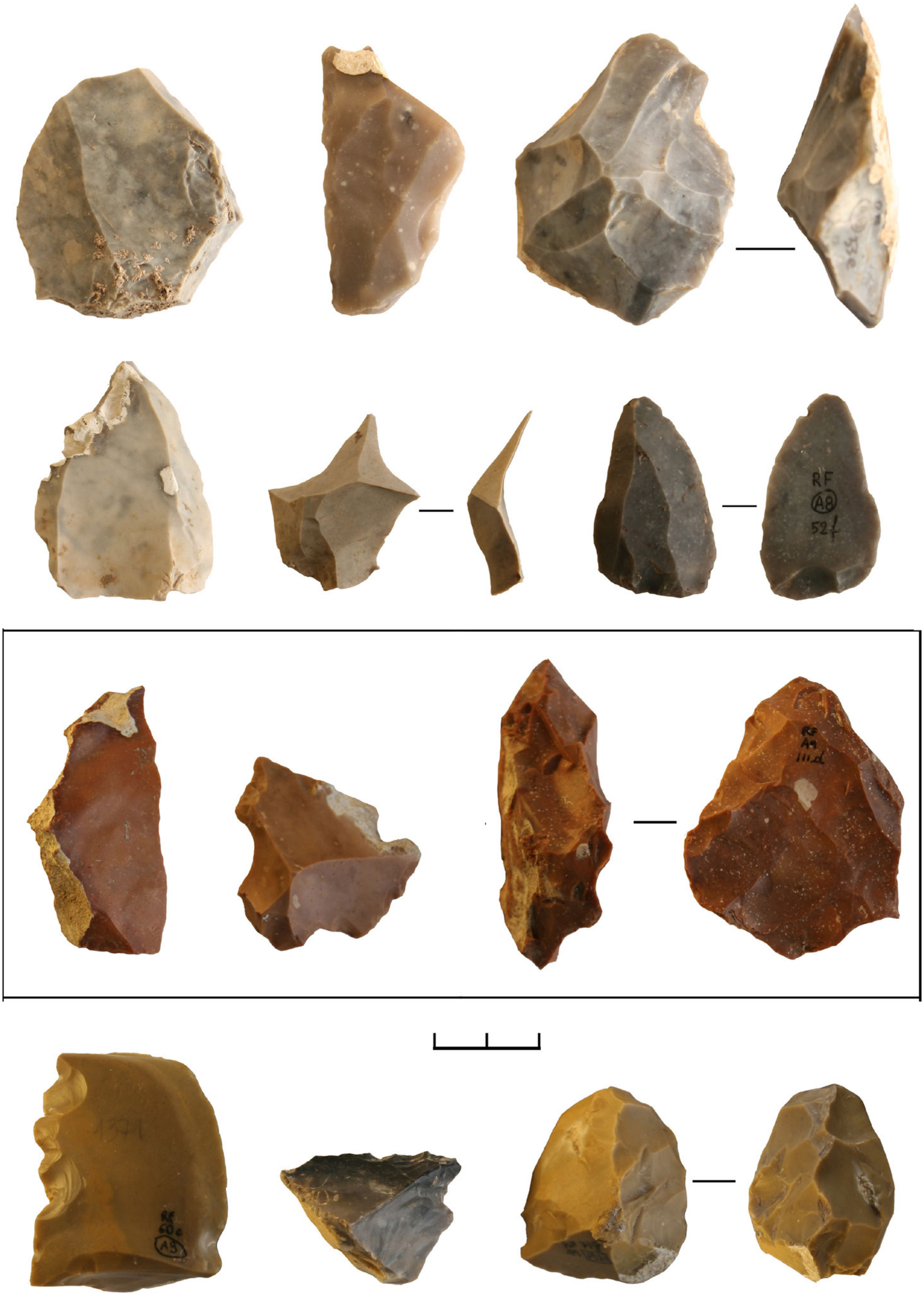


Fig. 8 – Discoid-knapping products made of local (0-5km) raw materials: Bi (gray and white varieties), SR, and SVA (yellow-green and black varieties) flints. The colour version of this figure is available at the JASs website.

Fig. 9 - Discoid artifacts made of flint from semi-local and allochtonous sources: the first band includes Eoc flint and the middle one Ool flint, from primary outcrops in lower Lessini area and high Valpantena respectively; the farthest sources are flints from Rosso Ammonitico collection areas (primarily in the higher Lessini mountains, secondarily on the gravelly Adige plain) and Rosso ad Aptici outcrops (Lombard pre-Alps), showed in the lower band. The colour version of this figure is available at the JASs website.

groups suggests a fragmentation of the reduction sequence. In fact, flakes bearing portions of cortex are considerably less common (16.5%; Tab. 1), with maximum dimensions much lower than those exhibited by other lithotypes (57mm vs a range between 67 and 91mm). The full production phase, as well as re-preparation and rejuvenation, are, in contrast, over-represented, with a very high percentage of primary products (25.4%) and by-products (25.9%), hinting at a positive selection favouring the main reduction sequence (Fig. 7). As far as the secondary sequence is concerned, a significant amount of Kombewa-type flakes (11.9%) and cores-on-flakes are recorded, nearly doubled in comparison to the cryptocrystalline raw materials. However, reduction sequences on flakes are shorter compared to ordinary Discoid products. The latter reach undeniable levels of standardization and regularity, testified by the relatively high proportion of pseudo-Levallois points (7.2%) and unidirectional centripetal flakes (3.4%).

Eoc flint in the form of nodules, blocks, and undifferentiated block/slabs outcrops approximately 5km as-the-crow flies from Fumane, while nearer primary formations have not been located. Eoc flint can also be found as nodules in stream beds. Despite their proximity to the site, these secondary sources were far less frequently exploited (8.1%) than farther outcrops, which are present in 80.7% of the analyzed cortical pieces (Fig. 6). Also little exploited were block/slabs from palaeosols (6.5%), and blocks with neocortical surfaces (4.8%). There is an interesting dichotomy between primary- and secondary-source operational sequences. Despite Eoc flint outcroppings being located further away from Fumane than Bi, SR, and SVA flints, Eoc flint exhibits full-range reduction sequences. Conversely, cobbles collected from streams are only present in the form of cortical flakes. This, along with the lack of evidence for the exploitation of such raw material obtained from paleosols (one flake/core and one cortical fragment) indicates off-site reduction sequences and the introduction of these pieces to the site and suggests that the use of such secondary source has to be considered as occasional and opportunistic.

Finally, 1.9% of the total determinable lithic assemblage was produced on microcrystalline flint from the Oolitic formation (Figs. 5 and 9). Fragmentation and a specialization in knapping reduction sequences is well attested for this raw material. Decortication and core preparation seem to have been carried out only partially at the site, as reflected by the low frequency of cortical flakes (12.7%). The amount of Kombewa-type products made with this particular material is remarkably high (15.5%), which demonstrates a preference for flake blanks. Their exploitation is further suggested by the predominance of flake-cores compared to normal cores (four out of five; Fig. 7). The main Discoid production testifies to a conspicuous production, focusing on centripetal rather than chordal products. The high frequency of Oolitic Discoid fragments (nearly 40%), is possibly due to their concentration in areas that are prone to the effect of post-depositional processes, such as the inner part of the cave. Tools in Ool flint are present with a frequency of 9.4%, which is comparable to the presence of local Bi and SR flints. This may be the result of particular technological choices such as the preferential manufacturing of centripetal products and thick flakes, which in turn may have been influenced by the microcrystalline texture and rheological characteristics of this raw material type.

Sources of semi-local Ool flint are located beyond the critical 5km radius from Fumane, making it the least accessible among all the autochthonous raw materials exploited at the site. Cortical analyses show that this flint was predominately procured from primary outcrops (92.7%; Fig. 6). While the morphology of most of raw materials cannot be determined in this case (87.5%), determinable outcrop procurement includes slabs, block/slabs, and nodules. Secondary source morphology is only determinable for fluvial cobbles (2.4%). Furthermore, palaeosol (4.9%) shape is also indeterminate. While the procurement from primary outcrops is comparable to that of the other raw materials thus far discussed (with the exception of Bi flint), the lower frequency and the above mentioned different technological organization may be a product of its poorer rheological characteristics and of the higher distance of the source from the site. As far as operational sequences are concerned, full reduction is only observed on materials from primary outcrops, while secondary sources reveal truncated reduction.

The presence of allochthonous raw materials only represents 0.4% of the total assemblage, of which 20% consists of cortical pieces (Fig. 5). The majority of the allochthonous materials seem to be ascribable to blanks obtained in an advanced production phase. 20% of allochtonous assemblage is retouched, and a single Discoid core with bifacial exploitation, obtained from the Rosso Ammonitico Veronese formation, was recovered.

The truncated reduction sequence of these allochthonous materials (mainly Rosso Ammonitico Veronese and Rosso ad Aptici) suggest that these artifacts may be part of a mobile toolkit.

The assemblage uncovered in Unit A9 also supports the possible reuse of patinated artifacts through retouch, as testified by the presence of small to medium-size flakes produced and subsequently exploited via Discoid technology. The observed cores point to low-effort exploitation with the removal of one or more short, thick flakes, while retouched tools were made exclusively on ordinary flakes (Peresani *et al.,* 2015).

Considerations: resource exploitation strategies and land-use patterns

From the above mentioned patterns in the data, we hypothesize that Neanderthals using Discoid technology exploited mainly local raw materials and, occasionally, flint that was available across large patches of land. Payoffs between transportation costs and versatility were evaluated in a manner similar to other groups exhibiting, for instance, Levallois technology (Porraz & Peresani, 2006), for which the provisioning of raw lithic materials also involved procurement within 5km of the cave. Furthermore, no particular differences between Levallois and Discoid faunal assemblages from the respective stratigraphic units (A5-A6 and A9) are observed at Fumane (Peresani *et al.,* 2011; Romandini *et al.,* 2014). Both groups were thus characterized by a logistical pattern of mobility (according to: Binford, 1980; Kelly, 1995) with one main residential site from which less frequent and targeted movements were planned within a local foraging radius, without significant extension of geographic range. Contrary to a general view that considers Discoid technology to be an opportunistic strategy for exploiting resources, the A9 lithic assemblage can be considered as an indication of prolonged – and possibily seasonal - residential occupation. The scarcity of fetal and neonatal individuals in the zooarchaeological assemblage, however, makes it difficult to identify a preferential use of the site within the yearly cycle (Romandini *et al.,* 2014).

These observations are further supported by cortical analyses which highlight the selection and management of high quality raw materials. There is a clear preference for flint exploitation from primary outcrops, which could support two, possibly not independent, hypotheses: 1) the first, that primary outcrops yielded higher quality and/or larger raw blanks; and 2) the second, that raw material procurement was linked to other subsistence activities that contemplated exploitation in these landscapes. As an example, SR outcrops yield the largest blocks and slabs although they can only be found at sources that require high travelling and access costs. While raw material form was indeterminable for the majority of material types (60.0%), outcrop exploitation seems to be more frequently characterized by a preference for blocks and slabs (87.4% of determinable pieces) over nodules (12.6%). In addition to accounting for size, this may be partially indicative of the distribution of form in the landscape (nodules are generally less common). Technological analysis and experimental study of reduction sequences suggest that the preference for these forms may instead be dependent on the amount of planning required by Discoid technology. Future analyses will reveal if preferences linked to such raw materials are in agreement with what was observed for the Levallois Mousterian layers preceding and following the Discoid Unit A9.

The exploitation of cobbles from secondary fluvial sources represents nearly 25% of the determinable raw material forms in the cortical analysis. A conspicuous portion (70%) of this frequency is in Bi flint. The privileged procurement of Bi flint from secondary sources is interesting. This is clearly the preferred lithotype by the cave's occupants (65% of assemblage), likely because of its consistently high rheological qualities, in addition to its proximity and lower procurement costs. The differences in procurement strategy between the Bi flint and other less used raw materials may represent economical choices aimed at maintaining a steady supply of this preferred raw material type. Stream beds served as a nearly immediate

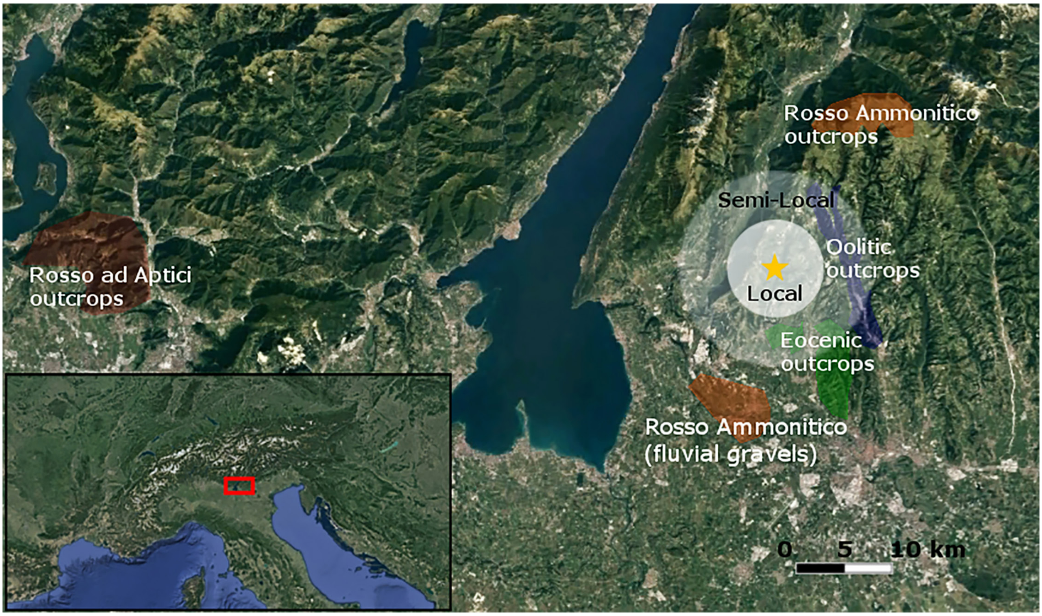


Fig. 10 - Distribution of the semi-local (5-10 km; Eoc and Ool flints) and exotic (over 10-20 km; indeterminable Oligo-Miocene) flints, Rosso Ammonitico and Rosso ad Aptici flint sources exploited in the A9 Discoid lithic industry (summertime image of northern Italy from www.visibleearth.nasa.gov). The colour version of this figure is available at the JASs website.

supply source (see Delpiano *et al.* 2017; Delpiano & Peresani, 2017), substituted by nodules, blocks, and slabs during forays into the areas of the landscape where primary outcrops occur.

It should be recalled that Eoc and Ool supply areas are located beyond the Fumane stream basin, which flows about half a kilometer from the site and carries primarily Cretaceous flints. Closer and most convenient outcrops of Ool flint are in the majority of cases located in the middle-upper Valpantena, while Eoc flint is located at lower elevations than the site. These materials were mostly procured from primary outcrops and show nearly-full reduction sequences, indicating that procurement was direct rather than opportunistic. However, the lower frequency of cortex, the lack of block-opening products, and the elevated frequency of retouched pieces in these lithotypes further support their management over time and space.

Resource exploitation strategies thus show clear evidence of lithic production planning. The proportions of some techno-typological categories deviate when local raw materials are concerned, especially when counting cortical products. The two semi-local raw materials (Ool and Eoc), are, in fact, introduced into the site as already partially worked or prepared products, in order to maximize the exploitable volume and to minimize transportation costs (Figs. 10, 11).

In this way the Eocene flint could have been introduced in the form of small blocks. The original nodules, already smaller than other raw materials, were probably tested and at the same time decorticated directly in the supply process. The Eoc lithic assemblage is the most prolific, both in terms of "primary" products and by-products or second-choice products. It is possible that, due to the greater transport distances from Eocenic outcrops to the site, the nodules were also partially reduced during the transport phase, according to a strategic mobile manufacture, resulting in an increase in the number of stone tools with reduced size.

Conversely, the Oolitic flint which is naturally present as larger nodules and beds must have required specific extraction techniques that influenced its subsequent transportation. It is likely that this material was preferably introduced to the site in the form of large flakes, which were then exploited with a Kombewa-type knapping adapted to the Discoid method. This phase was probably carried out inside the cave, as suggested by the significant amount of related products. Therefore, from these data we hypothesize that the operation of obtaining exploitable supports directly on supply sites was not opportunistic, and was rather an intentional procurement strategy in which, the first stage of the operational chain was probably performed at the provisioning site. The biggest product in the whole assemblage (106mm), a large core-edge removal flake manufactured in this flint, could represent the typical transported and blank introduced at the site following this process.

Supporting the hypothesis of a planned strategy in resource exploitation, the semi-local microcrystalline Ool and Eoc have very different physical characteristics and flaking properties when compared to the local cryptocrystalline Cretaceous flints. Bi, SVA and SR flints, which derive from marly limestone formations, reacted differently to the compressive pressures caused by tectonic stress, and are therefore more prone to shattering due to the strong cleaving and fragmenting of the rock. The Jurassic and Tertiary flints (Ool, Eoc), characterized by a weaker cleavage, present with a more limited number of fractures (Bertola, 2001). Therefore, the integrity and homogeneity of these flints, at the expense of their limited vitreosity, may have been a determining factor in their selection and exploitation. Eocene flint production seems oriented towards the obtainment of morphologically standardized products, including flakes often obtained with unidirectional exploitation of the block and regular core-edge removal flakes, as evidenced by the numeric percentages. The coarse texture of this flint does not, therefore, represent a defect in this case, where the homogeneity lends regularity to the products, and a low-prepared unidirectional scheme can be easily achieved.

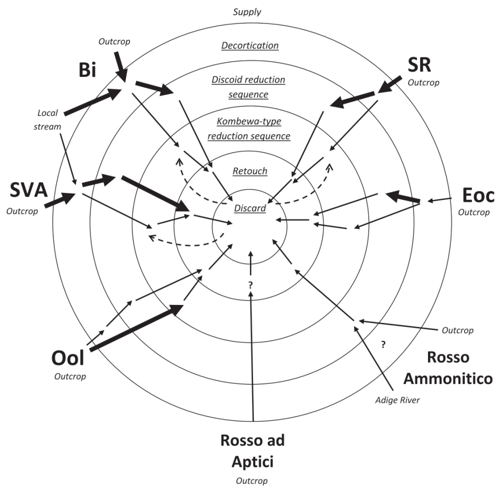


Fig. 11 - Sketch representation showing the development and fragmentation of the reduction sequences in A9 Unit for each group of flint. Concentric rims correspond to the different phases from the first (external rim) to the last (inner rim: discard of the core). The arrow represents the existence of the phase; arrow thickness means that the phase is the most represented in the respective raw material. Reversed dashed arrows indicate recycling of patinated pieces.

Conclusions: a complex behavioral and economic system

The data presented in this paper further support the existence of planning in the management of knappable raw materials in the territory around Grotta di Fumane, an area of about 200-300 square kilometers, or 10km around the site (Figs. 10 and 11). This picture is particularly relevant for a novel interpretation of the Discoid reduction method as a result of a defined technological and cultural tradition rather than a purely adaptive strategy, since it fits into a totally Levalloisian late Mousterian context where the type of occupation and resource exploitation remain essentially the same (Peresani, 2012; Peresani *et al.,* 2013; Romandini *et al.,* 2014). Evidence of long-term planning in Neanderthal lithic raw material management at a regional scale is not common in the same context. Where good quality and abundant raw materials occur in proximity of sites, operating chains are usually begun and carried out entirely within sites. Furthermore, within Discoid lithic assemblages in south-western France, a preference for local raw materials is especially attested when compared to those of Quina and Levallois technologies (Turq *et al.,* 2017).

However, evidence for planning interpreted as site specialization and systematic fragmentation of the operating chains is not uncommon for Discoid-based technologies (see Turq *et al.,* 2013; Soressi, 2005) in areas where raw materials are not close or easily available. In those cases, procurement and transportation exhibit recurrent patterns which may indicate the existence of some strategic planning. At Fumane, despite the large availability of good quality knappable raw materials, the introduction of semi-local materials with different rheological qualities to the site attests to a more or less elaborate planning.

Such behavior cannot be related to the case of a complex settlement system within which the site plays a specific and specialized role (see Meignen *et al.,* 2006). It should, however, be noted that the repeated residential occupation characterizing Unit A9 of Grotta di Fumane would not allow for the preservation of occasional episodes. The only "fossilized" picture of economic and technological behavior is currently represented by the lithic workshop in which the operational chain in Biancone flint was almost entirely refitted (Delpiano *et al.,* 2017). Among other things, this structure reveals a behavior that can be considered representative of the entire lithic production in this type of raw material, reflecting objectives, modes, errors, repairs, and the selection criteria of first choice products (Delpiano & Peresani, 2017). Considering then the occupation type and the provisioning of resources, such data enables us to advance hypotheses about economic organization and planning concerning raw materials.

It should be considered, however, that the data that lead us to these conclusions are mainly related to semi-local raw materials, representing the 5% of the entire Discoid industry of Unit A9. Most of the provisioning of lithic raw materials was likely intertwined with hunting routes and daily gathering, in turn suggesting an opportunistic exploitation. If this is true for a local radius, a planning is evident for the semi-local one. The entire analyzed assemblage therefore suggests the existence of a range of responses to the need for raw lithic materials, that took into account their quality and distance from primary and secondary sources in order to optimize management.

In conclusion, the very rare but not isolated (0.4%) presence of exotic raw materials testifies to the transportation of resources over long distances. This possibility has also been subsumed from lithic studies at Grotta del Broion, a late - Middle Palaeolithic cave isolated from sources of knappable stones in the Veneto sub-alpine area, where a Discoid flake was introduced as a finished product comparably to the Levallois ones (Porraz & Peresani, 2004). Whether these are related to mobile Neanderthal groups carrying Discoid technology or to resource exchange between different groups, they offer evidence of sporadic trips over tens or hundreds of kilometers. Different sources of data further contribute to delineating Neanderthal territoriality. These include the presence of flint from Rosso ad Aptici formations and *Aspa marginata* shell collected in areas outcropping more than 100km from the site in the Lombard pre-Alps or the Northern Apennine fringe (Peresani *et al.,* 2013). A temptative reconstruction of the possible regular movements practiced to and from the Monti Lessini from pregnant Neanderthal females and their offspring is in course based on strontium isotope analysis on the enamel of deciduous teeth recovered in Unit A9. With the hope this investigation produces positive results, a more integrated scenario will be proposed on the energy-demanding mobility strategy of the human groups settled in Grotta di Fumane.

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