

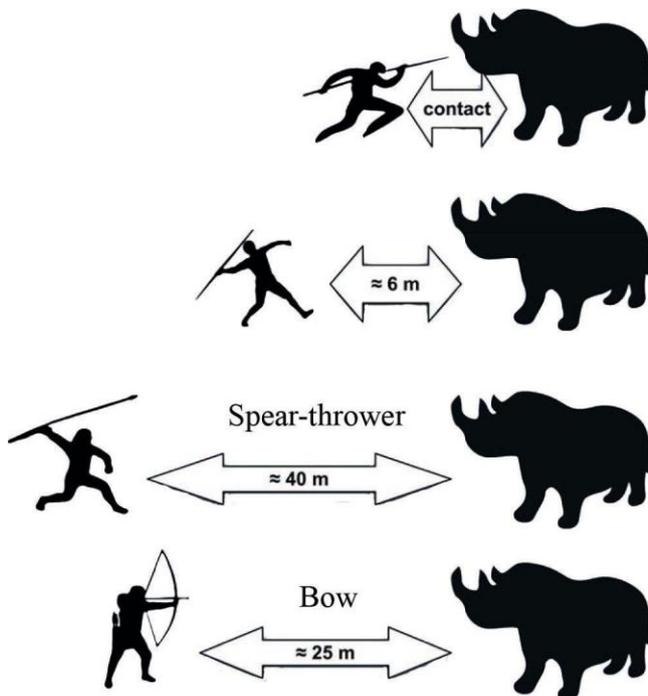
Valentina Borgia

Plants, Poisons, and Paleolithic Hunters

Introduction

The emergence of Anatomically Modern Humans (the species to which we belong) is characterized, in terms of hunting equipment, by the appearance of small stone armatures (backed tools) and osseous points.

The desire to optimize the aerodynamic and penetrative characteristics of these artifacts suggests a change in the delivery system of spears and possibly the invention of the spear-thrower -or atlatl - and the bow.



Iovita et al. 2016

The spear-thrower is a throwing weapon intended for both hunting and fishing, consisting of a stick with a hook, where a long spear is supported. With this system it is ineffective to launch spears shorter than 100 cm in length.

This tool has the function of extending the arm, creating a lever with the basin and shoulder. The impact of the spear is extremely powerful. Its range is even greater than that of a simple bow (max 40 m), but, compared to the bow, the

accuracy of the shot is only possible over short distances.

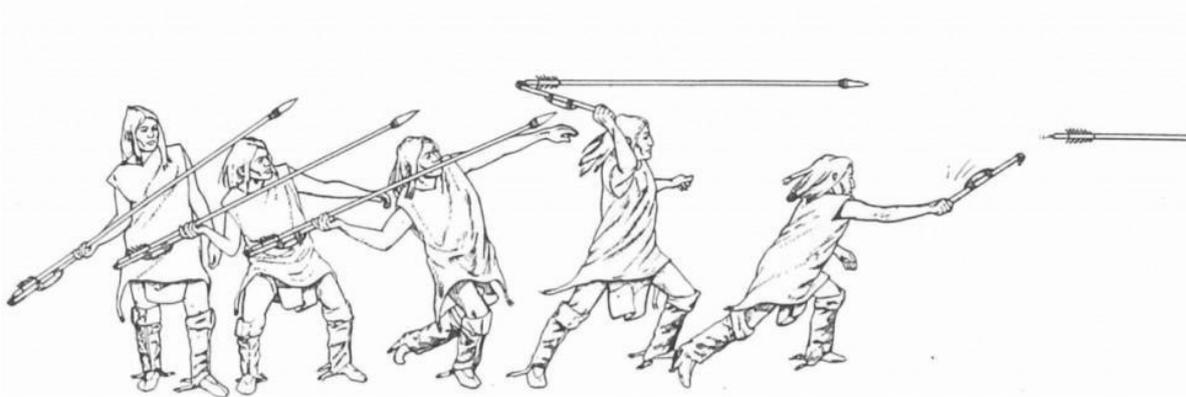
The oldest spear-throwers were found in the French sites of Combe Saunière and Le Placard (Cattelain 1998, 2004), dating to about 20,000 years from present.

The specimen found are made of bone, a durable material that can survive for very long periods. It is more likely that those weapons were frequently made of wood (since bone processing takes longer), a material that has little chance of resisting over time; we may therefore have no trace of earlier specimen.

As for the appearance of the bow, it is not possible to determine exactly when it was invented and whether it has replaced the spear-thrower as a hunting weapon.

The archaeological evidence tells us that the first specimen, though fragmentary, date back to the end of the Upper Paleolithic/ Early Mesolithic and were found in the Stellmoor peatland (only such a humid environment could allow for the preservation of wood) in Germany, and dated to about 11,000 years from the present (Rust 1943). In the site of Holmegaard (Denmark), several bows were discovered: these are dated to 8,000 years ago (Cattelain 1997). In all cases, bows are straight, made of pine wood (Stellmoor) and elm (Holmegaard). The ropes have not been preserved.

Both spear-thrower and bow allow to throw a spear/arrow to a distance of 25-40 meters, therefore far more distant than a hand-spear, which can be launched at a maximum distance of 6 meters (= very high physical confrontation).



Use of a spear-thrower

The invention of long-range hunting weapons (which might have occurred more than once) was a real revolution in hunting strategies and represents a milestone in human history. It illustrates the ultimate replacement of our phenotypic competitiveness with survival strategies based on social cooperation and the use of technology.

Killing at a distance does not require physical confrontation anymore, but the use of a “strategy of deceit” which is deeply linked (although not unique) to our species may have

been a key factor in the eventual dominance of modern humans.

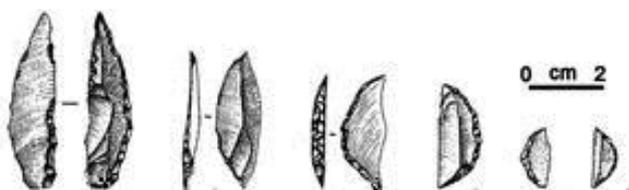
The first stone tools that are considered to be part of composite long-range weapons are the backed bladelets (also called armatures, microliths, *demi-lunes* or lunates) found in the South-African Middle Stone Age settlements dated from 70.000 to 50.000 years BP (Sisk and Shea, 2010, Villa *et al.*, 2010, Lombard and Pargeter, 2008, Churchill and Rhodes 2009, McBrearty and Brooks 2000). Backed tools are small stone bladelets with at least one of the edges having been backed (= has been retouched to create a backed edge).



In Europe, similar tools appear around 40,000 years ago, in conjunction with the arrival of Ancient Modern Humans (AMH). In the Italian site of Cavallo Cave, AMH remains (Benazzi *et al.* 2011) are associated with a lithic industry with lunates (Moroni *et al.* 2013) and with bone tools (d'Errico *et al.* 2012). This phase of material culture is called Uluzzian. We do not know to what extent the Uluzzian lunates were linked to hunting weapons, given that functional studies on these materials are still absent.

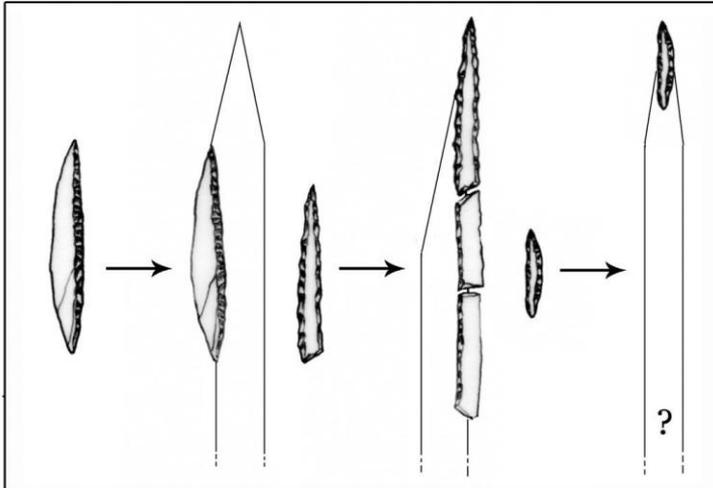
Certainly, from there forward in the Upper Paleolithic, the insertion of stone backed tools in wooden or bone shafts was a well-known technology, shared and spread (Knecht 1993; Roebroeks 1999; Letourneaux and Pétilion 2008; Borgia and Ranaldo 2009; Iovita and Sano 2016).

Technology using hard animal tissue was not less central in the production of hunting weapons. In fact, the archaeological record registers a large use of bone, antler and ivory to make spear points or spear-links.



Backed tools (lunates) from Cavallo cave (Lecce, Italy)





*Antler split-based point from Abri Poisson(France)
about 30.000 years BP (Tejero 2014)*

*Possible positions in the shaft of various typologies of
backed tools*

**Methodological approach to the
study of prehistoric hunting
weapons**

The methodological approach to the study of prehistoric hunting weapons can not fail to take into consideration every aspect and every possible piece of data obtainable from the archaeological context, from the comparison with other contexts and from the ethnographic studies. This approach can be defined as “global”.

In a global approach to the study of hunting weapons, the archaeological materials (bone, lithic points, and armatures) can not be separated by all other data coming from the same context, especially environmental data and faunal remains.

After all, in a context of active hunting with weapons, using traps, or more so hunting persistently (Liebenberg 2006), the most important skill of the hunter is the perfect knowledge of his own environment. To kill and track an animal means to be aware of all its habits and know its territory in detail, so that it can be tracked and followed during the escape.

The knowledge of the anatomy of the prey is essential for a hunter, and it must also be the basis of our studies on prehistoric hunting strategies. We need to know that the mortal wounds are those that affect the cardiovascular system and cause the collapse of blood pressure. These occur hitting the heart, or both heart and lungs simultaneously. In both cases, the animal collapses after a few meters. Even blows to the skull and the spine can be immediately fatal, but are complex shots that hunters usually do not try. In all other cases, the wounded animal will have the strength to stand up and run away: the duration of the his escape will depend on the type of bleeding and the intensity of the infection which has been triggered.

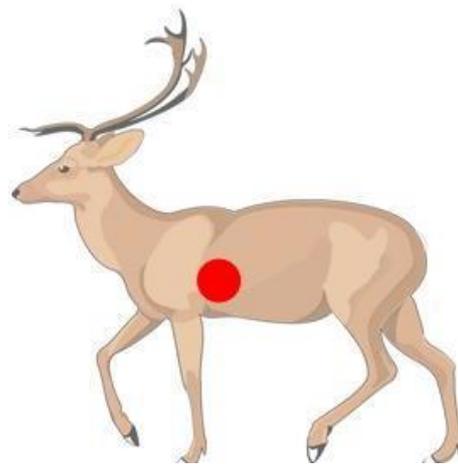
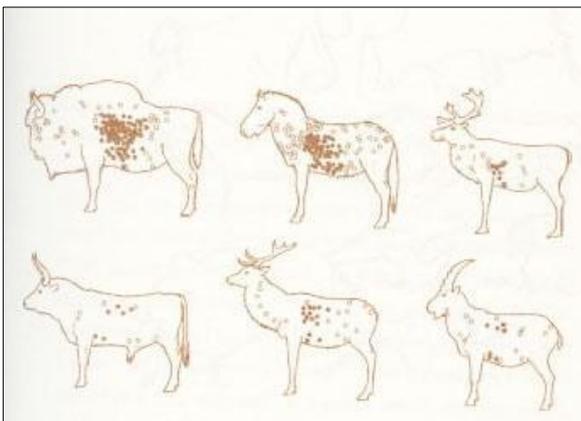
The goal of the hunters is to handle a rather short escape; if the wound inflicted allows the animal to run far, and the recovery of the carcass takes many hours, if not an entire day, the meat would be degraded. Certainly prehistoric hunters were aware that the

muscles of a fleeing, scared animal releases a quantity of adrenaline that would harden the meat and ruin the flavour.

Some kinds of wounds impairs the edibility of the meat, such as those to the abdomen, which cause the perforation of the rumen (leading to the contamination of the carcass), or the injuries to the oesophagus, causing leakage of the rumen.

Contamination of the meat has always been the first thought all hunters. The first operations of evisceration have to be performed as quickly as possible, without moving the carcass too much and certainly without waiting to bring the hunted animal at the base camp if it is far. The animal must be immediately bled, cutting the carotid. Depending on the outside temperature, a maximum of 3 to 5 hours are permitted to eviscerate and skin the animal. In fact, nothing is more dangerous than the muscles coming into contact with the gastrointestinal system, where are germs are that can lead the rotting of the meat in a few hours.

The sequence of actions taking place after the killing of the animal has been substantially identical in every place and time, as the fight against bacteria dangerous to humans is always first priority.



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Position of the spears/arrows in Paleolithic art and recommended target by modern hunters.

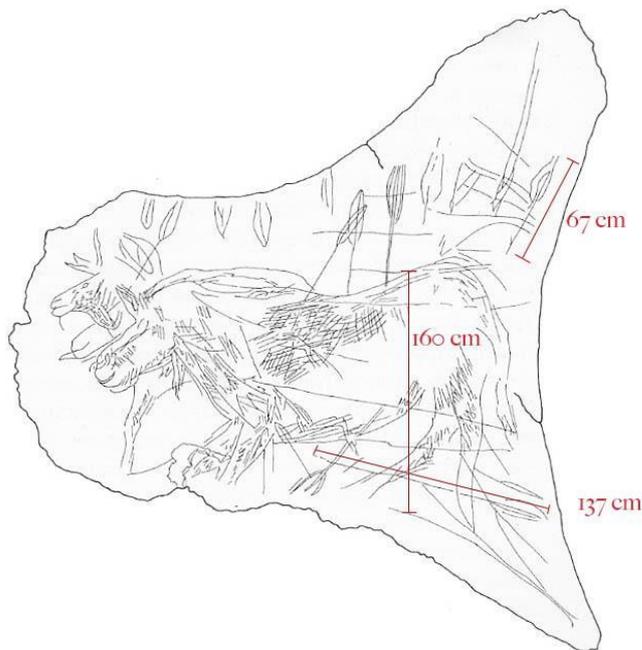
A close parallel between modern and Paleolithic hunting is also visible in the targets on animals which can be extrapolated from the artworks (Guthrie 2005): these are exactly the ones recommended by the modern hunters.

Not only. Following Leroi-Gourhan (1971), 15% of animals represented in Paleolithic art bleed from mouth or nostrils: a clear sign that it has been hit in the lungs or the heart, the best targets to bring down a prey.

While not considering prehistoric art as a mere description of reality, the information that we can draw about hunting from paintings and engravings are countless.

An interesting example comes from the Paglicci cave, in Southern Italy. The beautiful engravings on a horse basin found in the Epigravettian layer 8C (Mezzena and Palma di Cesnola 1972) represent a horse hit by several arrows. The arrows have different lengths and we can estimate their dimensions taking as a comparison the size of the prey. Palaeolithic people were extremely attentive to the anatomical details of the animals, therefore, while not considering the symbolism behind the representations, it is possible to trust the representation itself. Estimating 160 cm, the weight of the withers of the horse, the length of the short arrow (which seems to have a point and to be complete) is 67 cm. Being too short as a spear for a spear thrower, we can assume that is a bow's arrow.

Radiocarbon dating of layer 8C, 15.460±220 BP, could be compatible with the invention of the bow. In the same scene we can see a longer arrow, 137 cm, not really suitable for a



bow and therefore possibly a spear. From this picture we can assume that the 2 throwing methods (spearthrower and bow) were both known at that time, and maybe used in combination.

In this case it is necessary to come back to the archaeological material to confirm such hypothesis. At the moment the experimental studies have not been able to prove the existence of traces distinguishing the use of a spear-thrower from the one of a bow, but a promising line of

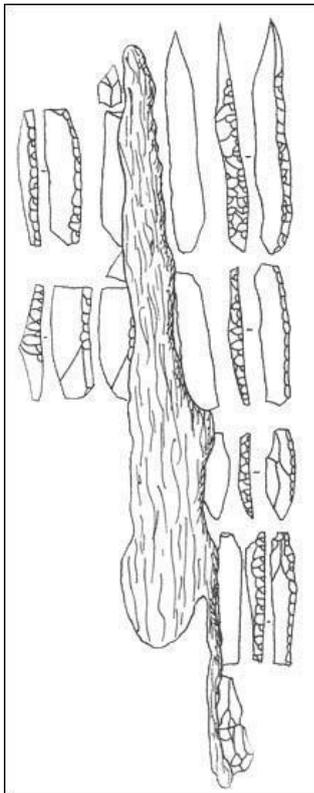
research, involving fractures propagation velocity (Iovita et al. 2016) , is now being explored.

Typological and technological data on backed tools and osseous elements are a starting point.

Stone or bone tools are part of the complex system of a throwing weapons, which comprises various elements (shaft, glue, ties, propulsion system). For these various elements to function effectively, each element needs to be fashioned in accordance with the other components and therefore needs the necessary morphological characteristics,

dimension and weight. “*The process of assembling diverse elements into a compound artifact such a projectile could be seen as analogous to the process of assembling words into a sentence. There is a grammar and an order to the tool assembly process that is partly universal and partly culturally specific; furthermore, each element of the tool can be exchanged for a different one, changing the meaning and the function of the resulting product*” (Brooks et al. 2006).

The analysis of these characteristics is carried out not in order to create a precise description of the morphologies and their attribution to a type, but rather to identify the operative chain which begins with the goal of tool production and concludes with the tool use. The information regarding the use of prehistoric utensils can be obtained primarily from the method of manufacture and then from the traces of their use (O'Farrell 1996; Gurova 1998; Soriano 1998; Perpère 2000; Montoya 2002; Grimaldi 2005; Borgia 2006 and 2009).



The functional specialization of elements of throwing weapons (armatures) or “projectile points”, which has been attributed to categories of prehistoric stone and bone tools such as the Upper Palaeolithic backed tools, is based primarily on archaeological discoveries from various regions of Europe (Nuzhnyi 1990, Skakun and Terekhina 2014). One of the most significant examples is the bone point fitted with flint armatures found at the Upper Palaeolithic site of Talitskij, in the North-Eastern part of the Russian plain (Nuzhnyi 1990), but there are also some examples of fragments of backed points found in animal bones (see Gaudinski- Windheuser 2016 for a review).

The inverse step, or to demonstrate with methods of functional analysis that those categories of tools are part of a composite hunting weapon, is a lot more complex.

The point found in the site of Talitskij

The experimental phase is at the base of the functional studies on prehistoric hunting weapons. Literature is very vast, counting on 30 years of attempts to reconstruct the operative chains linked to long range hunting, allowing scholars to experience first-hand the problems related to a very complex system (Geneste and Plisson 1989; Fisher et al. 2004; Cattelain 2004; Lombard et al. 2004; Letourneux and Pétillon 2008; Sisk and

Shea 2009; Wilkins et al. 2014; Sano and Oba 2015).

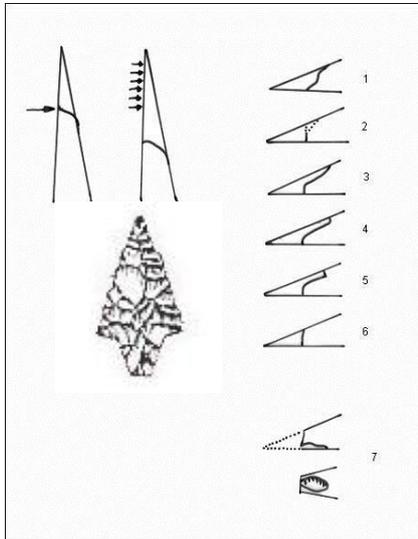
For the study of the archaeological materials it is not necessary to reproduce a hunting scene, especially because a serious experimentation should take into account a number of variables which are very difficult to manage together.

The carcass of an animal that has been dead for a long time, for example, or the gel used in ballistics, do not have the same characteristics as a live and moving animal. An experimental phase that involves the use of improbable prey/weapons is not plausible and does not add useful information to the research.

To quote the French philosopher Gilbert Simondon (1958) “There is no pure technical device free of symbolic meaning”.

Hunting is totally immersed in tradition and symbolism, which are translated into care, attention to detail, craftsmanship at the highest level. We find the same maniacal care in all ethnographic weapons: not only the technical characteristics are always punctual, but often there is room for sophisticated adornments. This is much more evident in the well crafted Paleolithic objects and this aspect is often neglected by scholars.

The most important and universally recognized method to classify impact fractures on stone projectiles points has been developed from an experimental phase by a team of Danish researchers in 1984 (Fisher et al. 2004).



stone projectiles points has been developed from an experimental phase by a team of Danish researchers in 1984 (Fisher et al. 2004).

The team carried out a hunting simulation using Neolithic arrow points accurately reproduced and emerged the significant evidence that impact tended to cause diagnostic fractures.

However, the mechanics of fractures permit only statistical observation, not an incontrovertible result: diagnostic fractures most frequently – not uniquely - occur as a result of an impact.

Classification scheme of impact fractures and the Neolithic projectile point used for the experimentation (Fisher et al. 1984)

Data obtained by the Danish researchers are inextricably linked to the Neolithic projectile points used for their experimental program and are not applicable to the very different Paleolithic armatures (Rots and Plisson 2013).

A methodological approach based on the mere typological description of stone and bone tools (dimensions, morphology, retouch) and the dogmatic application of diagnostic impact fractures on every prehistoric projectile, as well as the application of a single method of analysis and not of a global approach to the study of prehistoric materials, has negatively marked the research for more than a decade.

The analysis of impact fractures should be considered statistically and only among other data. Especially it is necessary to take into account the morphology of the objects and the possible position they could have in the shaft: it is meaningless to look for apical impact fractures on elements that were hafted laterally in a shaft.

A recent paper (Coppe and Rots 2017) offers an updated overview of the confusion generated by the terminology on impacts in use during the last 20 years and a proposal of a shared terminology and new attributes linked to the impact. This article is, to-date, a mandatory starting point for any functional study on Paleolithic projectile points.

As far as micro-wear on stone projectile elements are concerned, these are caused by friction between the surface of the tool and the animal skin, meat, or bone at the moment of the impact. These traces can be observable with a metallographic microscope at 100X-200X, but are generally very slight and are defined as linear polish or linear features.



Linear feature and polish and micro-fractures on the lateral edge of backed tools (100X -Borgia 2008)

Micro-wear analysis does not help the functional interpretation of stone armatures of composite weapons much, but the position of the polishes permits researchers to have information about the hafting of the pieces, to determine the position of the tools in the haft (Rots 2010).

Microscopic residues of the glues, resins, or the materials which have come into contact with the prey can be trapped in the surface of the flint or bone tools.

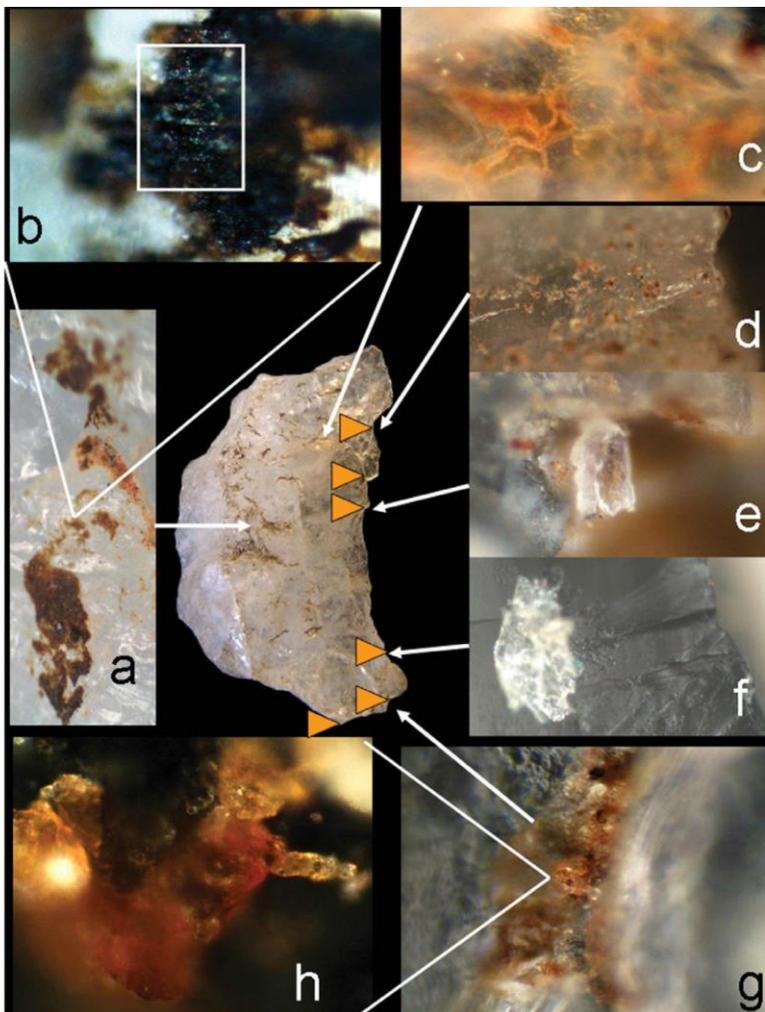
In the last years, the morphological identification and chemical analysis of these micro-residues led to a higher level our knowledge on tools function, DNA analysis, dating, site

function and cognitive evolution (Loy 1993; Hardy and Garufi 1998; Boeda et al.1996; Rots and Williamson 2004; Vandenabeele 2004; Williamson 2005; Fullagar 2006; Lombard and Wadley 2007; Veall and Matheson 2014; Wadley et al. 2015; Langejans and Lombard 2015; Borgia et al. 2017).

However, residual analysis on prehistoric projectiles points are still rare.

The main study is certainly the one of the lunates of Sibudu Cave, in South-Africa (Lombard and Pargeter 2008; Lombard and Philippson 2010; Lombard 2011). On the examined elements, various organic residues have been found (see picture on the next page). These are bone, plant, animal fat, animal tissue, and blood macro-residue suggesting the use of these tools for hunting.

This promising line of research can be determining to have objective data on glues, animal DNA, blood traces of the preys and even poisons.



Quartz lunate from Sibudu Cave, South Africa. Orange arrows indicate microfractures, a) residue of resin 50x; b)vegetable residues transversally oriented; c) blood residues; d) transversal striae; e,f) bone residues 100x; g,h) animal tissues 100x (Lombard 2011).

The “coward's weapon”, as the English playwright John Fletcher defined the poison, is further deceit that hunters could use

against the prey, so that it is immediately knocked down or at least can not run away, and not become an easy target for other carnivores.

The investigation of the use of poisons in ancient periods is an innovative field of

research, that adds to our understanding not only of the hunting techniques and rituals, but also of how the plant world was known and exploited by ancient populations, involving a network of scholars engaged in researching prehistoric hunting strategies from various points of view: archaeology, paleobotany, ethnography, chemistry, forensic toxicology, and ethnopharmacy.

And finally, my project: Plants, poisons, and Paleolithic hunters

My research project is about the development of a method capable of detecting poisons on ancient spears/arrows with the goal of going back in time in order to find when hunters started to add toxic substances to the weapons as a way of further improving their hunting success.

This project is based on some considerations:

1) Hunting always requires a good knowledge of the territory and of the animal world. Paleolithic hunters were able to make very precise observations, as demonstrated by their artistic expressions, their exploitation of the territory, and their use of materials.

We do not know to what extent, but Ancient Modern Humans had the appropriate naturalistic knowledge to recognize toxic plants and their potential.

2) Paleolithic arrows did not have good penetrating skills. From a ballistic point of view, these were not very well performing. An ethnographic research on present hunters (Noli, 1993) highlights that many weapons would be quite ineffective without poisons. Although few hunter-gatherer societies remain today, most of them are known to use poisons.

3) To use poisons is easy and economic. The risk for the group is minimal because poisons are handled by an expert and are conserved in a protected place. The edibility is not compromised: in certain cases it is necessary to cut the meat where the arrow has penetrated it.

4) Benefits associated with the use of poisons on arrows are notable: the safety distance of the hunter from the prey is enhanced, as well as the speed with which the prey is killed. The toxic substances prevent the animal from escaping too far, allowing the hunter to retrieve the prey more easily, and, at the same time, to have meat and skin in better conditions.

The fact that toxic substances were available, and the benefits arising from their

application on hunting weapons suggests that the use of poisons could have been widespread among prehistoric hunters.

The earliest supposed evidence of poisoned arrows used for hunting or war dates back to the Egyptian Predynastic period. The black compound found on the tips of some arrows found at the site of Naga ed Der tomb (2481–2050 BC) are presently being analysed but a preliminary test (rather cruel: the compound has been injected in mice) has proven the presence of a toxic substance (Stanley et al. 1974).

The first written evidence of the use of poisons, conversely, dates to the Assyro-Babylonian period. A tablet found in the Library of Ashurbanipal (7th century BC) has the following inscription: “Shoot [...] the bow. Let your arrows carry poison!” (Bisset 1989)

In the Atharva Veda (900 BC), the use of aconite to poison arrows is noted (Nougayrol 1952), as well as in the *Iliad* and *Odyssey*.

The Greek word used to indicate that something is poisoned, *toxicon*, has the same root as the word for bow, *toxon*, and both are linked to *Taxus* (Yew) the tree used to make bows, but also a very toxic plant. *Acontizo* (throwing darts) remember *Aconite*, one of the most toxic plants of the Mediterranean region.

This circle of words is very important and shows us how ancient the tradition could be, likely having its origins in prehistory.

Despite all evidences and citations from historical documents, the presence and nature of poisons on archaeological weapons has been very scarcely scientifically investigated.

The only study, so far, refers to a wooden stick (32 cm long) found in Border Cave, South Africa and dated about 24,500 BP (d'Errico *et al.* 2012). The stick is similar to the ones used by modern Bushmen to apply poisons on arrows.

The gas-chromatographic analysis carried out on the stick shows traces of ricinoleic acid (castor oil, *Ricinus Communis*), which the authors argued was the poisonous substance applied to arrows. Yet, the conclusion of the paper has been questioned (Evans 2012; d'Errico 2012), as castor oil is only slightly toxic (if not chemically treated) and not commonly used as a poison.

In a pilot study (Borgia et al. 2017), the chemical characterization of some of the best-known toxic plants has been performed by means of Liquid Chromatography – Mass Spectrometry. Samples have been collected (or purchased) and analysed to obtain standards. Major attention has been given to plants that can be found in European territory, especially *Aconitum napellum* (Monkshood), *Datura Stramonium* (Devil's

snare), *Conium maculatum* (Hemlock), *Veratrum album* (White veratrum), *Helleborus* (Hellebore) and *Taxus* (Yew).

The main challenge was to find a completely non-invasive method for sampling the archaeological materials in order to have realistic access to it. Modern analytical techniques enable very detailed chemical information even on very small samples, but the analysis involves the destruction of the sample itself, and scientific analyses involving destruction of even small parts of the archaeological materials are never permitted by the Museums or the other institutions where materials are stored.

A sampling method that modifies only partially and temporarily the surface of the specimen was tested.

A cotton swab and approximately 1 mL of distilled water was used, simply rubbing the surface of the artefacts. The swabs were then placed in a sealed container and transferred to the laboratory for analysis (Department of Forensic Chemistry, Northumbria University, UK). Swabs were treated in the same way as the plant standard prior to analysis by GC-MS and LC-MS.

Ethnographic samples were collected at the Museum of Archaeology and Anthropology of Cambridge, at the Pitts Rivers Museum of Oxford and at the Museo Etnografico Pigorini of Roma (Italy). Samples refer to pots and glass jars that contained poison for arrows, poisoned arrows and spearheads of various types coming from different parts of the world.

This preliminary work gave positive results, as it was possible to identify toxic components present on some of the artefacts, even after decades.

In another recent study Wooding et al. (2017) performed a blind test analysing poison recipes used by South-African Bushmen.

The study highlighted a great deal of difficulty for unambiguous assignments (in fact same chemical compounds can occur in different plant species), nonetheless the results also in this case have been quite encouraging. In the blind test, two on three toxic plants were identified, based on unique markers.

Despite the problems encountered, some factors play into our hands:

a) In the majority of the ethnographic arrows that we had the opportunity to examine, a dark residue (poison) was visible to the naked eye and covered most of the arrowheads; that means that the quantities of poison applied are not small: this can be of help when we try to identify toxic substances after a long time;

- b) toxic plants used for poisoned arrows have a regional nature; particular climates, or geographical places restrict the range of plants that can be used;
- c) the preparation of a poison for hunting is part of a passed-down tradition linked to a territory, not susceptible to sudden changes. In Europe, for example, the variety of toxic plants used for hunting/warfare seem to be rather limited.

My research project builds on the hypothesis mentioned above.

The methodological approach includes:

- 1- The creation of a database (with information on chemical composition by means of chromatographic and spectroscopic analysis) on toxic plants in order to compare the standards with the ethnographic/archaeological samples.
- 2- The use of ethnographic samples to assess the efficiency of the database in relation to the main research question on whether it is possible to detect plant alkaloids or cardenolides many time after they were applied to the hunting weapons, taking into consideration the implications of the findings in relation to sample preparation.
- 3 – the analysis of archaeological samples.



Clovis projectile points

Case studies for the phase of the project taking place at the Italian Academy will be the hunting weapons used by indigenous populations of North America.

Paleo Indians hunter/gatherers who lived in North America at the end of the Late Glacial Maximum (around 13.000 years ago) were equipped with hunting weapons characterized by big, fluted style, stone projectile points (Clovis) and rarely, ivory points. These weapons were likely used to hunt megafauna, as the faunal remains of many archaeological sites can testify. The use of poison on the arrows has been proposed (Haynes 2002, Osborn 2016) and now will be tested.

Modern Native Americans weapons, of which we have a lot of information (Mason et al. 1891; Culley 1936; Taylor 1940; Elmore 1944; Vogel 1949; Carpenter and Hassrik 1957; Bean et al. 1972; Frison and Bradley 1980; Hart 1981; Frison and Stanford 1982; Ellis and Deller 1997; Frison 1998; Osborn 1999), including on the use of poisons (Jones 2009), will be used as starting point of the research (as ethnographic reference) with the dual purpose 1) to improve the analytical method, and 2) to exploit useful information about the hunting strategies, traditions, and the use of toxic plants based on their presence on the territory.

Ethnographic and archaeological collections from North America often contain entire arrows, darts and spears, complete with even the most perishable components; this is an ideal opportunity from one hand to find traces of toxic substances, and to the other hand to understand better how projectile weapons could be assembled, and what traces the entire construction leaves on the surviving elements of the artefact, particularly stone points. The findings of this research will directly inform studies of ancient artifacts associated with early modern humans in Europe.

During my talk, the coming Wednesday, I will refer to how I am approaching this phase of the research and the results achieved thus far.

