The prehistoric throwing sticks and their representations: Development of tools and methods for measuring their characteristics and evaluation of their functions

Wall covered with paintings depicting hand stencils and throwing sticks. Cathedral cave, Carnarvon Gorge NP, Queensland (Bordes 2018).

Master's Thesis of Prehistory, Palaeoenvironment and Archaeometry

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I Introduction

I 1 A "weapon-tool" present from the beginning of humanity

The first projectile weapon is probably a stone for its ease of use and accessibility. However, this can also be a simple broken branch at hand. A simple stick may seem less precise and effective than most hard stone, but it is more likely to reach its target, because of its turning radius on itself. These first primitive missile weapons probably played a significant role in the development of the first projectiles used by hominids as they had to get a big advantage over their predators and the prey. The ability to hit a distant target had to be held early as synonymous with strength and power by those who mastered it.
While a stone requires little modification to an effective use, a stick launched in rotation around its centre of gravity is subject to a high drag due to air resistance. It must adopt a regular shape and a good distribution of its mass. While stoning have changed little, the throwing sticks have been improved to keep their uses as any projectiles throughout human history, adapting to new functions. By specialising, some throwing sticks gradually evolve into objects of fascination and play, like the famous boomerangs.
It seems unlikely that the transformation of this simple modified branch to most advanced throwing sticks have been happening randomly, or only because of direct imitation of nature. A process of gradual technological improvement of the tool, similar to that known for the stone tools, most likely occurred. The wooden tools has coexisted with early stone tools, whose evolution has probably conditioned the shaping of this material and vice versa. The chance of the invention, often referred to the innovation of the return object is probably not the only factor of development for the throwing sticks. Pre technical requirements for their improvement under the pressure of a new uses, or loss of other uses, probably came into play in this process, leading as a result to their high diversity. The weakly preserved archaeological traces left by prehistoric throwing sticks require a multifaceted approach that includes the study of archaeological discoveries and representations from different angles: a descriptive approach to their characteristics whose analysis can go back to their different functions, but also a comparative approach using ethnographic available information. The experimental approach can also validate assumptions about their uses. These two kinds of artefact analysis will finally be applied to evaluate two examples of archaeological finds.

I 2 Terminology and definitions

Let us focus first, to define our objects of study, what are throwing sticks, and justify the choice of the term "throwing stick", which is preferable to that of " boomerang ", too confusing and too narrow.

The term "boomerang"

The term 'boomerang' derives from several Dharug words, Aboriginal language group of the South East region of Australia. It would be a compression of two words, bumarit and wumarang (Clark, 2012). This term referred to the natives themselves, only to the returning projectile that has so fascinated the European colonisers. A recent study of the word "boomerang" (Butz, 2011) shows that these same colonisers extended by ease and ignorance, this Aboriginal word to all sorts of objects launched very different, often not returning, maintaining a confusion that lasted until today. This name is so to speak, more connected today, at the mention of the phenomenon of return of the projectile than to a category of well definite objects. Considering the diversity of objects called "boomerang", there is a tiny minority which have the return of properties assigned to them. For example, only 10% of such objects made by Australian Aborigines, have real return capabilities (Leroi-Gourhan et al., 1948).

There are also projectiles with curved trajectory that are not able to return to the thrower. Should we call them boomerangs or throwing sticks?

The term "throwing stick"

Although in some studies there are both "throwing stick" and "Boomerang" used with no real distinction (Jones, 1996), other authors such as (Davidson, 1936) trying to restrict the "boomerang" label to objects whose advanced airfoil shaping raises aerodynamic lift phenomenon, while keeping the name throwing stick (throwing stick or throwing club) for objects with less developed airfoil shaping. Again, this is an artificial division, which excludes close technological relationship between so-called "throwing sticks" and "boomerangs".

The English terminology has also met with this variability of throwing sticks. It is noteworthy that we find in it, on one side, the redundant expression "returning boomerang," and on the other hand, a contradictory term "non-returning boomerang" for example (Jones, 1996) or (Hess, 1975) who use it. Other Anglo-Saxon names are trying to attribute terms like "hunting sticks" or "killing sticks", "hunting sticks" or "killers sticks" to designate the category of non returning objects. Again, these terms are not suitable for the general case, involving specific use and already designating directly a specialised sub category of these objects.

Finally, to avoid a last pitfall, it should be noted that we also still find in the old English literature for example (Calvin, 1974), the term "throwing stick" to denote sticks used to propel spears, so that an accurate term to use is "spear-thrower".

Faced with this complex situation, we will adopt in the pages that follow, the term "throwing stick", not as a substitute for the term "boomerang" but as most suitable to describe a larger whole group within of which are smaller subsets of objects, being more specialised, such as boomerangs.

To avoid confusion, the term “boomerang” will be only used in this work for the type of returning throwing stick, located in the parts of Australia concerned with these specific returning objects. We can still retain the name of "returning throwing sticks of boomerang type" to other locations and cultures.

Definition

I will adopt for this work a very broad definition, which considers throwing stick as a projectile consisting of one or more pieces of wood, or more rarely other natural materials, forming between them an angle from 0 to 180 degrees. These parts are called "blades" and have an airfoil section more or less shaped. The object itself is launched in rotation in the air around its centre of gravity, in a plane of rotation. I will insist that this rotational movement on itself distinguishes throwing sticks from other projectiles thrown like javelins and spears, that can rotate during their flight around their axis, but never around their centre of gravity.

II General issues

II 1 Throwing sticks: unrecognised and poorly preserved weapons tools

Very few museums and archaeological sites evoke throwing sticks and their relationship to the activities of prehistoric man. Among the prehistoric museum tours that I have done in France, only the museum in Saint Germain en Laye has dedicated a small sign that restores the possible prehistoric projectile weapons including the throwing sticks and the Mesolithic open air museum of “Haute Ile” (Seine et Marne) included a notable written panel presenting the discovery of throwing stick of Oblazowa (Valde-Nowak, 1996) and possible use of throwing sticks during Mesolithic period. During throwing stick workshops, I have repeatedly found that frequently the unsuspecting public and sometimes archaeologists were unaware of the use of throwing sticks and how throwing sticks worked, often perceiving their role in human history as reduced to the gaming boomerang or being curious ineffective sticks. The low interest in this type of archaeological object is directly in relation with poor preservation of throwing sticks consisting mainly of perishables. Indeed, the main difficulty in the study of throwing sticks is the nature of the material in which they are manufactured. Mostly of wood but sometimes of ivory or bone, these objects are poorly preserved excepted in exceptional circumstances. In fact, the wood is usually preserved in anaerobic wet or very dry environment or in condition when biological degradation is little active. Fortunately, some rare archaeological discoveries have been made and pose precious milestones, particularly in Europe. Contrary to popular belief about the origin and antiquity of this weapon tool on the Australian continent, it is in Europe where the discovery of archaeological throwing sticks is best documented, but also the oldest. This surprising fact is probably a reflection of intense archaeological research in European prehistory and landfill conditions for their preservation. However, It will not matter in the context of this work to cover all archaeological findings, but to give some examples of archaeological objects found in Europe, dating from the Palaeolithic to the Gallo Roman period:

The oldest discovery is concerning the double pointed stick of Schoningen (Fig. 1) in Germany dated from 400,000 BP (Thieme, 1997). This object, measuring 80 centimetres long, shaped in spruce, was discovered in a context similar to that of the famous spears from the same site. Discoverers report it as an ambivalent object between the throwing stick and digging stick. Besides its size, which falls within the range of that of throwing sticks, its double point trimming may indicate its use as a projectile.

Figure 1: Drawing of the archaic throwing stick/digging stick found at Schoningen Germany (400 000 BP). 80 cm wingspan. (Thieme, 1997).

However, the prehistoric throwing stick most famous in Europe, is certainly the mammoth ivory throwing stick found at Oblazowa (Fig. 2) Poland, a Gravettian object dated to 23,000 BP (Valde - Nowak, 1987). The density of ivory being double that of wood, this object has a large mass concentrated in a small average thickness.

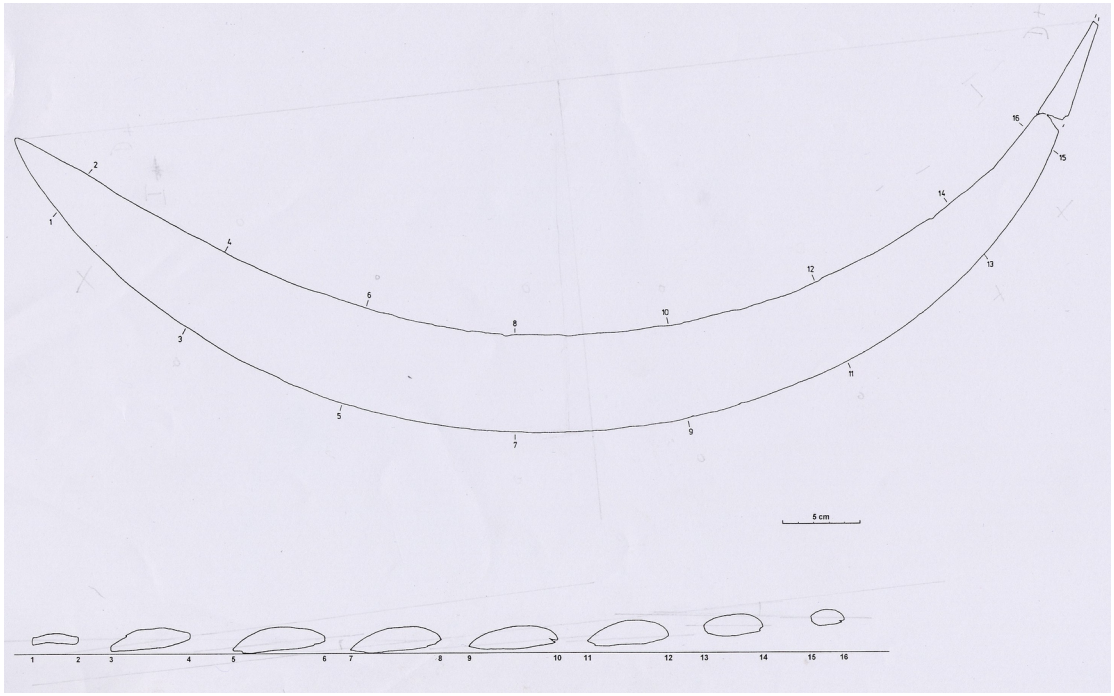


Figure 2: Reading of throwing stick in mammoth ivory discovered at Oblazowa (Gravettien, 23,000 BP). 70 cm wingspan. (Valde-Nowak, 1987).

This finding confirms that other organic materials as wood, were viable for the construction of throwing sticks to prehistoric times, such as ivory or bone.

There are also several throwing sticks discovered in Denmark, dated approximately to 6000 BP from sites of Roanes Skov (Andersen, 2009) and Braband (Thomsen, 1902) (Fig.3).

Figure 3: Drawing of short throwing stick from Braband in Denmark (6000 BP) . 42 cm wingspan (Thomsen, 1902).

The discoverers of the object from Braband (Thomsen, 1902) tend to identify this object as a harpoon, used for fishing spear ends found at the same site. The fact that harpoon type objects are made all in hazel wood and have sections of very different shapes and dimensions compared to that particular object built in maple wood, suggests that this item was not necessarily a fishing spear part, and could then fill another function. We can see that this object does not have the same section in each of its branches in a configuration close to some Aborigines throwing sticks from Australian centre. Its dimensions and thickness are consistent with a small-scale throwing stick. The comparative analysis of the characteristics of this object seems promising to improve reading of that object and can be confirmed by experiment to clarify its flight possibilities.

Also concerning Neolithic this period, were found a series of throwing sticks (Fig. 4) classified as such by Ramseyer (Ramseyer, 2000) from the lakeside site Egolzwil 4 in Switzerland, dating from 5900-5400 BP belonging to Cotaillod culture and a throwing stick from the Moringen site dated from 3200-3275 BP (Ramseyer, 2000).

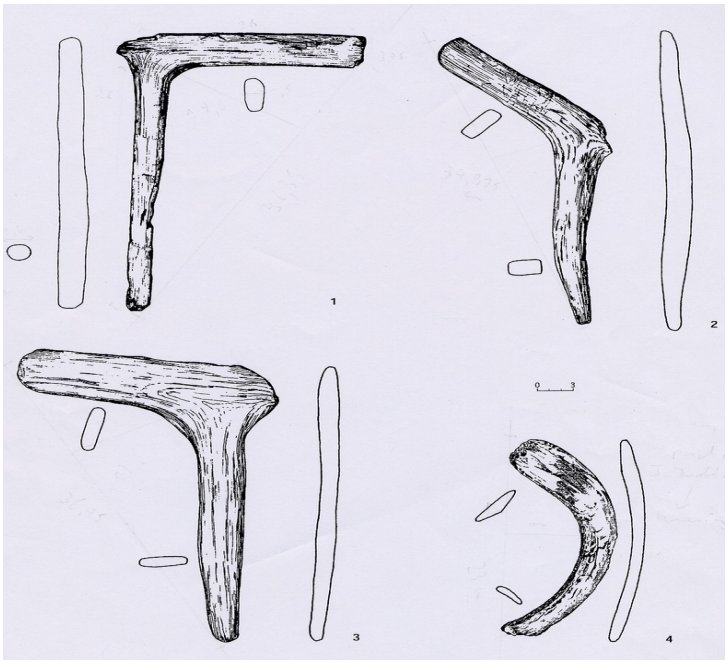


Figure 4: Drawing of Neolithic throwing sticks found in Switzerland: 1-3: site Egolzwil 4, 30-40 cm wingspan. 4. Site Moringen, 23 cm wide (Ramseyer, 2000).

The series of Egolzwil throwing sticks will be treated in detail in the example of functional analysis of the last part of this work. Classified also as such by Ramseyer (Ramseyer, 2000), the throwing stick found on the site of Moringen (Fig. 4, 4) is of a rather different kind from those of Egozwil (Fig. 4, 1-3) because it is much lighter (about 70 g, from theoretical estimation). Compared to the average throwing sticks (40-80 cm), it has a very small wingspan (23 cm). In addition, it has a plano-convex section which makes it very suitable for bird hunting. This object, given its size, question the use of small-scale throwing sticks by people during Neolithic period or the possibility of their use by children.

In the Iron Age, one can also cite the throwing stick found in Magdeburg in Germany (Fig. 5), of boomerang type that is dated from 800 BC (Evers, 1994).

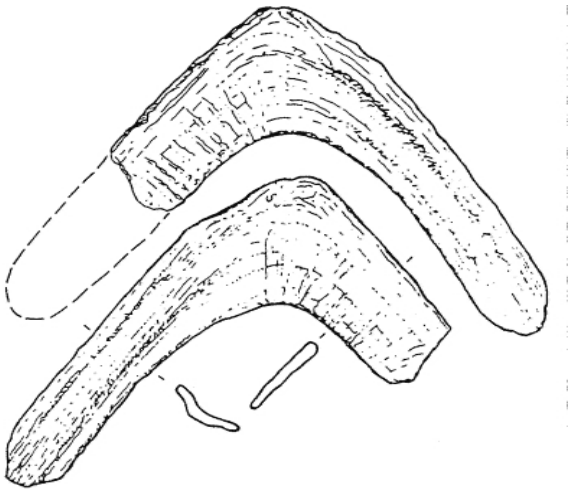


Figure 5: Throwing stick type "boomerang" from Elbschottern found near Magdeburg in Germany. C14 dated from between 800 and 400 BC. (Evers, 1994).

For the period of la Tène, one can cite the famous throwing stick of boomerang type found in Velsen Holland (Hess, 1975) (Fig. 6). As the object found in Magdeburg, it is a returning projectile that is comparable to Australian boomerangs (Hess, 1975), and has even preserved its blades tuning which plays a key role in this type of trajectory (Bordes, 2011).

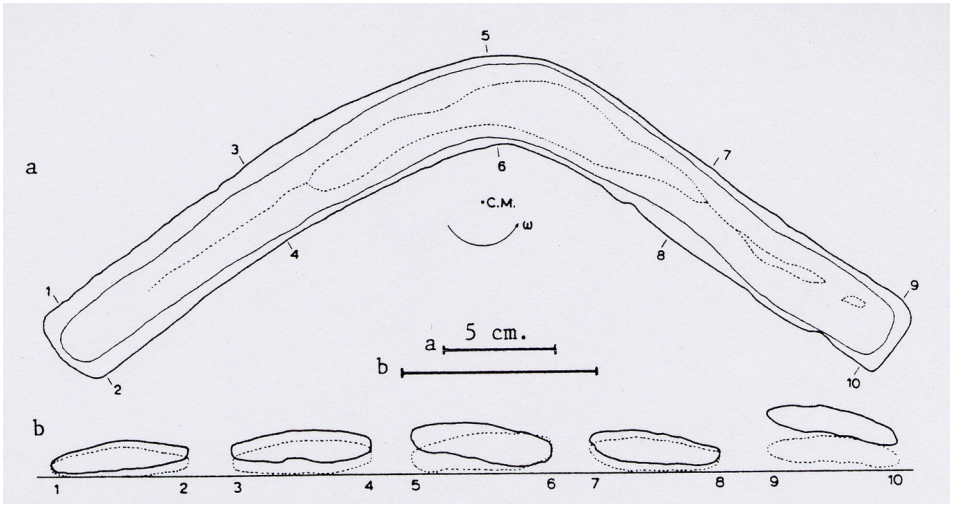


Figure 6: An object of boomerang type found in Velsen. Around 300 BC. JC. 39 cm wide (Hess, 1975).

These objects dating from the Iron Age and la Tène show that the existence of returning throwing sticks is not unique to the Australian continent. Are these objects were already reserved for games or participating in a birds hunting strategy as it can be observed among Australian Aborigines? The presence of such objects could correspond to a final phase of technological specialisation of throwing sticks, showing the continuity of the use of this weapon in prehistoric Europe.

Following these archaeological examples for Europe, it is also useful to consider throwing stick discoveries in Africa, including those from Egypt who are most well-known. The only Palaeolithic example discovered in Africa is dated to 125,000 BP and comes from Florisbad in South Africa. The wooden object could be a small throwing stick fragment (Fig. 7), but there are uncertainties (Marion, 2003) in its identification.

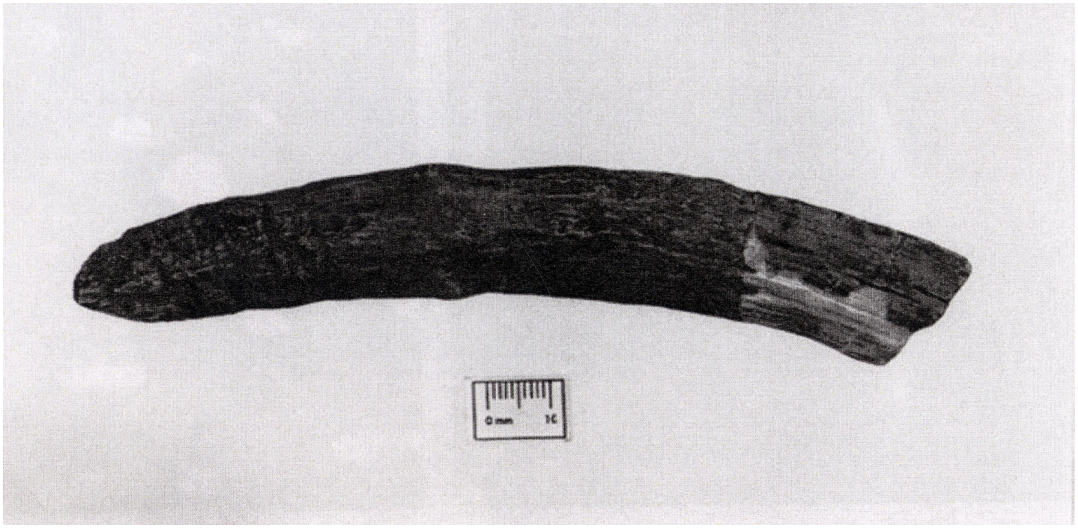


Figure 7: Probable throwing stick fragment. Florisbad, South Africa (Marion, 2003).

The discoverers suggest in their conclusion that this fragment of wood 15 cm long and 2 cm in diameter could belong to a throwing stick, excluding its interpretation as part of spear. Indeed, its oval cross-section and transverse striations visible at its ends are consistent with this interpretation.

The others archaeological remains of throwing sticks attested in Africa are much more recent and are concerning the historical period of Egypt with known examples from the Old Kingdom (Hess, 1975). In ancient Egypt, use of throwing sticks is well known, thanks to the objects from archaeological discoveries, as well as from depictions on wall paintings. Archaeological findings of objects concern mainly the tombs of ancient Egypt that have well preserved the wood by their stable low humidity conditions. The most famous examples are from the tomb of Tutankhamun, which have benefited from the detailed analysis of Jacques Thomas (Thomas, 1991) (Fig. 8):

Figure 8: Some throwing sticks found in the tomb of Toutankamun around 1340 BC, (Thomas, 1991).

In this tomb, one can have a glimpse of the diversity of throwing sticks used in ancient Egypt during the new Empire period: double curvature "snakes" throwing sticks, "L" shaped asymmetric curved throwing sticks and "Kepesh" throwing sticks style in wood or ivory. The double curvature sticks called "snakes" are from archaic clubs who have adopted a curvature to increase the stabilisation of their flight (Fig. 9). They are probably one of the oldest types used in Egypt and are often found in the hands of bird hunters represented in tombs. Indeed, their small dimensions, rounded shaped airfoil section and low curvature give them a short range capability which fit them well to hunting of birds at close range.

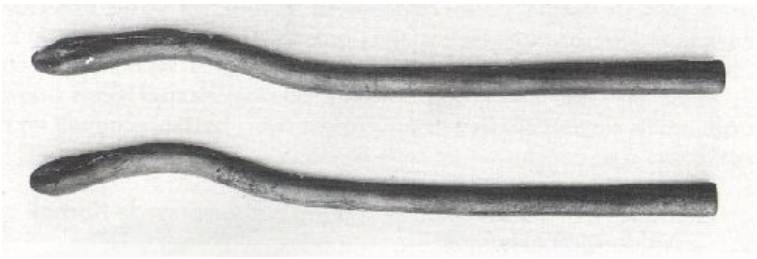


Figure 9: "snakes" sticks found in the tomb of Toutankamun around 1340 BC (Thomas 1991).

Among the objects found in the tomb of Tutankhamun, there is also a series of "L" shaped sticks (Fig. 9a). This type of throwing stick seems quite old in Egypt since this form appears already on the hunting pallet dating from pre dynastic period (Hendrickx, 2013).

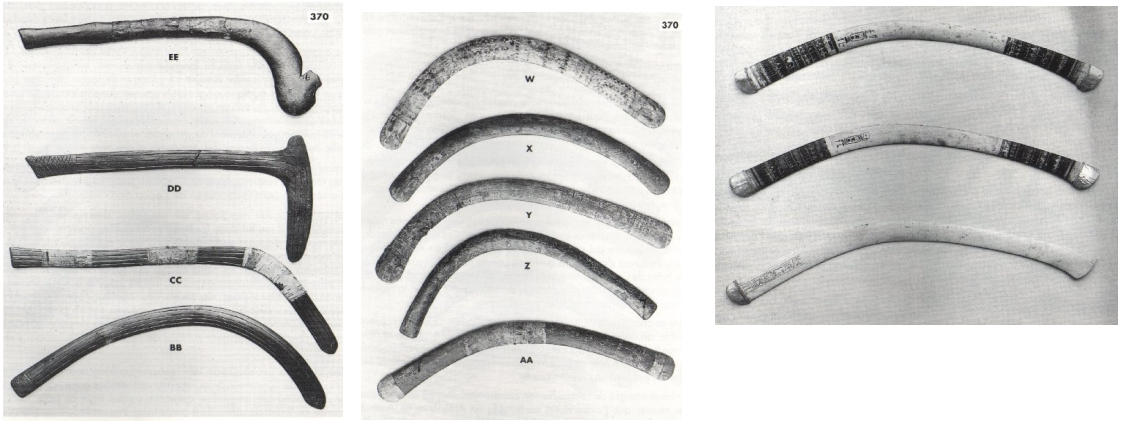


Figure 9a, 9b, 9c: "L" shaped sticks including grooved examples (left) and asymmetric curved sticks (center) and (right), found in the tomb of Tutankhamun, around 1340 BC. (Thomas, 1991).

It may be noted from the group of throwing sticks of various sizes, a large series of asymmetric objects which have often rounded or blunt extremities and have a characteristic "fan" shaped enlargement (see Appendix I) (Fig. 9c). Among the waisted throwing sticks with small wingspan found in the tomb, many probably have curved trajectories and some are even of boomerang type with returning trajectory as demonstrated Jacques Thomas (Thomas, 1991). Ancient Egypt is the testimony of returning objects in Africa (Thomas, 1991) and demonstrates that along with other archaeological objects found in Northern Europe Velsen (Hess, 1975), Magdeburg (Evers, 1994), the return trajectory for these projectiles is not reserved only to the Australian continent.

The American continent is not free of discoveries, and we can cite the example of Little Salt Spring site in Florida and discoveries of Anazasi throwing sticks in the South West of the continent. The discovery of Little Salt Spring (Florida) is relatively old for this type of object and is dated 9000 BP (Clausen, 1979). This throwing stick (Fig. 10) have been compared to a recent ethnological model from the same area and their similarity confirms this identification. This prehistoric throwing stick shows that far from being confined to the South West of the American continent, the throwing stick was also used by South East Paleoindians.

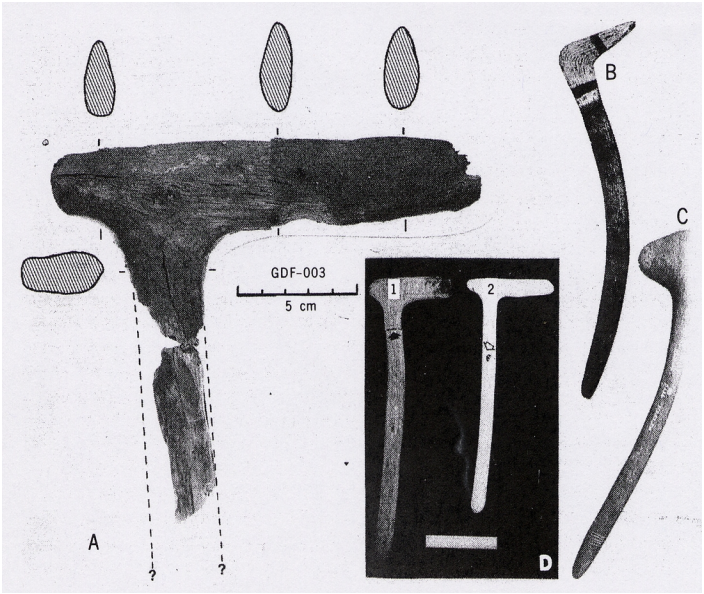


Figure 10: Discovery of Little Salt Spring in Florida.(9000 BP) and comparison with ethnological throwing sticks (Clausen, 1979).

The discoveries of Anazasi throwing sticks of have been made in the same areas of use of the "rabbitstick" or throwing stick for rabbit hunting. These throwing sticks are distributed North to South Western of North American continent (Heizer, 1942). The Anazasi peoples whose cultural period extends from 200 to 1300 AD, preceded the Pueblos cultures of Arizona and New Mexico, including the Zuni and Hopi which are best known for being throwing stick users (Heizer, 1942). Their shape tend to appear less curved than throwing sticks from this more recent Pueblos cultures and include double-curved type of sticks (Heizer, 1942) (Fig. 11).

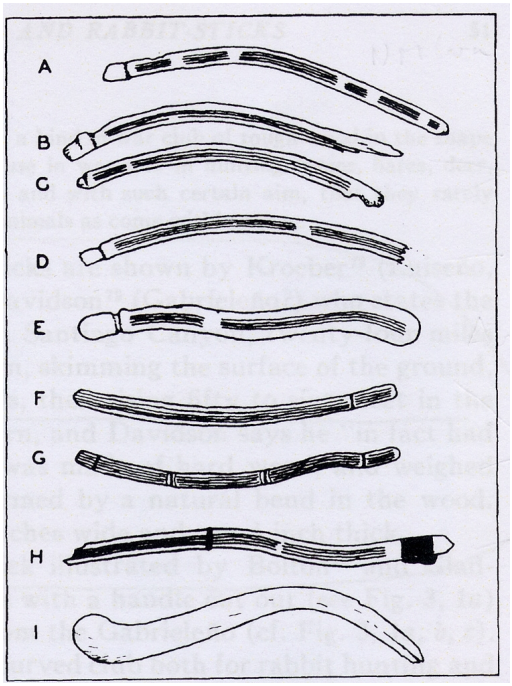


Figure 11: Some Anasazi throwing sticks identified by (Heizer, 1942).

Australian Continent:

We conclude this overview of archaeological finds by the Australian continent. Archaeological discoveries in Australia are less numerous than in Europe. In fact, the only well-documented in the literature is the set of famous throwing sticks discovered Wyrie Swamp in South Australia dated around 10,000 BP (Luebbers, 1975). It consists of few objects of returning boomerang type and throwing sticks having open asymmetric shape, similar to those used by Aborigines of this region (Fig. 12).

Figure 12: Object of boomerang type discovered at Wyrie Swamp and dated from 10 000 BP (Luebbers, 1975).

II 2 Issue: restoring the role of throwing sticks in prehistoric societies

Numerous questions may arise to better understand the role of throwing sticks in the cultures of the past in relation to their natural environment. For example, what might have been the role of throwing sticks in the hunting activity in Europe from the end of the ice age? What are their uses for breeders/hunters people or for breeders/sedentary farmers? The answer to these questions will not only hand in hand with a better understanding of the function of prehistoric throwing sticks, but also with the appreciation of their use related to other range weapons used for prehistoric hunting, like the bow or the throwing spear.

II 3 Pushing further the actual limit of research on throwing sticks

Before we can begin respond to various questions about the use of throwing sticks in the various prehistoric societies, we must identify and even reassess many archaeological discoveries. Indeed, many analyses of these archaeological objects remain unanswered, simply for lack of simple parameters measured on objects, or due to inaccuracies of drawing or again because of the lack of observation of some details. Although some surveys have been done carefully as done for Oblazowa

discovery (Valde-Nowak, 1987) or Velsen (Hess, 1975), others as the object of Braband (Thomsen, 1902) omit the airfoil section drawing at the elbow or no airfoil section drawing at all as for the fragment from Florisbad (Marion, 203). The mass, yet one of the most important characteristics for a projectile, is almost always a problem for archaeological objects as it is never provided, probably because authors want to be cautious about possible variation in its value due to humidity changes in wood following the burial in wet environment. Yet, it would perhaps be possible to make at least a coarse estimate of the mass of dry wood from the one in that state. Finally, as it has been found in the publications cited above, frequently only a drawing and photograph of one side of the object has been done. However, throwing sticks sometimes have different making and treatment on each side and these differences can provide crucial information about the orientation of the object and even indicate the nature of the projectile. Improving their study therefore requires the development of measurement and comparison methods adapted to the analysis of throwing sticks that will be the central concern of this work.

We can offer a number of these tools and methods to overcome the current study limits and progress in the knowledge of these archaeological objects:

II 3a A purely morphological approach

The experiment shows that the potential use of these weapons as projectile, are dependent on a range of aerodynamic characteristics (Callahan, 1975), and not only from their general shape. Studies on throwing sticks have often only a morphological approach and lack of systematic physical objective measurements on ethnological and archaeological objects. For example, the only authors who give importance to a fairly complete record of throwing stick features and boomerangs Australian Aboriginal are André Turck (Turck, 1972) and Errett Callahan (Callahan, 1999).
Many studies of throwing sticks are dominated by morphological determination as the distinction of their main shape used by Australian Aborigines, for example by Davidson (Davidson, 1936). The distinction between throwing sticks types based solely on morphological criteria do not allow to make fine distinctions among these projectiles. The consequences are also the interest in publications is going mainly to the boomerangs subclass (Hess, 1975), and simply group throwing sticks in great shape types (Davidson, 1936) without venturing into the complex diversity of the great assembly to which they belong. The shapes of throwing sticks are often cultural and are the complex result of an ancient tradition that has evolved according to their uses and their constraints. Their multi-functionality and their variability within a particular group does not facilitate this work. Therefore, Davidson (Davidson, 1936), in his presentation of the main types of Australian throwing sticks, does not consider the usefulness of a systematic classification system. Other authors are trying to extract large set of throwing sticks, those with the return of property, the famous boomerangs as Jacques Thomas (Thomas, 1991), or focus on the physics of flight of modern boomerang (Hess, 1975). This distinction based solely on the type of trajectory is illusory, because of the continuity of variation of curved trajectory that can be observed on the throwing sticks from straight flight to complete return. Indeed, sometimes a close related object types can be returning while other can fly curved without complete return (Hess, 1975).
I therefore propose to consider a larger set of measures to better understand the characteristics that govern functional possibilities of throwing sticks, not only as projectiles, but also through other uses as a tool. This consideration requires a precise tracing of the objects. It is possible to trace by hand and photographs number of features on a throwing stick. These features can be used to predict the type of

flight and range. This is of course in this case, to do a coarse evaluation and allow to compare objects relatively between them and not allow to make flight computations as achieved in the work of Felix Hess (Hess, 1975), but valid only for one specific type of throwing stick. For example, boomerangs airfoil section used by this author are all of plano convex airfoil type with a marked difference to the leading edges and trailing edges which is only found as characteristic of modern boomerangs. However, few boomerangs traditional Aborigines have such a section with differentiated edges, and some are even sometimes of biconvex section, but keep also return property (Bordes, 2011). This specificity to a given type of object considerably limits the use of computational study for ethnological or ancient objects that have a high variability of characteristics.

We can list the following selected physical characteristics:

- Mass/surface ratio
- Airfoil section
- Single or mixed airfoil section
- Wingspan
- Height
- Height/Wingspan ratio
- Attacking & following blades blade length symmetry
- Widths at the elbow and at the extremities of the blades
- Thickness at the elbow and at the extremities of the blades
- Thickness/Width Ratio
- Dihedral twists
- Incidence twists
- Shape type
- Shape symmetry
- Extremities type
- Grooving
- Decoration
- Laterality
- Reinforcement or repair
- Traces of shaping tool
- Traces of use

Deducted Characteristics:

- Probable trajectory
- Probable range

These characteristics were chosen because they have the advantage of being directly observable for some of them and evaluated for other rather intuitively, without using advanced physical concepts (center of gravity, etc.) nor complex equations, as could be apprehended by the men who built these implements in the past. These parameters are not independent and should be considered together to evaluate an object, or compare several objects together. Information about the changes in each of these characteristics discussed below are results of the experiment and are detailed in Appendix II.

II 3 b Absence of typological classification

There is currently no general typological classification of throwing sticks that allows efficient comparison of archaeological and ethnological objects.

The confusion created by this ancient morphological approach only explains this lack of systematic classification, since a class defined only by its form included too many different type of throwing sticks, if one ignores additional criteria that define subclasses. For example, clusters of large regional type established by Davidson (Davidson, 1936) are defined only by their shape. This criterion is not sufficient to achieve a detailed classification because if we take the example of a very generic and common form in Australia like crescent (Davidson, 1936, Fig. 7), the throwing stick may origin from different regions Australia based on different type of profiling and its wingspan. In addition, this criteria is not sufficient to distinguish the traditions of manufacture from different indigenous groups in a same region.

A classification of the many types of ethnological throwing sticks from Australia or Africa can serve as a starting point to establish a fairly solid database for this type of object.

The potential contribution of a classification to the analysis of this "weapon-tool" prehistoric is multiple:

- A more rational classification of ethnological objects to distinguish close confused throwing stick shapes.

- A possibility of more efficient comparison of archaeological finds, classified with the same criteria as the ethnological objects, taking into account a larger number of parameters. Especially for regions where ethnological objects are missing as for Europe.

- A comparison between ethnological and archaeological objects with an experimental object-based practices to determine their type of flight and throwing range.

- A functional revaluation of archaeological finds in their cultural and paleoenvironmental context.

- A more accurate comparison of the relative shapes and sizes throwing stick depicted in rock art or interpreted as such, with real objects.

- Finally, in a more theoretical way, this classification can be used to identify general or regional schemes of prehistoric technological development of throwing sticks, based on the various existing classes of objects, their manufacturing technology and aerodynamic constraints.

In this sense, a classification starting with conventional morphological types is desirable to be able to work both in continuity with previous authors that define the types of throwing sticks mainly from their shapes. However, these morphological types must be specified, and completed by the extremities type and symmetry. Then it will be taken into account an increasing number of criteria, such as blade airfoil sections and the mass ratio/surface of theses objects to distinguish different subclasses. I

propose a such classification in Part III 1.

II 3 c Weakness of the functional study

In the study of archaeological and anthropological throwing sticks, unsatisfactory functional analysis in connection with their physical characteristics can be noted.

The functions of archaeological throwing sticks are rarely addressed by their discoverers or incomplete and few ethnological comparison is attempted in the absence of database convenient to use. For example, regarding the examples discovered in Europe mentioned above, in addition to inaccurate designation using "boomerang" term, no specific function is proposed for Oblazowa object (Valde-Nowak, 1987), or for Switzerland throwing sticks (Ramseyer, 2001) and another function, different from throwing stick is proposed for the object found at Braband (Thomsen, 1907). This approach isn't facilitated by the large number of functions that can be linked to an object, throwing sticks being naturally multi functional (see Appendix II). All the different uses must be considered and known with as much detail as possible to be able to explain the morphology and some of their specific characteristics. Indeed, a given throwing stick is often both constraints as a projectile, such as the need for stability, or profiling to acquire sufficient rotation in flight, but also under the constraints related to other contact uses, which may impose certain other characteristics. For example, a throwing stick which needs to be thrown at long range but used for close fighting and firesaw, will be probably have enough thin shaped section, be medium or large, and will have tapered edges.

I propose to classify these functions into two main groups:

Function including the object as a projectile and the object contact uses. Throwing sticks are weapons-tools that have indeed consistently oscillated during their history between these two types of uses. Second, we will classify the uses as a projectile into two subgroups, which are use as a projectile to target ground targets and those to target aerial targets. The game use as return item will be included in the latter group since it involves a full trajectory in the air. Contact uses will be classified into several categories that are fighting in contact, the action of digging, uses the fire, uses with the cattle and others. Still others will be classified in the social and symbolic uses.

Projectiles

Terrestrial hunting

Hunting small game
Hunting rabbit/hare
Hunting kangaroo/emu
Hunting deer
Hunting buffalo
Distance combat
Fishing
Hunting livestock

Aerial hunting

Hunting bird/bat
Folding of birds

Games

Game (return)

Contact

- **Close fighting**
  - Hand to hand combat
  - Parade
- **Digging action**
  - Digging stick
  - Digging shovel
- **Uses with fire**
  - Fire management
  - Fire saw
- **Uses with herds**
  - Livestock guidance
  - Cross to project
- **Other**
  - Disarticulation of game
  - Flintknapping hammer
  - Plucking
- **Symbolic & social**
  - Music
  - Dance
  - Ceremonial
  - Exchange

These functions are explained in detail in Appendix II.

A connection of the function of throwing sticks with their characteristics could better explain the existence of certain types of throwing sticks and the adaptation of their technology to one or several uses. These features-function relationships are useful to be able to propose to use assumptions for archaeological objects for which we do not have that information. One such analysis be attempted in Part III 2 from our ethnological objects database.

II 3 d A poorly developed experimental approach

The experimental approach on crude wooden throwing sticks is weak, limiting the estimated potential of traditional or prehistoric throwing sticks as projectiles, compared to other weapons better known like spears throwers and bow. Nevertheless, some authors have documented experimental throwing sticks. Errett Callahan offers for example in his applied article (Callahan, 1999), document two types of throwing sticks optimised that correspond to Australian models, while the throwing stick model of rabbit stick type proposed in the same article clearly departs from ethnological styles by its small thickness. The author does not specify the type of construction (modern or traditional) used to reach large distances with reports for his projectiles (280m). In his thesis (Callahan, 1975 p35), the distance announced, achieved with a raw wood throwing stick (without, however, specifying the type of construction) is only 180 meters, which seems more reasonable for these projectiles. Indeed, modern plate materials (egplywood) worked in modern tool does not present unevenness of surface, which gives them a slightly higher rate of rotation and could significantly increases their performance, hence

their range. In this context, authors such as Jacques Thomas (Thomas, 1991) and Felix Hess (Hess, 1975) worked with plywood models for their experiments.

Considering that despite the apparent simplicity of the throwing sticks, a real technical skill is need for their construction and especially to throw them properly and achieve enough efficiency as a projectile. In this perspective, throwing experimentations are often rich in information about their technology. Therefore, the best method of evaluating possibilities of throwing sticks as projectiles or for other uses is the comparison with experimental models, as done already for the bow or the spear thrower. Since 2006, I have been able to produce about 150 experimental models of rough wooden throwing sticks of different types, with straight or returning flight. All these objects were worked exclusively by hand, on the spot, with raw wood pieces specially selected and sampled.

These throwing sticks are built with three different approaches:

Aerodynamic exploration:

- Experimental models that simulate one or more characteristics of an ethnological throwing stick which are intended to answer aerodynamic questions concerning the type of wood used, or the selected blade tuning. For example, how will a medium-density wood asymmetric widened blade throwing stick behave in flight ? Is it different with a high density wood ? What is the effect of positive incidence tuning on attacking blade on this throwing stick ? Or negative incidence tuning ? The objects constructed to answer these questions are shaped by a roughing metal tool (machete or axe), to fasten the coarse wood removal.

Exploration tools and shaping techniques:

Models experimenting the shaping process of throwing sticks with a specific toolkit. For example, a stone tool kit with no handle fitted which consists of a large flake for cutting the wood piece and roughing, a shaving flint flake and a sandstone for polishing. Other tools kits simulate manufacturing with handle fitted tools, polished hatchets, adzes and chisels of flint, or again recreate a particular manufacturing technique as the twin throwing stick splitting technique, that was practised among Australian Aborigines (Bordes, 2010). For experimental use of stone tools to complete construction, a fresh green wooden piece is selected to experiment in realistic conditions. These experiments are also rich in manufacturing information to assess the wood, gestures with different tools, the manufacturing time and the marks left by tools on wood artefacts.

Replicas of archaeological or ethnological objects:

Models that are close replicas of archaeological or ethnological models which are often built with mixed tools, metal for roughing and stone for finishing and polishing. These models are used to assess directly ethnological or archaeological throwing stick by one or more replicas. The wood used in this case is chosen carefully to approach as close as possible the density of the original object, or when possible, in the same timber. There is never perfect replica, but the characteristic of different replica will bracket original object and can give an good idea of its use. Thus several replica further improve the estimation of given archaeological throwing stick and comparing relative differences in their characteristics is allow to progress in the understanding of the properties and functions of the original.
These test objects are measured and classified according to their type in the same way as ethnological objects in order to make useful comparisons. Finally, they are used to mediate research on throwing

sticks, and to present models manipulated without using fragile and precious museum objects. They can be used in various experiments and flight demonstrations, as well as learning the gesture to launch to the public.

II 3e Low exploitation of rock art

Despite an inventory of Saharan rock art depiction of curved weapons (Leclant et al., 1980), the only throwing stick analysis through its representations was recently published by Serge Cassen (Cassen, 2012) on crosier shaped sticks signs and a short analysis of the representation of Choppo Spain (Picazo et al., 2001). There is therefore still a low exploitation of rock art to provide information about characteristics and functions of throwing sticks. The prehistoric pictures of throwing sticks or hunting scenes with throwing sticks are multiple worldwide, and are graphical documents of great importance for understanding the role of this weapon tool in societies of the past. They exist not only on the Australian continent (Lewis, 1996), but in Africa Sahara (Leclant et al., 1980), Middle East (Mellart, 1967) and Europe (Cassen, 2012). These painted or engraved pictures show throwing sticks, isolated, together with other elements figurative or included in real hunting scenes, conflict or ceremony. These graphical representations make us foresee the diversity of prehistoric throwing sticks and their different functions that we must decipher. The intrinsic difficulty in the study of prehistoric images and their interpretation are nevertheless a real obstacle to this investigation. Indeed, the volume parameter of throwing sticks disappear with the flat representation, particularly the section and thickness of the objects which are among their essential characteristics. On other hand, their dimensions may be also modified by the convention of graphical representation, which further increases the difficulty to understand the "real" objects in painted or engraved scenes.

There are numerous representations of throwing sticks in Europe:

Spanish Levant

The most spectacular cave paintings was recently discovered in the Choppo Cave in Spain and shows ten characters holding figure with not less than thirty throwing sticks around animal figures of deer and cattle (Fig. 13). They are dated around 7000-6000 BP (Picazo et al, 2001). This representation will be treated as an example of detailed functional analysis in the last part of this study (see Part IV 2).

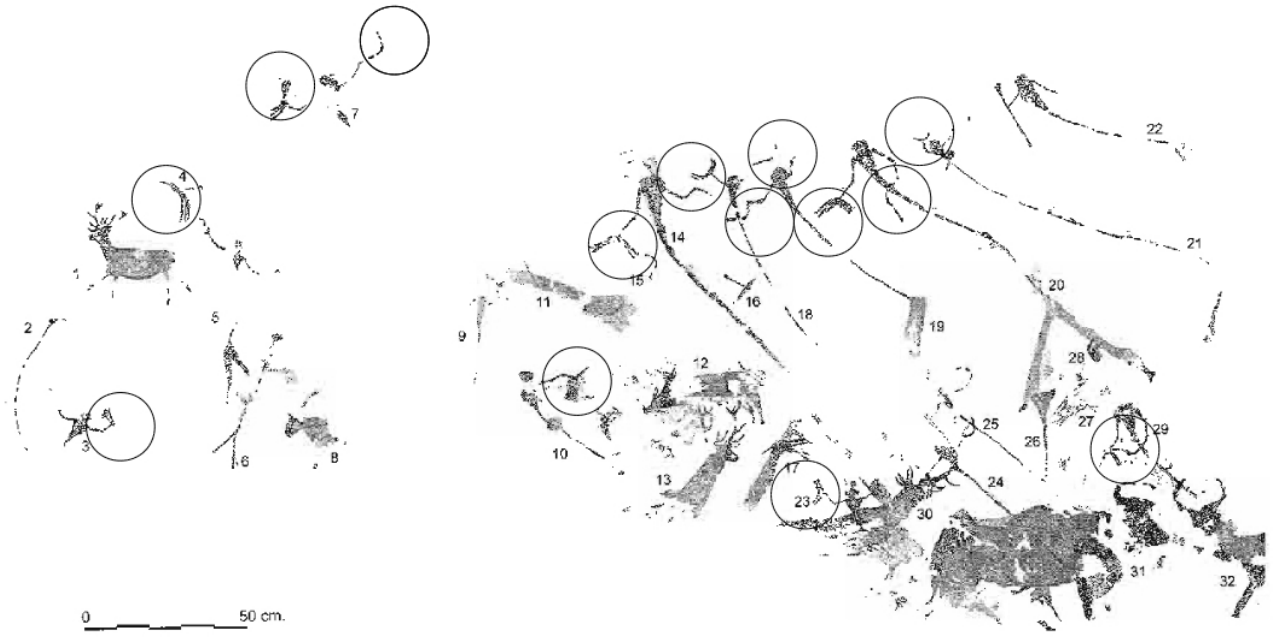


Figure 13: Representation of deer hunting with characters wielding throwing sticks, Choppo Cave, 6000-7000BP Spain (Picazo et al, 2001).

Serge Cassen (Cassen, 2012) also cites the numerous representations of crosier shaped sticks on Neolithic megaliths on an Atlantic front area extending from Britain to Portugal (Varela Gomes, 1994) and dated between the IVth and Vth millennium.

Atlantic Megalithic:

The stele Men Bronzo dated from around 6300 BP (Cassen, 2012) is interpreted by the author as a flying crosier shaped stick that seems to cut the trajectory of the figure of a bird in a quartz line megalith (Fig. 14a and b). As for my study, I recognise in this representation a throwing stick "L" distinct from the crosier shaped throwing sticks in the form classification available in Appendix 2.

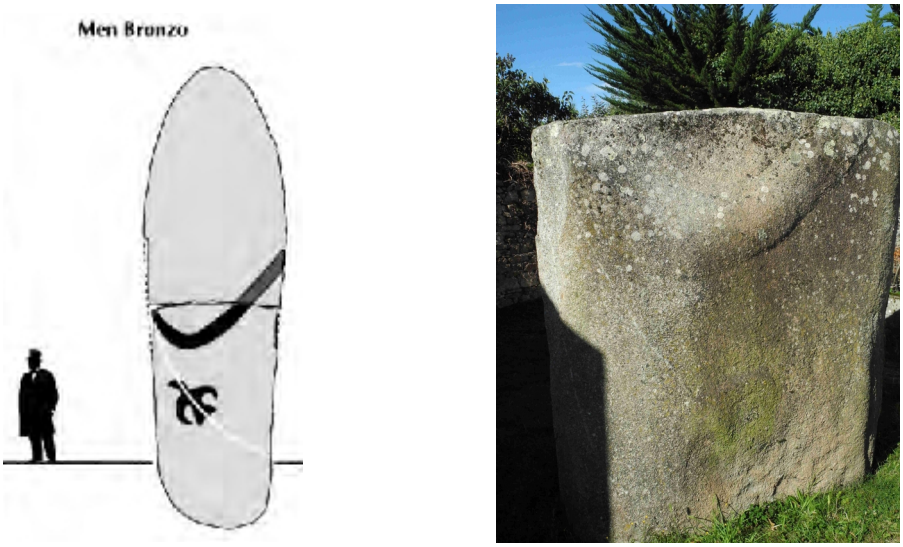


Figure 14a and b: Drawing of the stele of Men Bronzo 6300BP (Cassen, 2012) (14a), Photograph of the still erected lowest part (14b) (Luc Bordes).

Here is also a large series of objects related to throwing sticks on the slab of bedside of merchants table in Locmariaquer (Cassen, 2012) (Fig. 15a and b). If we make a form of distinction, engravings consist of three main shape types "L", "flag" and crosier shaped, which are found more sporadically on many other Morbihan megaliths.

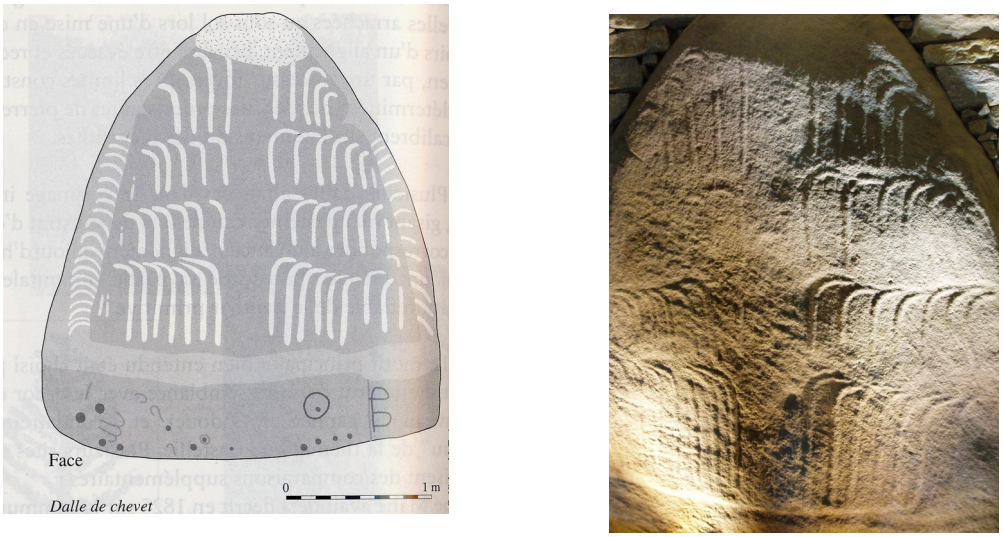


Figure 15a and b: Table of merchants bedside slab Locmariaquer 6900-6700 BP (Cassen, 2012) (15a) Photograph by the author (15b) (Luc Bordes).

The fact that there are different sets of sticks, successively nested shows that the organisation of this engraved depiction could be sequential, not produced as a planned whole depiction and done like single stream representation. This observation can afford to make the assumption that each short series of the same type of nested throwing sticks patterns may correspond to a separate symbolic event in time. This diversity shows that crosier shaped objects certainly cohabiting in Neolithic times with "L" shaped throwing sticks and flag shaped throwing stick from which it derives.
Other general question arise if the hypothesis of throwing stick identification is done for these representations: what were the uses of these objects during the megalithic period? Real weapons actually used or symbolic objects ? What new functions have made evolved the throwing sticks shape to the crosier shape ? Indeed this shape look like more uniform on Atlantic megaliths and seems to distinguish them from other styles of rock art depiction in Europe, including those of the Spanish Levant showing greater diversity of depicted throwing sticks.

Etruria:

Regarding the historical periods in Europe, there is a large number of representations of crosier shaped sticks in the influence of the Etruscan civilization. Serge Cassen (Cassen, 2012) focuses on the distinction between the Etruscan "pedum" which is the original throwing stick weapon and the emblem of the agro pastoral societies of primitive Italy, Lituus augural (curved augural staff, or a curved war-trumpet in the ancient Latin language) that has only of symbolic function and was an insignia of royalty. This author notes the recurrence of a nodal growth at the ends of pedums (shepherd's stick characterising some Roman deities) represented in Etruscan relief and paintings. This expanded club head is reminiscent of a form of this throwing stick representation at Catal Huyuk in Anatolia. This characteristic of the end of pedum would it mark a Near Eastern influences from older throwing sticks ?

Ancient Greece:

In the Greek world, a crosier shaped throwing stick for hunting, very similar to Etruscan pedum is called "lagobolon" and was used as a rabbit hunting stick. Indeed, the name of this throwing stick in ancient greek, is composed of two word, "lagos" meaning "hare" and "ballo" meaning "to throw". The "lagobolon" is thus the attribute of the god Pan, pastoral Greek deity who sometimes uses the stick as a projectile to hunt game, sometimes used to project stones and earth at stray animals in order to bring them back to the herd (Cassen, 2012). This double divine purpose seems to illustrate the link between the use of throwing stick for hunting and pastoral use and could explain quite well the development of the new crosier shape for that weapon. Indeed, for aerodynamic reasons, many throwing sticks used as projectile is an "optimal" form in an asymmetrical shape with short broadened blade (see Appendix I).
Could it be that men who used throwing sticks of this type launched for beating the game or bringing back animal in herds have observed that it was more interesting to keep in the end the object in hand and to project with the distal end of simple stone ground to bring back stray animals? This would not be surprising if the hunted game was rabbits, since we know through ethnology that throwing sticks in this case are launched very low to the ground, bouncing on the ground. According to my own personal experiments, with this way of throwing, it's possible to observe frequently stones and pieces tuft of grass or bark often thrown into the air during these rebounds and impacts on the ground.
This new use would be ultimately at close range on a sort of convergence of the sling to launch stones and throwing stick use. This seems natural if we take into account the frequent use of the sling by population pastors, hence the possible transfer of function. In any case it appears that this new use not only changes the shape of the throwing stick but also the length of the gripping blade that fits the use

of the stick projecting from the hand to the ground. This practice, even according to the analysis of Serge Cassen (Cassen, 2012), is the origin of the use of the game of lacrosse not only in Europe in antiquity and the Middle Ages but also by the Indians of America.

Middle East:

Some of the cave paintings of Catal Huyuk dating from 6500 to 5700 BC, are interpreted by the discoverers (Mellart, 1967) as a deer hunting (Fig. 16) in which hunters brandishing bows and small arms sometimes perceived as clubs or sling, or sometimes as hunters dancing (Fig. 17).

Figure 16: Representation deer hunting. Catal Huyuk 8500-7700 BP. (Mellart, 1967).

Indeed, the first scene (Fig. 16) seem to describe a real hunting action where we see the characters holding bows with one hand and little club shaped objects with an enlarged protruding ends in the other hand. The characters seem to run together in a given direction except one character on the left side. The fact that the characters each carry a leopard skins quiver helps reinforce their identification with hunters if one refers to the example of the current Saharan hunting peoples who frequently use skins animals for their equipment and clothing (Barouin, 2006).
A more accurate observation of club shaped objects reveals that they are slightly curved and the distal enlarged head is always oriented towards the inside of the curvature. These weapons could have in addition to their club use in contact, being use as throwing stick as projectiles. Indeed, this type of shape is found in South Eastern Australia as formidable throwing sticks used for ranged combat known under the term "Lil Lil" (Davidson, 1936) (see Appendix I , shape with enlarged head). This assumption can be also supported by the fact that the bow is frequently met in joint use with throwing sticks as seen most clearly in other representations Sahara (Leclant 1980) that we will address in the next part.

The other type of representation (Fig. 17) found on this archaeological site is interpreted as a dance hunter (Mellart, 1967) and also represents these characters with the same type of weapon, but in a different context. In this scene, the characters appear to move or dance around the deer in an act unknown ritual, especially the character beneath the hind legs of the deer and holding a pair of arms. The postures of the characters who are not just in the act of launching their club/throwing stick but rather involved in more complex actions, encourages interpret this scene more as a ritual than a true hunting action.

Figure 17: Representation deer hunting. Catal Huyuk 8500-7700 BP. (Mellart, 1967).

It may be noted that the Convention representations bows like the throwing sticks seem smaller than natural, considering the scale of arcs that would be only fifty to sixty centimetres. This "reduced" convention of graphical representation is often also found in hunting scenes painted in the Sahara.

Saharan region:

Exactly, the Sahara region is full of rock art of throwing sticks, dated between 6000-3000 BP and mostly located in the mountains of Akakous, Tassili n'Ajjer and Messak. (Leclant et al., 1980) draws up a veritable inventory by reviewing 136 prehistoric representations of Egyptian and Saharan curved weapons that can be regarded as throwing sticks. In Egypt, these representations are known in Upper Egypt and Nubia in the Akba area (II cataract) newer than the III millennium (Leclant et al., 1980). Some show the weapon in big cats and elephant hunting scenes. The throwing sticks shapes of this region are varied and included crosier types (Leclant et al., 1980). The scenes show characters in various stages of throwing these objects (Leclant et al., 1980). In Uweinat, between Egypt and Libya, there are engravings of these curved objects associated with bows in hunting scenes, sometimes in larger numbers than these (Leclant et al., 1980). For the Chad region and especially in northern Tibesti among pastoralists/hunters of Oudingueur, weapons representations of this abound, and are frequently

associated with bow (Leclant et al 1980). In this region, repeatedly found, the weapon is also found in big cats and elephant hunting scenes (Leclant et al., 1980). To understand such associations, it needed to consider that the throwing stick is not necessarily a direct hunting weapon, but can be used in complex folding and capture strategies against big animals in combination with other projectile weapons. In Western massif, a rock painting is representing a scene with a hunter equipped with curved weapon posted near a trap on where an antelope is heading. These representations also cover the region of Fezzan and crosier shaped sticks are found in this area (Leclant et al., 1980). In the central Sahara, Tassili region and Akakous also deliver throwing stick representations, often associated with bow, in postures of throwing (Leclant., et al., 1980). In the central Sahara, in the region of Constantine, (Leclant., et al., 1980) interprets the representations of this type of weapon as an attribute of local "shepherds gods" illustrating the evolution from a hunting throwing weapon to a projectile used on domestic herds. Also known is a set of representations about the throwing stick in the South Oran region, or they are reported in a hunting scene in association with dogs in the Tiaret region (Leclant et al., 1980). Hunting strategies can therefore rely on hunting dogs. In fact, the dog is helpful to flush the animal out of cover that is often shot in motion by throwing sticks (see Appendix II, according hunt rabbits). In Southern Morocco, it has been recognised some scenes engraved involving the use of this type of curved weapon in connection with representations of lions or elephants (Leclant et al., 1980). In Mauritania, at Aaouinegh, one of these weapons is shown after its launch as a projectile (Leclant et al., 1980). In this panorama of rock art, the authors (Leclant et al., 1980) highlights two archaic origin areas for the spread of throwing stick: One located in the Nile Valley Egyptian Nubian and the other in the central Sahara in the Tassili region. The weapon was probably transmitted to Chadian hunters and hunters/pastoralists in the Tibesti region, contact region between the first two regions (Leclant et al., 1980). It would then be distributed to the west of the Saharan Atlas to the south Moroccan Sahara and the Atlantic where are located the newest representations (Leclant et al., 1980).

Figure 18: Example of hunting representation throwing sticks & bows of Aglim-Immidir, Tassili n'Ajjer, Algeria. About 6500 BP. (Leclant et al 1980).

Given the importance and scope of the body of representations of the Sahara region for the projectile weapon, it can be concluded that use of the throwing stick was common, and answer various functions within these societies of hunters and herders hunters. These practices also seem to oscillate between hunting practices and pastoral use.

Ancient Egypt:

For the pre-dynastic and Pharaonic period, the "palette of hunting" is the oldest representation of throwing sticks (Hendrickx. 2013). It is dated from Naqada predynastic period around 3300 BC. This is a full hunting scene having four characters holding "L" shaped throwing sticks and a spear in the other hand and a sixth figure holding an asymmetric throwing stick and a mace (Fig. 19). In addition to these two weapons, several characters carry and use bows against lions. There are also two characters equipped with lasso. The bestiary cast is composed of lions, deer, gazelle, ostrich and rabbit. On this stage the use of the bow seems reserved for big cats which are slaughtered by several arrows. Were the throwing sticks reserved for the smaller game, being safer and more vulnerable?

Figure 19: "Hunting Palette" pre-dynastic Egypt. Around 3200 BC. JC (Hendrickx, 2013).

Australian Continent:

The oldest engravings are a pairs of throwing sticks which are engraved on the site Panaramitee North in South Australia, which date back to about 40,000 BP (Flood, 1997). The painted rock art of throwing sticks are very numerous in Australia. The best known are the "Bradshaw figures" (Fig. 20) of the Kimberley dated 17000 BP region (Walsh, 1994).

Figure 20:Bradshaw figures (Kimberley, Australie), 17 000 BP(Walsh, 1994). http://www.bradshawfoundation.com/bradshaws/kimberley5.php).

Hundreds of paintings including throwing sticks associated with other types of spear throwers, dot the Arnhem Land for more than 20 000 years (Lewis. 1996). These representations classified into several successive periods show that throwing sticks and boomerangs appear in a period called "boomerang period" from 20000 to 10 000 years BP, then disappear and leave room only for different types of throwing spear (Lewis. 1996). It seems that a transition from a dry environment to a humid landscape is the cause of this change of armament of the Aborigines of the land of Arnhem. Indeed, in this region where is one of the largest concentration of representations of throwing sticks, these weapons were kept only for ceremonial functions at the arrival of Europeans (Lewis. 1996). This phenomenon confirms the greatest adaptation of throwing sticks to open and arid environments that enable their use on land targets, without barrier and environment, and facilitates their recovery.

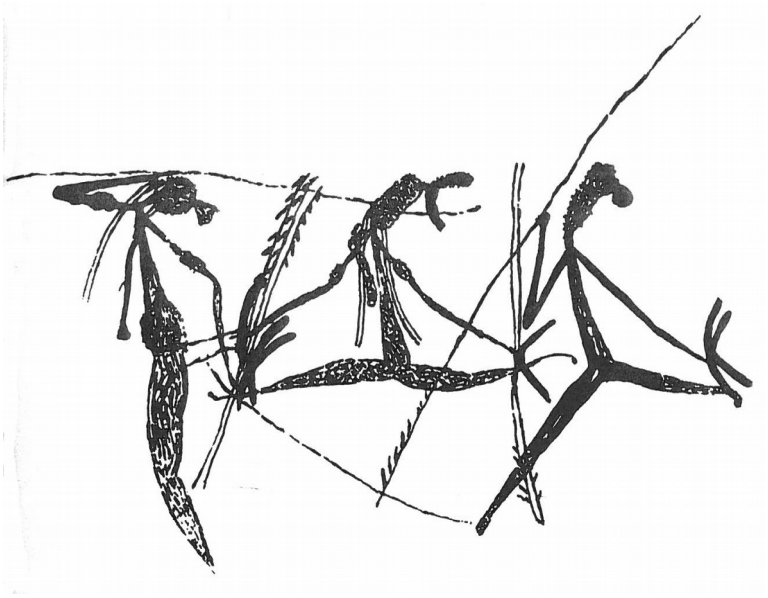


Figure 21: Character Painting equipped with throwing sticks and spears. Arnhem Land (Lewis, 1996).

Other hand, unique for the North and the North East of the Australian continent, and constituting exceptional statements to actual size of this object type, one can observe examples of negative blown painting of throwing sticks and boomerangs (Fig. 22) among these paints (Lewis, 1996).
Some of these representations, many are associated with negative handprints as in Cathedral cave (Carnarvon Gorge, Queensland, see title illustration). These negative sometimes involve missing throwing sticks shape today (Fig. 22) (Lewis, 1996) and thus are important witnesses of technological development of this weapon on mainland Australia. Could it be possible to reconstruct an evolution of throwing sticks in this region relying on prehistoric cave paintings as was already tried about Spears throwers by Walsh (Walsh, 1999)?

Figure 22: Stencil painting of a missing type of throwing stick. Arnhem Land (Lewis, 1996).

III Development of tools and methods

III 1 Primer typological classification

Given the diversity and variability of ethnological and archaeological throwing sticks around the world, a classification is necessary to better define what type of these projectiles is spoken about, and include in texts without confusion. To take one example of this problem, we can cite Felix Hess (Hess, 1975), who is presenting in his thesis a plate of traditional shape throwing sticks outline and all those are designated by the generic name boomerang or "non-returning boomerang" without distinction based on their trajectory shapes, nor based on other of their characteristics. How in this context to know of which object is spoken about, without drawing or geographical origin of the object? Relatives shapes are also confused. For example, Serge Cassen (Cassen 2012) designates by crosier shape type, some stick having several type of shape that are actually quite different, namely the real crosier shaped sticks, but also throwing sticks in the shape of "L", and the throwing sticks with enlarged head, and those shaped in flag shape (see Appendix I). All theses type are not necessarily equivalent in terms of functioning as projectile or in terms of others uses.

The interest of a typological classification is to better distinguish different types of throwing sticks currently confused in their shape, as well as throwing sticks of same shapes, but has different airfoil section or a very different mass. Also, integrate additional criteria such as airfoil section or mass/surface ratio to classify objects is also to address the distinction between them in relation to their aerodynamic and functioning as a projectile. A classification can search and compare many objects more efficiently and more quickly or bracket more effectively the comparison between objects of the same class or sub-class. In addition to the convenience of a classification, It can be also interesting in a perspective for general technological analysis to identify the most common type or absent type for a given region or establish technological relations between objects from distant regions.

To achieve this classification, it will be necessary to clarify the general shapes of objects with other shape features, such as the type of blade extremities or symmetry, which will give rise to different sub more specific classes. These will be further divided by sub-group of airfoil section and different mass classes.

The following criteria will be selected to specify the classification in that order:

- Symmetrical or non-symmetrical shape, if both possibilities exist

- The type of each blade extremity which may be of identical type or not

- The airfoil section type of each blade, which may be identical (Simple profile) or different (mixed) from one blade to the other

- The class indicated by mass/surface ratio of the object

Example of classification:

For example, if one takes the example of 1954.5.99 object from Pitt river Museum, its classification will be:

L-shape, truncated extremities, biconvex profile, heavy class (Fig. 23)

Figure 23: Throwing stick 1954.5.99. Pitt River Museum.

This classification was applied to 291 ethnological objects that I could measure and photograph, from the collections of several museums (Quai Branly Museum (Paris, France), Museum Pitt River (Oxford, UK), South Australian Museum (Adelaide, Australia) ethnological Museum of Leiden (Leiden, Netherlands) and in a private collection (Art Australia, Stéphane Jacob) and enabled with these first defined criteria to identify about 135 different classes of throwing sticks.
The created classes correspond pretty well with the regional ethnological type since the processing of extremities is often defined within each traditional area and seems very consistent. The airfoil section type applied to each blade of the object is often constant for a regional tradition and provides information on the third dimension of the object connected to the air penetration of the projectile. The classification by mass/surface ratio is useful to distinguish the more typical shapes and airfoil sections, for example, throwing sticks crescent shaped and biconvex profile in Australia. Depending on the needs of this classification, with the introduction of new objects in the database, other parameters may be added such as wingspan which could be an additional criteria. In this work, is started a simple classification primer that will serve as a research tool, and will be enhanced in future, depending on the extension of the database.

III 2 Initiation of functional study of ethnological collections

The value of a functional study of throwing sticks is to establish relationships between one or more characters (eg., small or large wingspan, tapered edges or other type of edges, pointed or rounded blade extremities) in relation with known real uses of the object from ethnographic information. In a sense, a function will require one or more characteristic of the object, but in the opposite direction, a series of characteristics for throwing sticks can also match multiple uses, since these objects are often multi functional. This does not systematically link the presence of one or more characteristic on an object to a single function. The variability of throwing sticks is also a factor that makes it difficult to establish a

simple relationship between a function and a given characteristic. Indeed, one can never say that a 50 cm wingspan throwing stick is necessarily dedicated to aerial hunting, but it will be more suitable for this type of flight than a larger throwing stick, measuring 60 cm. Nevertheless, some functions require opposite criteria, which allows to define a relative tendency of those for being use for a particular function: for example, a large throwing stick will be more suitable to use in close combat, compare to a throwing stick with a shorter wingspan, but this latter will be more fitted with the use as a long range projectile.

In addition, the study may help to explain the evolution of some of these characteristics in relation with change of use that explains their recent diversity. Indeed, with a view to changing practices in prehistoric times, the appearance or disappearance of a specific function, hence the removing of the related characteristic imposed on the object will turn it into a new type. For example, a throwing stick made with pointed ends to dig, which is no longer used for this particular function, probably will over time be modified a new type and probably made later with rounded ends. These changes are not only based on the change of use, but due to technological constraints such as strength, stability, and rotation braking facing the relative wind, since it must be remembered, these objects still need to serve also as projectile. These constraints will therefore influence the evolution of throwing sticks to suit their purpose both as projectiles, but also for contact uses, to the most commonly encountered types, such as throwing sticks in crescent shape or with broadened following blade throwing sticks. However, this thorough evolutionary aspect is beyond the scope of this paper and will be treated later.

For this approach, we have built an array of classes, by criteria selected from the characteristics that can be measured on these artefacts (see Appendix I).

For example, the mass criterion can be defined in four classes depending of the mass/surface value:

- Very light throwing sticks <0.7 g/cm^2
- 0.7 g/cm2 <light throwing sticks <0.9 g/cm^2
- 0.9 g/cm2 <medium throwing sticks <1.1 g/cm^2
- Heavy throwing sticks> 1.1 g/cm^2

These classes are limited with arbitrary values, but selected based on experimental observations on the general behaviour of objects belonging to each of these mass/surface classes (see Appendix I). For example, setting one of these limit value, I never able not produce returning throwing sticks or raw wood boomerang for mass value/source area of greater than 0.7g/cm^2. The class limits on each of the criteria may change depending on the experimental. For example if I produce a boomerang having 0.8 g/cm², the limit of throwing sticks very light will move accordingly and if I find an increasing number of ethnological sticks heavy whose value is often greater than 1.1g a new "heavy" class might be necessary to distinguish them. These criteria are crossed with the functions that are documented for each throwing stick.

III 2a About ethnological collections studied

Ethnological collection object consists of 291 objects. They come from the collections of the Museum of the early art (Paris), the South Australian Museum in Adelaide (South Australia), the Pitt River Museum of Oxford (UK) and Volkenkunde Museum (Leyden). Most of the objects are from mainland

Australia (214 artefacts) and Africa (35 artefacts), India (21 artefacts), Indonesia (11 artefacts) and the Americas (10 artefacts). The only artefact that comes from Vanuatu was treated for the moment with the Australian objects, being its typology influenced by the Pacific style, but with local characteristics.

For Australian collected objects, light and symmetrical objects close to the boomerang tend to have been preferentially collected at the expense of heavier objects, bulkier, or more simply constructed, bringing their over-representation in this sample. The collectors also often selected the most decorated and spectacular objects introducing another selection bias. Geographic representation is pretty good, and it can found just near the main types of Australian throwing sticks, though some types such as crescent shapes of eastern Australia are over represented.

Although having almost always has some ethnological information about the features of Australian objects, they are not available or sufficiently accurate only for types of the best known throwing sticks, while for the less common types some information are assigned by it extensions. For example, we know a set of functions for "Kylies" (see Appendix I) emblematic of central Australia (McCarthy, 1961). So all throwing sticks of desert centre that is morphologically closer are being assigned the same functions regardless of major gap of thickness or mass that may affect the proposed use. This implies that some functions are often attributed too broadly to a sets of objects that exhibit a variety of characteristics that must be addressed critically by case basis. In addition, many generic artefacts shapes, like especially the crescent shape is not clearly described functionally, since it was based solely on the shape of the object to do this. The functional information is therefore in this case less accurate and made by extension or based publications giving very general information. It is in this case compel either to extrapolate its function relative from better known standard, or reject the artefact of the table because of the lacking information.

Sampling of African artefacts studied is more balanced, containing quite diverse objects, but here suffers from low typological and geographical representation one would expect for this continent. Ethnological information is accurate enough for these objects, as annotated by individual record by collectors.

The series of Indian artefacts presents two main types of throwing sticks known to this region of the world, with a majority of throwing stick called "Valari" (see Appendix I) from the southern part of the subcontinent. The functional information depend from too general information that does not differentiate symmetrical throwing sticks used in Gujarat by Koles, from the "Valari" used by Tamil, yet a very different type.

The series of Indonesia is very homogeneous and only one type of throwing stick is represented, the "Parimpah" in the form of two regional variants which are characterised by a treatment of their airfoil section and their extremities. Their function is well known being birds hunting above the rice fields (see Appendix II).

The group of objects from American continent belong almost exclusively to the "rabbitstick" throwing sticks style used for rabbit hunting with the exception of a more frustrating copy and a particular distinct crosier shaped stick.

III-2 b Relationship between functions and characteristics of objects by continent

A table summarises the functions-characteristics relationship and its use in Appendix III.

Australia:

The throwing sticks of Australian Aborigines are certainly those which are most multi purpose. For example, many of them as "Kylies" of desert centre are used both for close combat and projectile uses for hunting. There is levelling differences that can be observed for each criterion between two functions. This effect "multi-function" does not, from these data, allow to connect airfoil section types to functions because of lack of statistics, but it is possible to discuss their symmetry and existence of one type of airfoil section on both blades or existence of mixed airfoil. Nevertheless, in the shapes encountered, we can report the lack of crosier shape among this collection. Crosier shape seems to be very rare or absent Australian throwing sticks. Other shapes seem peculiar to this continent as hook shapes or "number 7".

Considering their mass/surface ratio connected to the melee combat use, there is a range of value ranging from medium to heavy, confirming the appearance of more massive objects concerned. The use of digging sticks concerns more massive objects compared to other contact uses, and are located in a light-medium mass/surface ratio range. By comparison, the practices of land game hunting seem to concern lighter objects, especially for ranged combat, which corresponds to a sharper airfoil shaping. One can observe that the scale of the objects used for ranged combat is also smaller than that of the objects used for contact purposes, while for land game hunting purposes, this one remains average. There also is a more reduced thickness for objects used for land hunts than for objects used for melee fighting and also a tendency of their edges to have a sharper character. Note that the only contact that can use tapered edges are those of fire saw, disarticulation and shovel digging. This allows to make the assumption of the role of these uses in the existence of tapering edges on throwing sticks.
Note that the thick to fine range is surprising for digging stick use, then we would expect strong and so thick objects for this function. This is because some straight doubled pointed Australian throwing sticks are ambivalent as digging stick and throwing stick, have an elliptical or double convex airfoil section that led to this particular thinning. The use of digging stick is characterised by pointed extremities which also appear to introduce this type of stick ends in throwing sticks. Although this characteristic cannot be connected to another specific feature in this table, there is a large amount of Australian throwing sticks with pointed ends, particularly those intended as distant combat. The adaptation of many types of throwing sticks of central Australia to the use of digging sandy soil, with rounded ends, also connects to another contact function , but somewhat distinct, the shovel digging.

Australian objects used for a contact function seem to have a tendency to be asymmetrical. This is not surprising since the contact uses involve gripping the object and tend to shape objects with a distal blade (following blade) rather different of the proximal blade (attacking blade). It is also observed that there is a greater proportion of grooved and decorated objects for contact uses. This trend tend to weaken for throwing sticks for only land hunting uses and be absent for objects used for only aerial hunting. This observation can be interpreted by the fact that the majority of throwing sticks which are intended for contact purposes are also those which have higher number of others known functions. Is

the manufacturing steps, sometimes very time consuming as with grooving, meet increased prestige of throwing sticks that just accumulate the most functions ?

The mass decreasing and the reduction of scale of artefact for the aerial hunting uses over terrestrial uses are well marked and show that the use of throwing sticks for hunting or folding birds require lighter and smaller objects. Indeed, launching throwing sticks high in the air fatigue the arm with unnecessarily heavy objects, and would be useless for hunting fragile birds which can be shot by lighter projectiles. The smaller scale responds in the same direction to a requirement of speed of rotation and less braking to the relative wind in flight.

The table shows that the curvature of the objects used for aerial hunting is growing in relation to objects used for terrestrial hunting. These latter seem to have a tendency to be narrower. Both trends are logical, since throwing sticks for aerial hunting need more stability in flight, so more curvature, but don't need high resistance and have consequently a smaller width. Note, however, that this reduction in width is not necessarily uniform and a greater width is frequently held at the elbow of these objects, at the expense of the blade extremities. This point is not trivial, because transfer width to the elbow changes the centre of gravity and increases the rise of the flying path due to the flight nosing up momentum (Thomas, 1985). Another marked difference between objects for flight uses compared to those used for terrestrial use is the presence of more frequent positive incidence blade tuning. This particular adjustment aims to raise the projectile trajectory and to accentuate its curved path (Hess, 1975).
The aerial uses seems to concern more symmetrical objects than for land and contact use. Indeed, in these functions, throwing sticks need intensive hand gripping, hence leading to the need of a longer handling blade and consequently leading to an asymmetrical shape, compared to symmetrical objects built more like pure projectiles. In a convergent manner, there is lower frequency of mixed airfoil section for throwing sticks designed for aerial uses, compared to throwing sticks made for terrestrial hunting and contacts uses.

Throwing sticks used to play, as these refer to boomerang, still seems to accentuate their divergence criteria with air uses and therefore a fortiori compared with terrestrial hunting and contact uses.
Compared to air use, the game objects are characterised by a decrease in thickness and accentuation of the curvature. These differences are mainly due to a rapid rotation necessary to produce enough aerodynamic lift for a returning flight and optimum stability. The difference in thickness, specifically for this purpose, is also explained by the presence of a larger number of objects with the plano-convex airfoil, more common encountered in boomerangs, but it must be remembered, not exclusive.

Africa:

In the series studied, there is a predominance of asymmetric shapes with broadened blade, "L" shape and the crosier shaped sticks.

In general, African objects from the series studied are more massive in relation to their mass on surface ratio, thicker, and almost always have rounded edges, and mostly with rounded and truncated extremities at the expense of pointed ones. The absence of functions as evidenced ethnologically as fire saw or disarticulation of the carcasses uses, could explain this significant difference with Australian object. Do we have here very different uses in the past in the development of the throwing stick in Africa or difference arising from disappearance of these functions in more recent times ?

The series of African objects also includes only asymmetric objects.

African objects do not appear to have significant differences between the close combat use and land hunting uses, except the accentuation of the curvature for stability as a projectile. There is a trend of reduced mass for throwing sticks used for aerial hunting. There is also a decrease in the range of wingspan, blade wideness, and thickness and at the same time an accentuation of the curvature and the positive incidence tuning for objects used for aerial hunting compared to those used for terrestrial hunting. This reinforces a similar trend for these characteristic related to that function, already observed for Australian objects. The series of artefacts is too small to observe significant differences between functions related to blade extremities apart their general characteristic mentioned above. We need only mention three objects collected near Lake Chad equipped with a pointed end on attacking blade (handling blade) may be indicating the presence of the use as a stick digging in that area, unless it has also be preserved as an offensive feature for ranged combat.

India:

The Indian throwing sticks in the present series are classified into the range of heavy objects and small wingspan. They have an average accentuated curvature and a thickness in the range from medium to thick. They are more curved and have finer airfoil section than the average African objects above, by this trait approaching Australian objects. As the Australian objects used for aerial hunting, the Indians throwing sticks frequently use positive incidence for their blade tuning, but are distinguished by their rounded edge and rounded or truncated extremities without presence of any pointed ends.

The Valari belong to the class of asymmetric throwing sticks with broadened blade blade, an optimum shape commonly used also in central Australia. Their distinguishing attribute is a ball-shaped handle which reduces the aerodynamic lift by rotation breaking of the attacking of handling blade aiming to constrain these projectiles to a straight trajectory.
The other main type of throwing stick encountered is that used by Koles peoples in Gujarat (Lane Fox, 1868) belonging to truncated crescent-shaped symmetrical class. Is the presence of throwing sticks symmetrical crescent in India could indicate technological similarities with the Australian continent? This is not impossible, as prehistoric populations who populated Australia 60,000 years ago were probably already mastered this "weapon-tool" and probably followed a route through the Indian subcontinent tens of thousands of years earlier.

Indonesia:

The Indonesian series presents birds hunting sticks distinct compared to those we can find in Australia: With asymmetrical waisted shape, they are both heavier, larger and thicker. They also differ from Australian Aborigines artefact by their rounded edges and their frequent bevel extremities, but especially by their asymmetry and their mixed airfoil section. A personal experimentation and exploration in detail of these objects allowed me to explain the solution they adopted in response to a hunt for short-range birds, practised over rice fields (Bordes, 2009). It seems that the particularities of these throwing sticks do in fairly recent objects in the technological development of this weapon, but could constitute the final leg of a much older tradition.

America:

With broadened blade asymmetrical shapes or asymmetric waisted shapes, Zuni and Moki rabbitsticks of this group are characterised by their common rectangular airfoil section. This airfoil section is probably an adaptation to the most commonly used wood in this region for its manufacture, oak, generally of lower density than Australian or African timber. This airfoil solution allows to decrease thickness to increase rotation speed while maintaining maximum surface section to keep good resistance, as these type are use predominantly for terrestrial hunting. The edges of objects in the present series, have mostly rounded and beveled blade extremities. The rabbitstick are frequently decorated with painting that shows their symbolic use in ceremonies. According to oral tradition Pueblos gathered from local when I visited a museum Hopi in Arizona, but not verified by other sources, the pattern of double line of black paint on the edge of the throwing sticks (Fig. 35, Part IV 2) would even directly involved in the chase function, since it would represent the ears of rabbits ...
Note the presence of a Zuni crosier shaped object, also distinguished by its treatment of non-rectangular airfoil section, showing the existence of this type of throwing stick in this region.

III 2 c Functional Assessment by continent

The most comprehensive functional information about the three types of contact use, land hunting and aerial hunting is given by the Australian collection that is the most representative in the number of objects. The series of Australian object seems essential to establish a theoretical diagram of a relationship between throwing sticks characteristics and their function. If we place the different functions of the Australian Aborigines on a diagram whose origin is the contact functions, with increasing airfoil shaping on X axis and increasing of throwing range on Y axis, it can be sketched the diagram below (Fig. 24):

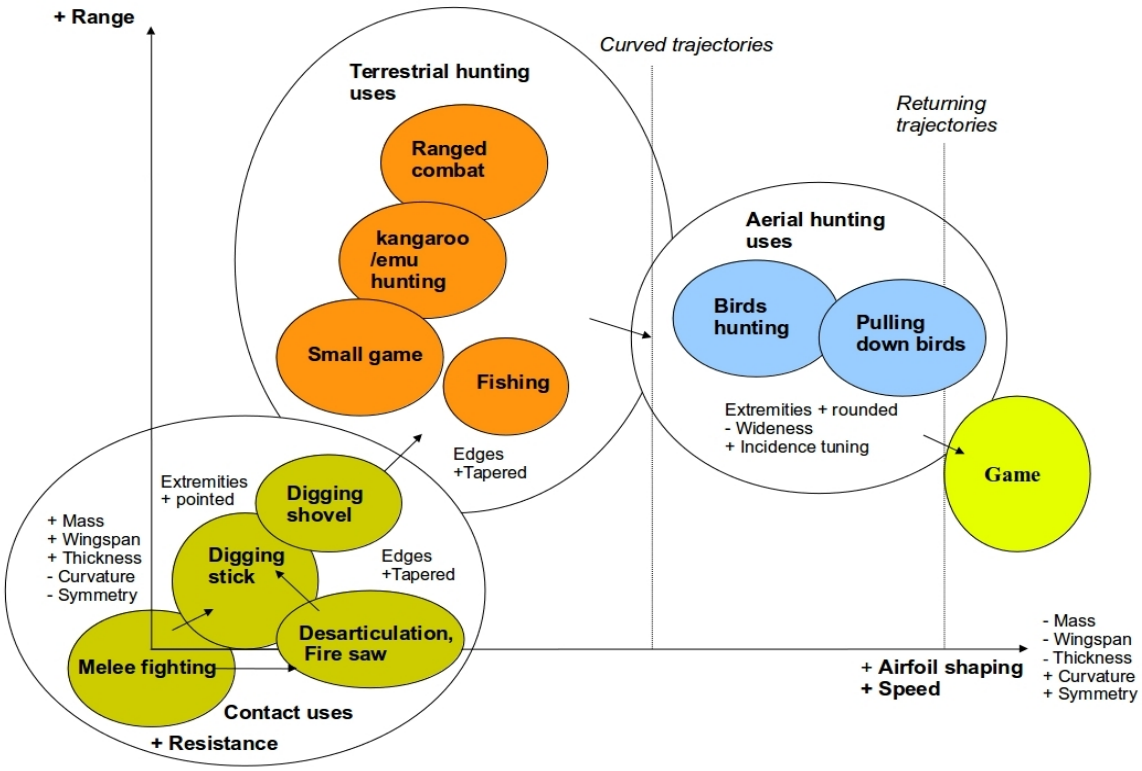


Figure 24: Representation of the characteristic tendencies (or criteria) for functions encountered for Australian objects positioned according to their airfoil thinning related to increasing of rotation speed (x-axis) against range (y axis).

On this scheme, it can be found a summary of characteristics related to differences between contact uses and terrestrial uses, and between terrestrial and aerial uses. We thus find a trend of increasing mass/surface ratio, wingspan, and thickness characteristics, related to the decreasing of curvature as well as the symmetry for the group of contact uses. Progressing towards land uses, then through the air uses, and finally one game, a change in direction opposite is observed on these characteristics: Reduction of the mass, the size and thickness, but increased curvature accompanied by some symmetry. The decrease in mass/surface area and thickness is concomitant with the increase in the airfoil section shaping on this axis. Similarly, The accentuation of the curvature ensures greater stability for objects becoming lighter. The evolution of the average width of objects between these poles of uses is more difficult to understand, since only a decrease from terrestrial to aerial hunting uses is evident in our results. This difference reflects the removing of resistance constraint on throwing sticks used for aerial hunting that decrease in average width. However, it must be remembered here, this reduction is actually inhomogeneous since the objects of this kind and often boomerangs keep more width at elbow than at their blade extremities. This is a general solution adopted on symmetric objects with marked curvature for more resistance, but as we discuss earlier, its changes also the centre of gravity of the object, by raising its trajectory (Thomas, 1985). This additional mass distributed to the

elbow is thus a factor to the invention of boomerang from throwing sticks that are have being selecting higher trajectory, facilitating their return flight by passive gravity (Thomas, 1991).

Always between these two poles of uses, is indicated an increase in positive incidence blade tuning that accentuate curves and rising trajectories with that appears with air uses. This mastery of blade tuning is already on Australian terrestrial uses objects. But the progressive trend to positive incidence blade tuning on aerial hunting objects is certainly the main critical factor that will invent the return path of the boomerang class of objects, having also better shaped airfoil section.
Although it is more difficult to follow their evolution between the different poles of use, the tapered edges character of throwing sticks and sharp or rounded character of their blade extremities must be emphasised. Indeed, we find in all uses of Australian throwing sticks compartments, objects pointed ends. This suggests that this character was introduced by a specific function. yet, digging stick use is the only candidate on this continent to require this feature, leading to situate this use very early on the paths of the functions of these objects. Another important use is the use for the disarticulation of kangaroo and also the fire saw that require sharp edges that we found very present among the group Australian of land-use throwing sticks, and a more general common feature of objects of this continent. Also within this group use, the junction between the digging stick function and uses requiring sharp edges, lead probably to a new use: The shovel digging adopted by "Kylies" central to dig the sandy soil. Another example of throwing stick feature adaptation to use can be found among the Pueblo Indians (Campbell, 1998) digging stick, the extremities flattening to give a new tool to dig and cut the roots of robust plants. This pointed extremities to flattened extremities conversion is very advantageous for throwing sticks, as it optimise the airfoil section of the object at blade extremities while keeping the use for digging. Indeed, it must be remembered that it is at the extremities of the throwing sticks that occur maximum of aerodynamic lift, often referred to as the most aerodynamically active parts of these projectiles. To return to a more general point of view, it is questionable if the functions that develop sharp edges for throwing sticks are simply not responsible for the invention of the shaping of their airfoil section. Beyond the use of disarticulation kangaroos by Australian Aborigines, this issue also raises the question of the prehistoric existence of wooden tools with effective cutting edges and their possible previous invention before cutting stone tools.
Finally, it should be noted the pivotal position of the Australian throwing sticks of terrestrial hunting use and particularly those dedicated to ranged combat, which form the best combination of resistance and airfoil shaping to reach maximum distance. Indeed, these throwing sticks may exceed the hundred meter range, resist rebounds on hard ground and crash impacts on the target or obstacles, while aerial hunting practices saw their resistance constraint decrease will crossing only air. This suggests that it is among the objects in this group that could be found a “technological peak” of throwing sticks, and not in the class of boomerangs, which simply continues a trend of decrease in mass and airfoil section shaping, already initiated with other uses like hunting birds function.

The assessment concerning the series of African objects (Fig. 25) gives results which confirm the scheme outlined for Australia. We thus find a mass, wingspan and thickness decrease, accompanied by a curvature increase from the contact uses toward aerial hunting use. A decrease width and increase of positive incidence is also a tendency found on African objects used for aerial hunting. On the other hand, the group of studied objects being all of symmetrical type and rounded edges, we cannot observe any differences between the three main areas of use for these criteria. As regards of the type of extremities, apart from the three objects originating from had having extremities pointed, others objects having truncated or rounded extremities cannot be put in relation with a particular function. These three pointed hunting throwing sticks are then particularly interesting since they are shaped asymmetrically with broadened short blade which converge toward the same optimum shape which is

common in central Australia. It is therefore possible that the contact uses similar to those documented in Australia (digging stick, shovel digging, disarticulation, fire saw are present or have been present in Africa, but that the small serie of objects studied here do not include the corresponding objects. One could make the same point about the lack of objects for pulling down birds and game, because these uses are evidenced for example in ancient Egypt (Thomas, 1991). In summary we obtain for the African continent an incomplete pattern since the diversity of uses is not fully represented in the short series of studied objects.

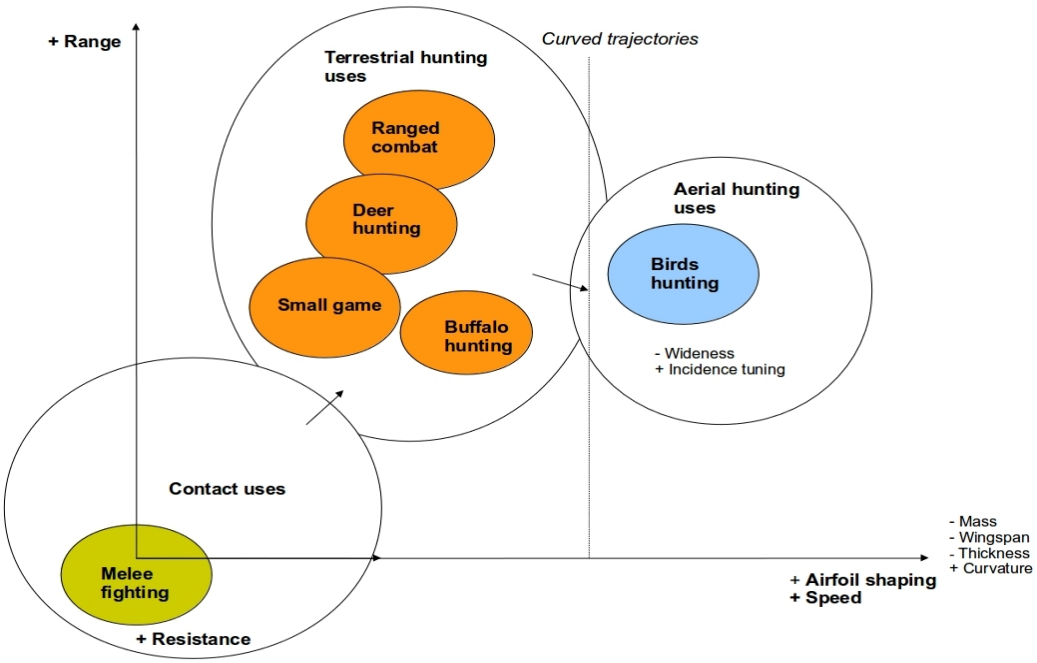


Figure 25: Representation of the characteristic tendencies (or criteria) for functions encountered for African objects positioned according to their airfoil section shaping requirements and speed (x-axis) against range (y-axis).

As for the Indian, Indonesian and American series, it was not possible to establish a similar diagram showing relationship between their characteristics and particular uses, since for these three regions, the objects studied showed no functional difference.

IV Example application of tools and methods

IV 1 Example of analysis of a set of Neolithic throwing sticks found in Egolzwil (Switzerland)

As noted above, three wooden objects, of which two at least been identified as made of hazel wood, were found on the site Neolithic lakeside Egolzwil 4, in Switzerland. The interest of this discovery is to create a set of three objects relatively close related and well-dated. The challenge is to better understand the role of throwing sticks in Neolithic societies. If one notes their main characteristics by arranging them according to typological defined above, the following details were obtained:

First object:

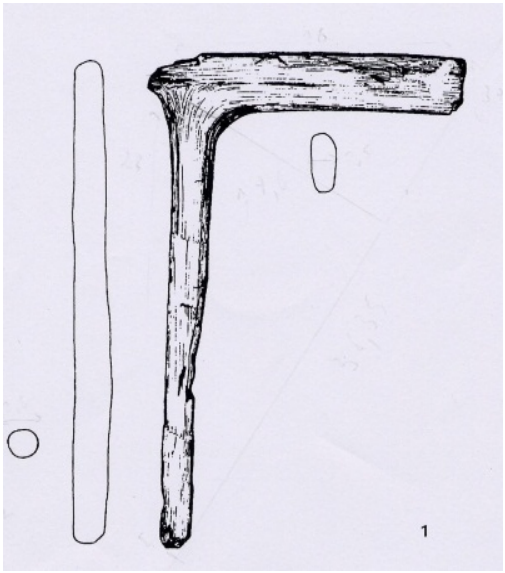


Figure 26:(Ramseyer, 2000).

Asymmetrical shape with broadened blade, mixed airfoil
Truncated extremities, circular/rectangular airfoil section
Wingspan 36 cm. Average thickness 19 mm
Mass evaluation 172 g
Mass/area ratio evaluation 1.28

Second object:

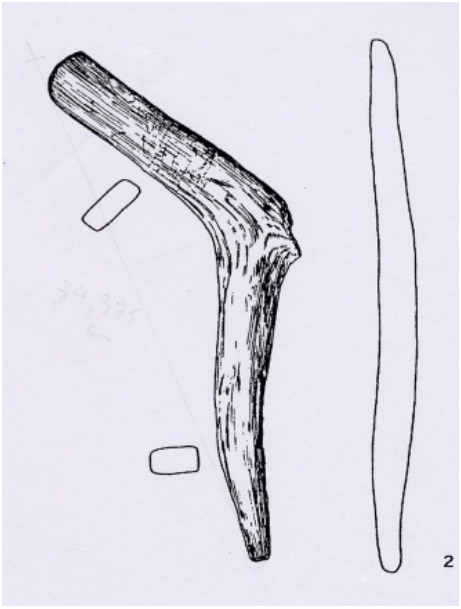


Figure 27:(Ramseyer, 2000).

Asymmetrical shape with broadened blade
Truncated extremities, rectangular airfoil section
Wingspan 37 cm. Average thickness 14 mm
Mass evaluation 136 g
Mass/area ratio evaluation 1.11

Third object:

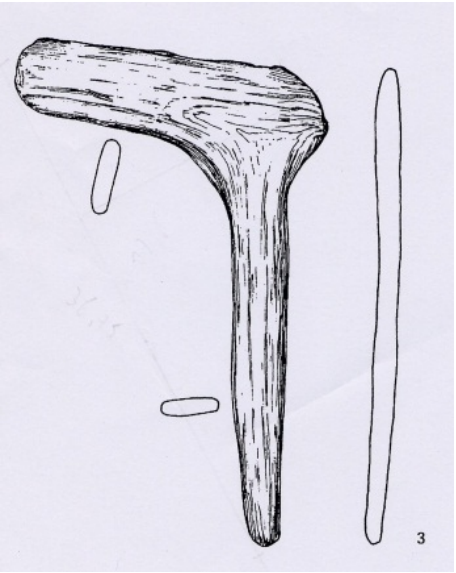


Figure 28(Ramseyer, 2000).

Asymmetrical shape with broadened blade
Truncated extremities, rectangular airfoil section
Wingspan 35 cm. Average thickness 17 mm
Mass evaluation 185 g
Mass/area ratio evaluation 0.91

It can be seen that the first object (Fig. 26) differs from the two other (Fig. 27, 28) by its handling blade having circular profile, while the wingspans and thicknesses are fairly homogeneous for all three objects. The problem here is to propose a use case for these objects, based on the classification for ethno-archaeological comparison, and on functional study for previously. The approach, similar to a method ethno-archaeological already applied to leather work (Beyries, 2008), is to tighten the assumptions of functions by progressive elimination considering detailed characteristics of these objects:

First, it is observed that the mass of these objects is below 200 g and the density of hazel wood is less compared to the heavier wood commonly used for most throwing sticks. As a projectile, their impact will remain relatively weak and may not allow to use them with efficiency on big game or for distance fighting. This is confirmed by the non offensive blunt extremities and the flat edges of the objects. It remains as use as to consider the hypothesis of small game hunting such as hare, hunting birds, pulling down birds and possibly fishing.

Their asymmetrical shape and the mixed airfoil of the first object (Fig. 26) shows that these objects probably derived from longer and more massive weapons which had contact use of, but this function is only residual here, if we consider the small size of these artefacts. This means that one can exclude contact uses such close combat, but the club use to finish small game is another possibility.

Using the typology for comparison with the ethnological base:

If call is made to the ethnological database for comparison and that one searches for objects belonging to the same class, we find two throwing sticks of Ethnic Tun from the Chari River region in Chad.

Figure 29: Quai Branly museum.

Asymmetrical shape with broadened blade
Truncated extremities, rectangular airfoil section
Wingspan 39/38 cm. Average thickness 15/14 mm
Mass evaluation 115/153 g
Mass/area ratio evaluation 0.85/0.95

This type of throwing sticks (Fig. 29) are most likely used for hunting birds as confirmed my own experiments with replicas of these objects. Both African objects are a little less thick and heavy than our Neolithic objects, but have very comparable dimensions. The hypothesis of hunting birds is possible for our Egolzwil sticks, but they seem too heavy and having not enough shaped airfoil section to be thrown very high and use to pull down birds. It would thus be a direct bird hunting in very short range (20-30 m), which corresponds to the lake environment in which these throwing sticks have been discovered.

Now let's look at the hypothesis of small game hunting:

In this function, another close class of objects is that of rabbit hunting sticks or "rabbitstick" from Moki people which are also asymmetrically shaped with broadened blade, often built with rectangular sections. However, these objects typically have a wingspan rather in a range of 40 to 60 cm superior to those of our Neolithic objects. In the case of small game, the wingspan increase could allow to sweep larger radius on the ground to increase the chance to hit the game. This is less necessary in the case of firing on a group of birds where the lightness and manoeuvrability is more important than achieve high trajectory. However the width of the Egolzwil objects elbow, and their thick section confers them

resistance allowing also to launch them to ground targets. The small game hunting use could be present, but be minor. The functional hypothesis made from the observation of the characteristics and ethnological comparison can be validated by experimental specimens, e.g., a replica of the first object (Fig. 30):

Figure 30.

Wood used: Hazelwood
Asymmetrical shape with broadened blade
Truncated extremities, rectangular airfoil section
Wingspan 41 cm. Average thickness 16 mm
Mass evaluation 161 g
Mass/area ratio evaluation 0.88

This object is approximated only as a replica of the first object of Egolzwil, since the airfoil section of the attacking blade has been constructed with a rectangular type, and thinner than the original which is of circular type. This means that the replica will penetrate the air or water better than the original since its blade attack is more streamlined and less thick.

Flight Experiments of this replica watch efficient straight course up to 20-30 m. Given the differences between the replica and the original, the range of archaeological throwing stick could be shorter, around 20 m for the Neolithic object. This one is suitable for hunting birds directly at very short range, with a minor use for the small game.

Let's look at the hypothesis as a fishing throwing stick:

Fishing use (see Appendix II) mentioned above is possible in the lake environment in which were discovered these objects. Indeed, it is on the edge of lakes, river and water body that often focuses bird populations and therefore it is possible to naturally carry both front activities. As the above, the use for fishing exists for the throwing stick in the Kimberley region in Australia. Nevertheless, objects from Elgolzwil have airfoil section significantly less shaped and have no sharp edges as Aborigines fishing throwing sticks. There are also considerably less dense and more thick (between 1 and 2 centimetres thick against less than one centimetre thick for Aborigines fishing throwing sticks) which would appear to limit their penetration effect through the surface of water to stun the fish.

To evaluate this purpose, experimental shots through the surface of the water along a river was conducted with three throwing sticks:

- The replica approached the first object (Fig. 30)

With throwing between 2 to 3 m from the surface of water, the replica of the first object does not penetrate much below the surface due to its low density and thickness close to 2 cm.

- The oak replica of the third object (Fig. 31)

Figure 31.

Wood used: Oak
Asymmetrical shape with broadened blade
Truncated extremities, rectangular airfoil section
Wingspan 37 cm. Average thickness 17 mm
Mass evaluation 321 g
Evaluation mass/area 1.37

There is a significant difference in mass between the replica and the original, since the archaeological object is measured around 185 grams against 321 grams for the test object, heavier.
The same tests as for the first object show that this last replica gets properly under the surface to several tens of centimetres, enough to affect fish swimming 15 centimetres below the surface. This shows that the mass is critical to the penetration of these projectiles in water.

A replica of a Kimberley throwing stick (Fig. 32)

Figure 32.

Wood used: Ventilago Viminalis
Asymmetrical V shape
Pointed extremities, biconvex airfoil section
Wingspan 58.5 cm. Average thickness 12 mm
Mass evaluation 438 g
Evaluation mass/area 1.04

Tests with this replica of Kimberley Aborigines throwing stick, having fishing function well documented, is showing their high performance and allows to compare them with evaluation of our replicas of archaeological objects. Its small thickness and its large mass enables a high penetration below the surface, to 60 to 80 centimetres deep at least near, the projectile having even hit the bottom of the river several times! This logical result shows that the penetration of water for fishing use is particularly effective as the thickness of the projectile is low, along with higher mass. Others throw with larger throwing sticks shows that the small size is preferred for penetration into the liquid medium as is the case through the air.

In conclusion, we can say that the Neolithic throwing sticks found at the site of Egolzwil are not very suitable for use as fishing throwing sticks as may suggest at first glance their compact design because they have poor penetration in water. Their primary use as a projectile would have been rather volatile hunting along with by minor use on the small side game. They had also a probable contact club use to finish this game. This functional study confirms the importance of considering all the detailed characteristics of a throwing stick and not only its morphology.

For a second example, we have chosen to show how to extract some information from rock art, when only a few features are available such as shape, types of extremities, wingspan and height, and sometimes width.

IV 2 Example of Analysis of the throwing stick hunting scene Choppo Cave (Spain)

Hunting representation Choppo Cave is currently the most convincing traces of prehistoric use of throwing stick discovered in Europe. Indeed, details and drawing-dimension of the objects, and the position of the characters leaves little doubt about the nature of the projectile represented in these cave paintings. There are on this scene no less than a dozen characters wielding total of thirty throwing sticks in total (Fig. 33). Serge Cassen (Cassen, 2012) attempts an analysis of this representation already distinguished three categories of throwing sticks and emphasises the information provided by this diversity.

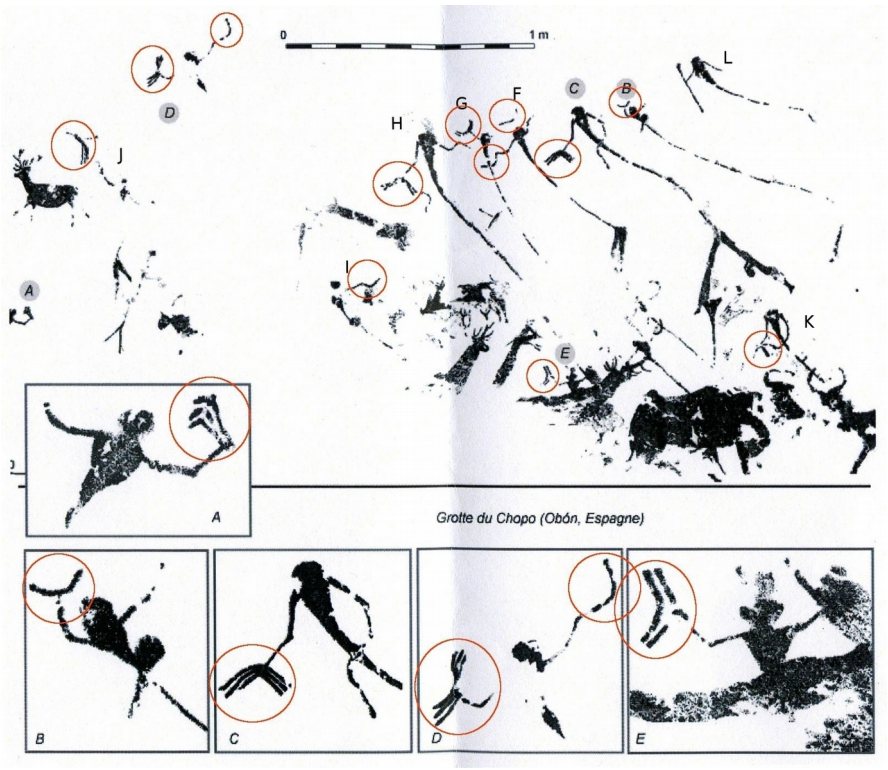


Figure 33: Representation of the Choppo Cave and details of certain figures. Throwing sticks are circled in red (Picazo et al, 2001).

Three types of information can be analysed in relation with objects represented:

- The recognition of different types of weapons to compare to our typology as defined in Part V 1
- The posture of the characters
- The multiplicity of projectiles held by the characters

Figurations count gives the following categories with respect to our classification:

Projectiles:

14 waisted symmetrical throwing sticks (apparent wingspan 55-70 cm), truncated extremities
1 waisted asymmetric throwing stick (apparent wingspan about 55 cm)
2 crescent throwing sticks (apparent wingspan 80-90 cm)
4 S shaped throwing sticks (apparent wingspan 60-75cm) pointed extremities
5 indeterminate throwing sticks
3 "L" shaped throwing stick (apparent wingspan 25-40 cm)

Non projectile:

1 asymmetric straight stick (apparent wingspan 145 cm)

There is the wide variety of throwing sticks represented with at least five types of different shapes and a majority proportion of symmetrical projectiles. The dimensions of the objects depicted, which are evaluated in relation to the arm length of the characters seem realistic with respect to the average throwing sticks size. The only exception concerns the two crescent objects held by the G character whose representation convention seems larger than life, although large-scale throwing sticks up to one meter wingspan exist. These realistic dimensions of throwing weapons represented here allow to make accurate comparisons between the represented shape and some ethnological throwing sticks. The ethno-archaeological approach that will use the shapes and functions of throwing sticks will be explained in Part IV.

Symmetrical waisted throwing sticks:

The presence of symmetric throwing stick with medium to small wingspan, reflects the development of the throwing stick as pure projectile within these Levant prehistoric society. This type of form involves an advanced aerodynamic shaping and light projectiles with straight or curved trajectories potentially including returning objects. This type of throwing stick, visible in particular in figures C and E are comparable with many ethnological objects of this type encountered in the South Eastern Australia (Fig. 34):

Figure 34: Example of symmetrically curved throwing stick. South Australia 57cm. Quai Branly Museum.

Nevertheless, symmetrical throwing sticks represented on the site of the Choppo Cave stand against Australian ones by their type with truncated extremities. This feature translates a loss of offensive function and loss of some contact functions such as digging stick. Symmetrical throwing sticks with truncated extremities were discovered in northern Europe more recently for the period of Tene (see Part III 1).

Asymmetric waisted throwing sticks:

The throwing sticks of this class with greater than 50 cm size, further denotes a terrestrial hunting use with distant straighter trajectories. The only form and dimensions of the visible throwing stick figure B does not specify the type of game to which it was most suitable, but one can compare such throwing sticks to those used by the Pueblo Indians for hunting rabbit which frequently have truncated ends (Fig. 35).

Figure 35: Example of asymmetric curved throwing stick Zuni, Arizona, 64cm.Musée Quai Branly.

Crescent-shaped throwing sticks:

The presence of crescent-shaped throwing sticks in the scene of the Choppo Cave is a both a technological marker and marker of significant function. This type of throwing stick result from early development of archaic throwing stick derived from the primitive double pointed stick. The crescent shapes reflect a good mastering of airfoil shaping and blade tuning necessary for their stability. The large size of this type of object and the presence of pointed extremities translate offensive use that can be found for example in Palaeolithic ivory throwing stick found at Oblazowa (Part II 1). As seen in Part III 2c, the large scale of these objects also consider a possible use in close combat. One can compare such objects held by the character of Figure G with crescent throwing sticks from Queensland in Australia (Fig. 36).

Figure 36: Example of asymmetric crescent shaped throwing stick. Queensland Australia 66 cm. Museum Quai Branly.

"S" shaped throwing sticks:

The presence of S-shaped throwing sticks translated diversification and some throwing sticks technology sophistication in the cultures of the Spanish Levant. Ethnographically, we find this type of throwing stick in the region of Queensland in Australia who is a early area for development of throwing sticks or as type of boomerang or throwing sticks precursors of type boomerang in "S" shape in west of the continent (Fig. 37). As for the crescent shapes throwing sticks, use of type "S" throwing sticks denotes a good mastering in the making of these projectiles.

Figure 37: Example shaped throwing stick "S" Western Australia 60 cm. Quai Branly Museum.

"L"-shaped throwing sticks:

Depiction of small wingspan"L"-shaped throwing sticks reflects an exclusive hunting use suitable for small game and birds and other secondary contact functions like club to finish the catch. Its exist very few ethnological throwing sticks with similar shape and dimensions comparable to the objects shown in Figure A, and “L” type throwing sticks found in Australia are generally larger. The objects represented are comparable to a throwing stick class that included "L" shaped objects from Chad used by young people (Fig. 38):

Figure 38: Example of "L" shaped throwing stick for children. Safrouk , Chad 46 cm. Musée Quai Branly.

This type of throwing stick "L" is easy to build, naturally stable in form and does not require an advanced airfoil shaping to achieve a average distance range (40-60m). It is therefore less technical investment and blade tuning knowledge to populations that no longer considers the throwing stick as a primary weapon, but as a great secondary weapon. It is indeed for the Neolithic period that we find a large set of engraving depiction of "L" or crozier shaped sign engraved on the megaliths of the Atlantic coast, from Portugal to Britain. The presence of these “L” shape could therefore sign the appearance of a new type of throwing sticks adapted to new uses, for most sedentary populations. Of all the types of recognised throwing sticks here, "L" shape one held by the A character is the only one having so small dimension that it seems little suited to deer hunting. Besides this, this object seems to be on the fringes of the scene or may belong to an adjacent different scene.

Asymmetric straight stick

This longer weapon cannot be in any case a throwing stick type of projectile, being longer than one meter, hence would have too much rotation braking in flight. This depicted stick is probably designed for contact use than to be used as a throwing stick. It can be identified as a big club for contact use.

In addition to the types of object represented, gestures of the characters is also informative:

All human figures look in the same direction, which gives the impression of an overall movement to the left. Figures A, B, D, G, I show characters holding at the end of the right arm a throwing stick ready to be launched, while their left hand is holding one or more projectiles in reserve by the their elbow. It may be noted that armed throwing sticks are oriented with curve forward as it happens most often for throwing sticks, as this way of throwing is transferring more rotation energy.
Figure E could be included in this series if we stick to the hand that holds two spare throwing sticks, but the throwing arm being not visible, it is difficult to conclude. Figures C, H, K show characters equipped in the same way, but their right hand has not armed the throwing stick for shooting and they stand ready to use. Note that the character H that nevertheless begins preparing his action of throwing placing his projectile backwards. The F character's position is special: the character is getting ready his throwing stick weapon in position to launch in his right hand but hold another projectile not by the elbow but by its extremity with the curve upward. It seems that this position reflect a different way of holding spare throwing sticks.

These observations show that the represented scene corresponds to a real use of throwing these projectiles. But what may be the exact hunting tactics in relation to the animals on this painting? The relationship between hunters with deer and cattle represented is not easy to interpret. There are two clashed cattle that did not seem to be attention from the characters. Those moves to the left over a deer group moving to the right, with the exception of one of the isolated animals, to the left of hunters.
Is the man group managed to isolate a deer from the herd for slaughtering it more easily?

The presence of multiple objects held in a reserve bundle may provide other information:

It is interesting that the characters C and D take up to three reserve throwing sticks. The use of spare throwing sticks by Aboriginal hunters is well attested ethnologically in Australia. When throwing sticks are large and quite heavy as used in the Australia arid centre, it is very often a pair of “kylie” which is used. In the case of lighter and thinner projectile, even more can be held in one hand. Indeed, the prehistoric paintings Kimberley (Fig. 39b) and Arnhem Land (Fig. 39a) frequently show us frequently characters holding more than two throwing sticks in one hand.

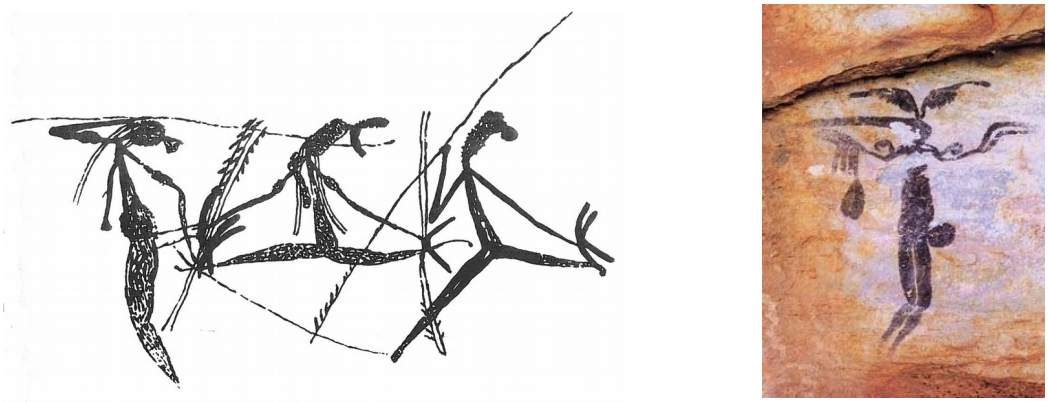


**Figure 39a, 39b: Example character holding bundles of two or three throwing sticks:
Hunter provided spears and throwing sticks, Twinfall creek, Arnhem Land (left). (Lewis, 1996)
Ceremonial dance with throwing sticks, Bradshaw figures, Kimberley (right).
(http://www.bradshawfoundation.com/bradshaws/kimberley5.php).**

However, holding three throwing sticks in one hand can only be done properly if the thickness of the object is less than 2 cm, and relatively comfortable with objects thickness of less than 1.5 cm (as indicating personal experimentation). This means that objects depicted in the scene are curved projectiles equipped with thin shaped airfoil section. Now, the only curved weapons known with thin shaped sections, which can have such variability of shape and extremities observed on this rock art scene are throwing sticks and boomerangs.
In conclusion, it seems that we can confirm in this painting representation of throwing stick with types and dimensions which are compatible with a direct deer hunting. The position of the figures may reflect an isolation tactics of the beasts of the herd by folding. Is it you the first phase of the hunt before slaughtering of the animal wounded by the follower character equipped with a long club?
More generally, we can say that the cave paintings of Choppo represent very diverse throwing sticks adapted to a broad use range as projectiles depicted could be designed to be used from small game to ranged combat. This shows that type of weapon have a well developed role beside of the bow use by the prehistoric peoples of the Spanish Levant, and could have played a role in hunting or war. The role of primary weapon in such prehistoric society also confirms that hunters depicted in the paintings are probably belonging to a long lasting Mesolithic culture in the Iberian Peninsula rather to the neolithic culture rising during the Neolithic VI millennium.

V Conclusions & Prospects

V 1 Conclusions

At first, it was shown in this work that an archaeological study approach of throwing sticks need first going through the adoption of clear terminology that can encompass objects used as projectiles running on the same mode in which it possible to distinguish subsets, without confusion. Indeed, separate groups of objects, such as boomerangs based on their returning trajectory, or another throwing club exclusively with clubs because of their lack of airfoil section shaping, is rather artificial, and may exclude archaeological objects that could illuminate the understanding of their role in the past, and their evolution. This hindsight, leads to a more general definition of throwing sticks which refers more broadly by their operating principle as projectile turning on themselves.
Secondly, it has sought to explain the low archaeological footprint of throwing sticks by the nature of their materials perishable, while presenting some prehistoric and historical findings that pose precious milestones to monitor their dashed presence in different regions of the world. These findings pose us a number of issues, especially in Europe where the finds are the most numerous, but unlike the Australian continent without their ethnological context. Before trying to answer directly to more complex questions about their role in prehistoric societies, its seems important to develop tools and methods to assess on solid ground features and functions of the finds. These tools and methods have been proposed in response to the current weaknesses of the approach of archaeological and ethnological throwing sticks. One problem consists in considering them exclusively by their general morphology. The usefulness of considering all of their physical characteristics and details of their shape is setting back the morphological parameter as a simple parameter among others. In this context, I developed a starting typological classification, to detail this general morphology including the extremities types and symmetry, and including new features on the third dimension objects. The development of this classification will continue progressively, in reviewing new types of throwing sticks from ethnological collections.

The study of the functions of archaeological objects is essential to understand their purpose in societies of the past. Using ethnographic sources, it was therefore indispensable to reconsider an inventory of functions that can be associated with throwing sticks, not only as projectiles, but also as a tool or symbolic object. The inventory of the functions of throwing sticks is in itself an assessment of knowledge of ethnological known uses for different regions of the world, and a permanent bibliographical research to clarify them.

Another part of the work was to make an attempt to link these functions with the physical characteristics of throwing sticks, using an ethnological database made beforehand about three hundred objects from the museum collection. Although this study was faced with the multi-functionality of throwing sticks and their variability, and could not set absolute relationship between certain types of objects and particular functions, it could be shown that it was possible to identify characteristics trends for certain functions or function group. These relationships can be used in a relative way to compare the adaptation of several throwing sticks for a particular purpose.

Beyond the application to archaeology, the study of the functions of ethnological objects in relation to their physical characteristics, also helps to better understand some of them in an environmental context or understanding other regional cultural specificities. To test the functional test assumptions and flight capabilities of these projectiles, experimenting with raw wood, shaping conditions and realistic throwing conditions will be preferred in my approach, to those in making throwing sticks with modern materials with significantly different performance. Another step to take seems to be the exploitation of rock art ranging from simple engraved patterns to comprehensive painted figurative scenes, carrying information about the role of prehistoric throwing sticks. In this sense, it seems logical to follow Serge Cassen (Cassen, 2012), which paved the way in this area by the detailed analysis of representations of a particular group of crozier shaped throwing sticks. This, with trying to improve their interpretation using the most systematic comparison tools developed here to study real objects.

As illustrated by the two examples discussed, the use of methods and tools for the study of prehistoric throwing sticks can help illuminate the use of archaeological throwing sticks or make better use of the information contained in its representations. The methods of gradually tightening function hypotheses, by rejecting some of them, seems to be most effective. However, one need to be careful and keep in mind the always possible multi functional aspect of these objects, and giving percentages or evidence of use could prove to be a better way of presenting the results. The test analysis throwing sticks Egolzwil (see Part IV 1) highlighted the importance of the determining wood and the density of the materials for throwing sticks. Indeed in the case of these archaeological objects the possibility of fishing function is played critically on this parameter, and this use had been proven to be not possible with objects hazel having too low density. As against this function could be envisaged with higher density of wood as shown in the tests with the oak replica of the third object (see Part IV 1). The need for comparison of throwing sticks with ethnological models also emphasises that the knowledge of the function of these objects is a condition to this ethno-archaeological approach. The study of archaeological throwing sticks goes hand in hand with an upstream work on ethnological collections in which the functions and features of many objects are often misunderstood.
The test for analysing the representations of the Choppo Cave (see Part IV 2) stressed the importance of crossing morphological characteristics of the objects represented with more context information, in this case the gestures of figures human and observation of holding multiple objects in their hands, to consolidate an hypothesis. The morphological variability of the type of objects in the scene and the presence of archaic shape marker as the low specialised crescent shaped throwing sticks (see Part IV 2) which appear to be less present in Neolithic societies or posterior historical civilisations having greater

specialisation the use of the throwing stick, can help make us a sketch of the place of these weapons in prehistoric societies hunting. Finally the consistency of measurements of throwing sticks found on this rock art scene with those of real objects shows that dimensional measurement can be used in some cases on prehistoric depiction being "naturalist" proportionate.

V 2 Prospects

The outlook of this first approach is to continue both to develop tools and methods of analysis for objects and rock art depiction, but also to start paying attention to broader archaeological questions about throwing sticks.

The tracks of development of analytical methods are many, but we note some priority areas:

- Improving and increasing the ethnological database that serves as a basis of comparison for the analysis should be continued, by systematically adding functions known for each object. Some ethnological throwing sticks must be experimented and their functions explained in relation to other objects with similar characteristics. In addition, the study of more throwing sticks from African collections could prove to be a significant contribution to complete this database. The density and type of wood from which these objects are manufactured is missing data and it will consider the development of a technical evaluation of the systematic volume, simple and inexpensive, and applicable on a large number of items, to remedy. The precise recognition of wood species would also be useful, but seems for the moment difficult to achieve systematically on a high number of objects with only the current naked eye observation technique.

- The development of a photographic references of crafting traces and traces of use would be useful to systematically identify ways of throwing stick making and complete the functional based study on the characteristics of these objects. Some traces could be done by technological analysis. For example, the scraping action often leaves on dry wood throwing stick surfaces scrapings waving pattern (see Appendix 1, shaping trace). The spacing and frequency of these pattern appears to be variable according to several factors such as the scraping angle, cutting edge, scraper type and the hardness of wood surface etc, which may be traceable to crafting tool used.

- Establishment of a rock art representations database would be a step towards a better use of this corpus. This base would record the morphological characteristics of each throwing stick sign, its location, its date and context of each depiction, and in the case of scenes including human figures, their relative dimensions with respect to them. This tool would allow easier and faster comparison and can help to better understand the distribution of morphological or dimensional type in particular for the Sahara region or in Northern Australia where paintings and engravings are numerous and where an overview is currently difficult.

- The development of theoretical tools and particularly the evolution of throwing sticks patterns can also improve their understanding. Indeed, in all of these projectiles, from simple throwing club to boomerang with returning trajectory, evolutionary relationship could be united by a technological development tree. However, the Australian continent can be considered to contain a reservoir of ethnological throwing sticks of sufficient diversity to be able to restore at least the main branches.

Indeed, the isolation of this continent allows us to observe the conservation of the use of many types of archaic or intermediate throwing sticks that appear to have disappeared in other parts of the world, probably because of the appearance of other weapons firing projetiles as spear throwers and bows.

Concerning the study of the role of throwing sticks in prehistoric societies, we could follow, provided with these first systematic classification tools and methods of functional analysis, various lines of research regarding this weapons-tools in Europe and Near East:

- In the future, analysing the characteristics of archaeological objects found on Neolithic Swiss lake site Egolzwil could be compared to others, from the same period found on the Chalain site in the Jura, France. Bringing these throwing sticks in relation with megalithic representative body of the Atlantic coast could allow to get insight on their practical and symbolic role in the Neolithic period in connection with the work already achieved by Serge Cassen (Cassen, 2012).

- A comparison might be attempted between the corpus of prehistoric Saharan representation with that of Europe, particularly with the paintings of the Spanish levant. These could also be compared with the types of Neolithic throwing sticks depicted on megalithic in Portugal. Indeed, the Mesolithic-Neolithic transition that sees living aside crop farmers with pastoralists hunter seems to have been the scene of the emergence of new uses and growing importance in the symbolism of such weapons-tools. This work could be developed in relation to the laboratory in Toulouse (UMR 5608 TRACES) where researchers are studying these representations of the Spanish Levantine.

- It would also be useful to list the prehistoric and historical representations of throwing sticks in the middle east with those as a starting point the site Catal Huyuk. Are there connections with representations of these objects in Europe? The expertise of CEPAM (UMR 7264) of the Neolithic period in the Near East and Neolithic currents to Europe might be possible to support a line of research in this direction.

Appendix I Detailed characteristics of throwing sticks:

Physical characteristics

Mass & Surface:

The mass is well before the shape of a throwing stick, one of the most important parameters. If one keeps the other parameters constant, the experiment shows that two throwing sticks of identical shape but different mass, will have a very different flight behaviour: while two variants of different form, but the same mass, may have similar aerodynamic behaviour. It can be intuitively assessed by simply weighing the object.

The surface is, on the other hand, regarded as the aerofoils of a throwing stick. It acquires a meaning in ratio with the mass. It can also evaluate by naked eye relative to the dimensions of the object. It determines in relationship with the surface (mass/area) the aerodynamic lift and glide capacity due to the aerodynamic lift force.
It possible to classify, for example, different throwing sticks with respect to this ratio. Thus a stick can measure 80 centimetres wingspan, weighing 450 grams and yet be ranked in the "light sticks" because of its large surface area, while a throwing stick with 30 centimetres wingspan, with circular airfoil section built in dense wood can rank in the "heavy sticks" if it has a smaller surface. This ratio therefore gives an indication of the relationship of the aerodynamic lift with a given surface relatively to the mass. It measures whether a throwing stick operates with a predominant mass effect (higher mass/surface ratio >1) or with a greater contribution of the aerodynamic lift (lower mass/surface ratio <1).

I define different classes of mass/surface ratio as follows:

Heavy throwing sticks

$1.1 g/cm^2 < M/S$

These are throwing sticks which operate driving by their mass, and stabilised by the rotation. Their range is often shorter, but their impact most powerful. They fits well with close range hunting. Their trajectory is often straight even without fine adjustment. They are particularly suited to hunting in a closed environment with a lot of obstacles where the resistance of the object is critical and when range is not a priority.

Medium throwing sticks

$0.9 g/cm^2 < M/S < 1.1 g/cm^2$

These sticks are very effective at impact but also have a greater range due to aerodynamic lift. It is a sort of ideal balance between weight and surface around ratio of 1 g/cm^2. This class presents a good compromise between gliding flight, power and durability.

Light throwing sticks

0.7 g/cm^2 <M/S <0.9g/cm^2

These sticks gain a significant aerodynamic lift and requires an adjustment to achieve specific trajectory. It is in this class we find the long-range throwing sticks that can be used for hunting birds and for the large, fragile and fast game in a open environment.

Very light throwing stick

M/S <0.7g/cm^2

The famous boomerangs, objects returning back to the thrower, who gradually lost the use of hunting, but have outstanding flight properties, belong to this class. Even without returning property, very light throwing sticks frequently have curved paths or "S" because of the influence of aerodynamic lift on such projectiles. In this category, throwing sticks will be reserved primarily for bird hunting due to low resistance to withstand impact with ground obstacles.

Airfoil section:

There is an infinity of section to produce a throwing stick, but the main types are:
circular, elliptical, bi-convex, rectangular, almost plano-convex (less convex surface on intrados relatively to extrados), plano-convex, diamond (Fig. 40).

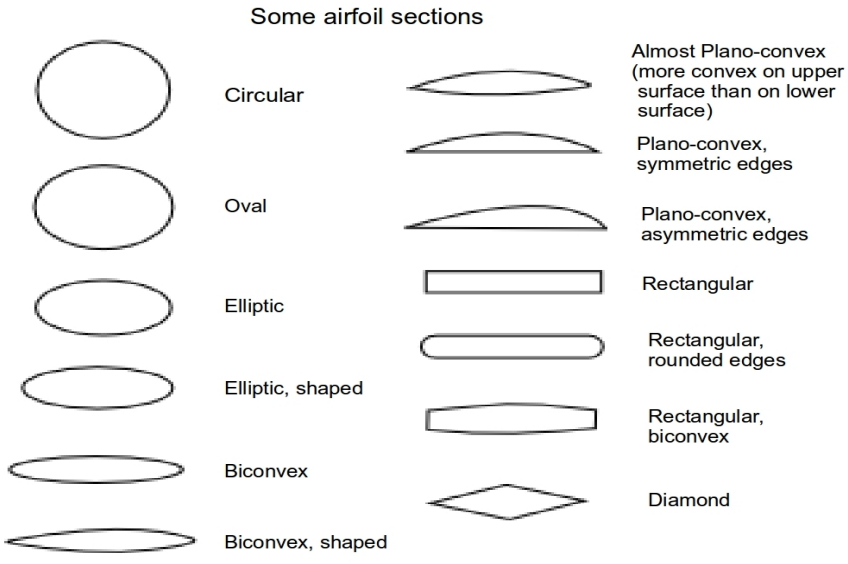


Figure 40: Types of airfoil section encountered for throwing sticks.

The airfoil section is observed by holding the object by the elbow and looking in the axis of the blades towards the latter. The airfoil section can be combined to be different on each blade, to obtain throwing sticks with mixed airfoil section, for example a throwing stick with the long blade having biconvex section and the short blade a plano-convex section.

It may be noted the airfoil section classes symbolically as follows:

Circular

Symbolic notation:

This is the natural profile of a piece of wood from a branch or a trunk. This is the section that requires the least removing wood shaping, except regularisation of its diameter. Although this airfoil section does not enjoy a good penetration in the air, one need to do not underestimate throwing sticks with circular airfoil section, especially if they belong to asymmetric shape weighted at one end, such as throwing clubs. This ballast end will increase their rotational inertia. Are frequently found with this airfoil section some throwing sticks with low curvature shape or hoe or crozier shaped or bow shaped which by lack of width, must be resistant. It is a airfoil section suited to rugged throwing sticks and will often remain limited in range and speed.

Elliptical

Symbolic notation:

This is a circular section from which has been removed material on two opposite faces. So this is the most archaic airfoil shaping that we can find. The speed of rotation is enhanced by a greater penetration into the air with this airfoil section compared with the circular airfoil. The throwing sticks which are too narrow to develop a true bi-convex airfoil may have this one. The elliptical section may produce throwing sticks that reach a respectable distance that can exceed 50 meters, with minimal material removal. This section is most often produced by removal of matter on wood heart.

Biconvex

Symbolic notation:

This is the type of typical airfoil section of Australian throwing sticks. It is one of the most popular worldwide. As with the elliptical airfoil, you can connect it to a design of symmetrical shaping that could be compared to the invention of biface to the lithic industry. This section is the result of a consistent material removal on the two opposite faces, and but allows a performance range beyond 80 meters. There are returning objects (boomerangs) with this airfoil section, particularly as some South Australian boomerangs (Bordes, 2011).

Almost plano-convex

Symbolic notation:

This type of airfoil section is improvement of biconvex section. It introduces a difference of convexity between the extrados (top) and the intrados (underside) of the object which increase the aerodynamic lift and allows better glide of the projectile. It is likely that the throwing sticks have reached maximum of speed and range having this airfoil section. It also has the advantage of maintaining a sufficient mass to maintain a good rotational inertia. This type of airfoil section may have been facilitated by the construction technique of throwing sticks by splitting a piece of wood into two halves (Bordes, 2010). Indeed, the flat surface of separation of the two parts favours this type of airfoil section, saves raw material, and diminishes the amount of wood to be removed during the shaping.

Plano-convex

Symbolic notation:

This profile is the result of technological improvement that began with the almost plano-convex section, since it requires more material removal for its shaping. The aerodynamic lift is maximum in this case. This section presents the advantage of reducing considerably the thickness of the section and accelerate the rotation, resulting in more aerodynamic lift. The lightness of the object is another advantage, and this section will enable to produce throwing sticks with high glide, which can be launched more easily and with more range. However, the flight path provided by this airfoil is difficult to hold in a straight line and it is easy to get "S" or curved flights, if the twisting tuning is not perfectly compensated from one blade to the other. Another disadvantage is the weakened section of the object that is sometimes unsuitable for certain uses which involve violent contact with the ground. Australian boomerangs, for example, have fully exploited this type of airfoil section to improve turning ability. This section requires a maximum removal of wood which makes interesting for its making the technique of splitting and direct extraction of sapwood from trunk without cutting (a proven technique among Australian Aborigines).

Biconvex rectangular

Symbolic notation:

This is an evolution of the biconvex section since the additional material is removed at opposite edges to obtain the flattened edges. This section is intermediate between the biconvex section and the rectangular profile. The flattening of the edges can slow the rate of rotation of a biconvex profile and decrease the thrust of the object so as to maintain a straight path. This intermediate airfoil section is rarely met and there are more commonly ethnological throwing sticks with a rectangular profile.

Rectangular

Symbolic notation:

This profile is found in North America for the Pueblos throwing sticks and for African throwing sticks. The biggest advantage of this section is to minimise the thickness while maintaining maximum section , hence maximum resistance. This solution is interesting for throwing sticks built with medium density wood which must keep sufficient mass to ensure their range and not need offensive tapered edges for a specific use. The performance in terms of range and speed obtained with this section are almost comparable with that obtained with a biconvex section, which explains its development in the technological evolution of throwing sticks. The geometry of this airfoil section involves a relatively advanced technology of wood working including at least performance-fitted tools (polished adzes and hatchets).

Semi biconvex

Symbolic notation:

This type of airfoil section can be found among some African heavy throwing sticks designed for hunting buffalo. This section is intermediate between the biconvex section for an edge and the rectangular section for the other. Its purpose is probably to keep maximum strength and mass with a rectangular edge, while retaining another edge biconvex more offensive in melee use and distance impact.

Diamond

Symbolic notation:

We find this profile in Indonesian throwing sticks hunting birds called "Parimpah". It is probably a fairly recent origin, the result of regular work with metal tools.

Simple or mixed character profile

A throwing stick can have blades with identical airfoil section or having each of its blades cut in different airfoil section. It will be said in this case that it's a mixed airfoil section and will be scored as follows:

Attacking blade section/following blade section

Example: biconvex/plano-convex

Wingspan, height, length of attacking blade and following blade

This diagram summarises the reading of these lengths:

Figure 41: Wingspan, height, length of attacking blade(attacking arm) and following blade (following arm).

Wingspan

The major classes are defined as follows:

Small wingspan<60 centimeters

Medium wingspan 60 centimeters - 80 centimeters

Large wingspan > 80 centimeters

Height/Wingspan

It will be defined the height to wingspan ratio generally being between the values from 0 to 0.5. This index is not completely equivalent to curvature but will be chosen preferentially because it gives a better indication of the stability of the projectile than this one. Nevertheless, it can be can be considered for simplicity in most of the cases that a throwing stick with a increasing ratio height/wingspan is also increasingly curved. Throwing sticks with a ratio below 0.2, may be prone to instability as twisting in flight. Of course, this ratio is not independent of other parameters such as the mass/surface or blade tuning that will influence this behaviour.

Light curvature

H/W<0,2

Medium curvature

0.2 <=H/W<=0.3

Accentuated curvature

>0.3

Blades length Symmetry

The symmetry of the blade length is the ratio of the value of the following arm length to the value of the attacking arm length. Objects with a value close to 1 will be more symmetrical. In the strict sense of the term, objects are considered to be almost symmetrical if this value is between 0.9 and 1.1.

Blades and elbow widths

These are the widths of the object measured at the elbow and at 3 centimetres from each extremity. From these three measurements, an average is determined.

We define the average width classes as follows:

Very narrow W <= 30 millimetres

Narrow 30 <W<= 40 millimetres

Medium 40 <W<= 60 millimetres

Broad >W 60 millimetres

Thickness at the elbow and at the blades extremities

These thicknesses of the measured object at the elbow and 3 centimetres from each extremity. From these three measures average is determined.

We define the average width classes as follows:

Very fine T<= 8mm

Fine 8 <T<= 10mm

Medium 10 <T <= 15mm

Thick 15 <T <= 20 mm

Very Thick T> 20mm

Incidence and and dihedral twists:

When installing a throwing stick or raw wood boomerang with his elbow on a flat surface one realises that certain parts of are not in contact with the table plane. A throwing stick is rarely flat ! Indeed, the object follows the twist of natural wood that served as raw material, or have undergone adjustment twists that improve its flight, not counting the twists that may be due to drying, or to variations wood hydrometry related to storage conditions. The incidence is defined by the angle between the table plane and the median plane passing through the centre of the airfoil section of the throwing stick, taken in the direction of travel of the blade (Fig. 42).

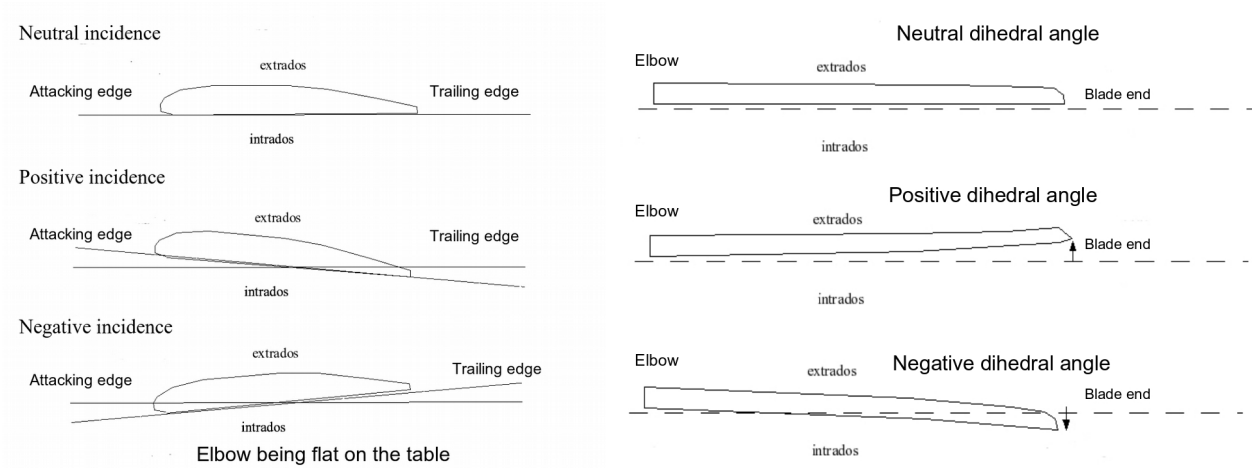


Figure 42: Incidence and and dihedral twists.

The point to remember is that a positive incidence increases the aerodynamic lift of a blade considerably, while a negative incidence decreases it. These tunings plays a large role for the old traditional throwing sticks and boomerangs and this tuning is the same at the base of the Aboriginal flight returning boomerangs. These tuning are critical to properly control the flight of throwing sticks as they have an airfoil section. They can be already observed on the throwing sticks from Oblazowa (Valde-Nowak, 1987) in Europe and on boomerangs from Wyrie Swamp (Luebbers, 1975) in Australia. The prehistoric men that have produced the throwing sticks and those many newer cultures around the world, were aware of these tuning.

We define classes of tuning as follows:

A positive tuning on attacking & following blade will be scored “positive-positive” or “ ++ “ , a negative tuning on attacking blade and neutral tuning on following blade will be scored “negative-neutral” or “-0”. It will be remembered that the attacking blade and following blade of a throwing stick are never aerodynamically equivalent and a positive-negative tuning (+ -) will be very different from negative-positive tuning (- +).

Dihedral:

A dihedral or dihedral angle is the angle formed by the plane on which the blade is placed and the plane formed through the elbow and the extremity of a blade throwing stick (Fig. 42). A positive dihedral angle will give slightly more aerodynamic lift than a negative dihedral angle, but this parameter plays a less important role for the objects studied here. Their effects become more important for modern boomerangs, much lighter compared to their carrying surface. For this reason, we will focus more on the angles of incidence for ethnological and archaeological objects, but their contribution in particular cases should not be neglected. The dihedral angles will adopt a scoring

system of the same type as the incidence.

The type of shape

A number of classes and subclasses of shapes defined as follows will be recognised using a symbolic representation.

The shape symmetry

Apart from the shapes having intrinsic asymmetry, there is a symmetry criterion for shapes that can be either symmetrical or asymmetric. For example, the straight shape can be symmetrical in the case of double-pointed sticks, or have a extremity weighed by a mass and be asymmetric in the case of throwing clubs. In this case, they will belong distinct class and subclass.

Symbolic notation:

In a second case, as for the symmetrical crescent shape, there may in this class symmetric and asymmetric croissants. This is what will be measured further and designated by asymmetric blade length.

Symbolic notation:

Class: Straight Shape

These simple forms of throwing sticks which have no curvature. They are very simple to make and certainly the oldest. This kind of shape is very suitable for the use of the digging stick (Fig. 43), from which it has probably originated. It is generally multi use.

Symbolic notation:

This type of form has mostly a circular section as with further airfoil shaping, it would be unstable in flight, without stabilisation given by any curvature. Nevertheless, we sometimes encounter elliptical sections that have utility as "flattened shovel" to dig. According to experiments to launch this type of object, the launch could take place in this case vertically, instead of horizontally to avoid the twisting effect in flight.

Figure 43: Example of straight double pointed throwing stick. Australia 81 centimetres wingspan. Musée Quai Branly.

Figure 44: Example of straight double pointed throwing stick with a central mass. South Australian Museum.

Subclass: Simple asymmetrical straight shape

This type of asymmetrical shape provided with one weighted extremity compared to another, is drifting from close combat clubs that have gradually reduced their size to suit use as a projectile. It is a precursor of an important family of asymmetric throwing stick that will put the biggest advantage of this shape advantage: increased rotational inertia that maintains the rotation of the projectile in the air. With this feature, the throwing sticks are heavier and have a more powerful impact than their symmetrical equivalent.

Symbolic notation:

Figure 45: Example of asymmetric straight primitive shape, Masai, Kenya. Quai Branly Museum.

Class: Broadened head curved shape

Shapes that have one curve, and a short, wide head flattened on the extremity of the following blade, inwardly directed from the curvature. It can be round, triangular or elongated.

Symbolic notation:

This type of shape derives from the previous one by flattening and shaping the head of a club. This change resulted in a flight instability of the object, which must be bent to be viable. The position of the flattened head shaped inside the curvature is enough to make the object more stable. In Australia, this shape is characteristic of the "Lil-Lil" (Fig. 46), which are combat throwing sticks from the southeast of the continent. While being an archaic form of the throwing stick, it is nevertheless very efficient in flight, combining the rotational inertia of the throwing stick with an acceleration of rotation. This form also allows to keep a good grasp of the object for contact use as a club. This type of shape is mostly produced with the lower part of a tree or a trunk root junction.

Figure 46: Example of a form enlarged head "Lil-Lil 'Queensland 61 centimetres wingspan. Pitt River Museum.

In South-Eastern Australia, particularly in Victoria and New South Wales, is a particular shape of flattened head throwing stick, drifted from throwing club and generically called "Lil-Lil."

Figure 47: Example of "Lil-Lil 'triangular head variant. Australia (NSW) .76 centimetres wingspan. Pitt River Museum.

Subclass: Elliptical head shape

Shapes that have any curve and a flat perpendicular elliptical head at the end of the short following blade.

Symbolic notation:

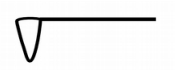
This shape is a rare variant of the previous whose flattened head must also be stabilised by the curve of the object. In this sense, it is may be a more archaic form for which the head has not moved to a placement inside the curvature (Fig. 48).

Figure 48: Example of elliptical shape head. Soudan. 72 centimetres wingspan. Pitt River Museum.

Subclass: Flag shape

Shapes that have either a straight handle or any curve, and a triangular head with convergent edges at the extremity of the short blade (following blade) inwardly directed from the curvature.

Symbolic notation:



For this shape, the elongate nature of the flattened head is sufficient to stabilise the flying object without the need of curvature of the proximal attacking blade. The triangular head helps also keep both a function of pointed end and cutting function for the distal following blade, more offensive. A classic example of this throwing stick shape in Australia are the "Marpungy" (Fig. 49) of Southeast Australia, at the same time combat clubs and deadly throwing stick weapons.

Figure 49: Example of flag shaped throwing stick of South Australia. 66 centimetres wingspan. Musée Quai Branly.

Class: Asymmetric widened blade shape

Symbolic notation:

Shapes which have any curve and a blade with diverging edges which widen towards the extremity. As a result, the following blade (or distal) is shorter and wider than the attacking blade (or proximal blade) and the measured width of the attacking blade increase toward the following blade . These shape have a symmetry value greater than 0.5.

This type of shape is probably a final evolution of a progressive lengthening of the enlarged head shape from the preceding classes. The lengthening of the short blade, while maintaining the asymmetry of the object allows you to benefit from both a greater moment of significant inertia and greater stability than older types with enlarged head. This increased stability allows the production of larger throwing sticks and with better shaped airfoil section. For these reasons, this class is one of the most common among the asymmetric throwing stick encountered around the world and we can say that this shape is the best compromise between conservation of the moment of inertia and aerodynamic development of the blades. Included in this class, it is found frequently throwing sticks with mixed airfoil section, having the long blade with section always less shaped than the short blade. This feature is playing different roles:

The long holding blade provides a moment of inertia and control on the rate of rotation of the object. This is to avoid too much aerodynamic lift which could divert the projectile from its straight line. The short blade, with more shaped airfoil section and thus thinner, accelerates the rotation of the object by

a greater penetration into the air. This type of shape is mostly produced by the bottom of a tree trunk or root junction.

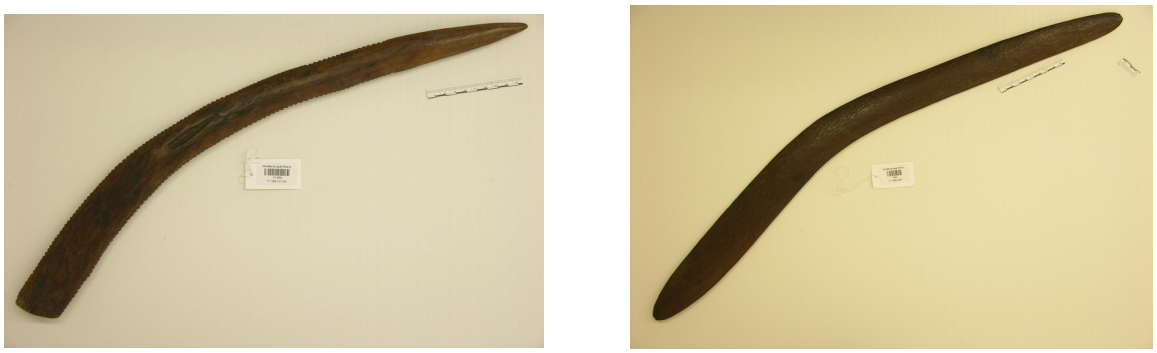


Figure 50a, 50b: Asymmetric widened blade shapes throwing stick. Left throwing stick is from Chad 63 centimetres wingspan. Right: Australian Aborigine throwing stick (NSW), 72 centimetres wingspan. Musée Quai Branly.

Among the most known type in this shape class is the famous "Kylie" (Fig. 51) present in the central desert region. This type have a characteristic grooving.

Figure 51: "Kylie" from the central desert area(Wingspan 72 centimetre). Private Collection Stephane Jacob.

The Valari or Valai Thadi (Fig. 52) also responds to this shape class, but with a ball extremity on attacking blade and the truncated blade extremity for following blade (see below types of ends). This instrument was used in Southern India Tamil region and has a crescent-shaped with characteristic truncated end with handles (Hornell, 1924). The Valari was used for hunting small game, birds and deer. It was also used for the war until the late eighteenth century.

Figure 52: Example of Valari Tamil. South India. 48 centimetre wingspan. Musée Quai Branly.

Subclass: Form Class Number 7

Shape that exhibit one curve and edges diverging blade which widens progressively toward following shorter blade as the previous described shape. These shape have a symmetry value greater than 0.5. Additionally, it has a spur feature, which enhances the length of their following blade outwardly directed from curvature.

Symbolic notation:

The main objects of this class are the famous "gooseneck" or "Number 7" of the central desert in Australia. This type of throwing stick is called "wirlki" (Fig. 53) in the local language which means jaw, in relation to their shape similar to the lower portion of a jaw. The spur itself is called "langa" which means "ear". We must consider this particular form as analogous to the asymmetric widened blade shape described previously, subsequently extended by a spur which allows in the case of central Australian throwing sticks to bypass past the shields in distant combat. This shape is produced and is used in the same regions of Australia as the simple asymmetric widened blade shape for which its derive, confirming this sub-class relationship. This shape is launched with the main curvature forward as other throwing sticks and not the reverse, the spur being too small and fragile to undergo a direct frontal impact. Even if one cannot consider this spur or additional part as a complete separate blade as in the case of a double-curved throwing stick (see below this class), this feature provides additional stability to the object.

Figure 53: Shape Number 7, Region Tenant Creek Australia (NT). 74 centimetres wide. South Australian Museum.

Class: Crescent

Symbolic notation:

Shapes which have a curvature and a width gradually decreasing from one extremity to the other (Fig. 54) . It is the class of oldest curved throwing sticks with symmetrical shape. Indeed, the increase in width by airfoil shaping of a double pointed throwing stick leads to an unstable object and must be stabilised by curvature, resulting in the crescent shape.

This shape is naturally very resistant to shocks and allows through point trimming of the extremity keep the digging stick function. This feature enhances also the offensive qualities of this shape as a projectile. This is the most common throwing stick shape in Australia. This shape has the advantage of being extracted from the trunk and piece of wood with a low curvature, making it easier to obtain.

Figure 54: Example of form low. Kimberley Region, Australia, 60 centimetres wingspan. South Australian Museum.

The Katurea (Fig. 55), which despite its appearance with truncated ends also belongs to the form of symmetrical crescent was used in Gujarat in the Northwest of India, among the Koles peoples (Lane Fox, 1868). It was used mainly for hunting.

Figure 55: Example of Katureea. India, Gujarat. 64 cm wide. Pitt River Museum.

We can see in this example, the importance of separating type of shape and type of extremity, hence their separation into two distinct criteria in our classification.

Subclass: hook throwing stick

Shapes that have a curvature and a width gradually decreasing from one extremity to the other and an acute angle hook at the extremity of the distal blade outwardly facing from curvature (Fig. 56).

Symbolic notation:

Do not confuse this form with "number 7" shape which is distinct.

We find this shape in Australia. This is a rare subclass of crescent class present in the Lake Eyre. The hook is attested ethnologically for ceremonial purposes, but a personal experimentation on these objects shows that they could be used to project spears, while maintaining good stability itself as a projectile, despite the loss of performance and gene due to the curvature of the object. Another indication in this direction and that, unlike the double convex shaped spur from "number 7" described

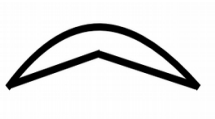
above, the hooks are of cylindrical section. Consequently, they can lodge in spears butt.

Figure 56: Example of hook throwing stick. Queensland, Australia. 66 cm wingspan. South Australian Museum.

Subclass: Strangled Crescent shape

Crescent shapes that show a decrease in width at the elbow

Symbolic notation:



It can be observed that most of strangled crescent shapes (Fig. 57) are crescent shape with a low curvature. Therefore, it is questionable if this deliberate narrowing of the width of the bend is not intended to increase the stability of the throwing sticks by moving the centre of gravity towards the outside of the elbow. This shape is found only in the Kimberley region in Australia and seems rather a recent type.

Figure 57: Example of strangled throwing stick. Kimberley Region, Australia, 55 cm wingspan. South Australian Museum.

Sub-Class: V Shaped

Forms V with a pronounced curvature and a sharp elbow.

Symbolic notation:

This shape is essentially found in the Kimberley region of Australia (Fig. 58) and is characterised by a important broadening of elbow which makes this type of object almost as strong as the crescent types from which they derive. This shape is characterised by a very large surface and a reduced wingspan that perfectly adapts to symmetrical or asymmetric projectiles with stable straight-flight and among the most efficient in terms of speed and range.

Figure 58: Example of asymmetrical V shape. Kimberley Region, Australia, 65 cm wingspan. South Australian Museum.

Class: waisted Shape

Shapes having a well-marked waisted bend and a width gradually decreasing from one extremity to the other.

Symbolic notation:

This is a very generic shape (Fig. 59) for throwing sticks which is distinguished from the previous by a rounded elbow and width comparable to that of the blades. Elbow waisted bend has the advantage of an increased stability compared to crescent shapes but with much less resistance. The waisted shapes

are easier and convenient to get from tree branches.

Figure 59: symmetrical waisted shape, South Australia. 66 centimetres wingspan. South Australian Museum.

SubClass: Waisted shape, S Shaped

Shapes having a well-marked waisted bend and a width gradually decreasing from one extremity to the other. One of the blades has an outwardly facing concave curvature giving a "S" figure to the object (Fig. 60).

Symbolic notation:

We find this type of shape in western Australia for objects of light type and very light mass/ratio, from those are many boomerangs. One can notice that it is a shape that can often obtained when one makes the construction of a throwing stick from branches which have naturally this “S” shape.

Figure 60: “S” Shaped throwing stick. Western Australia. 52 cm wingspan. Museum Quai Branly.

In the Central West region of Gascogne river, there is boomerangs with that particular shape belonging to this “S” shaped class. This shape can be found also on some throwing sticks from distant Queensland.

Class: L-shaped

Shapes having a straight attacking blade, a curvature close to a right angle and having a symmetry value of less than 0.5.

Symbolic notation:

This is one of the most common shape, among asymmetric throwing sticks, second after the asymmetric widened blade shape (see above). It is present not only in Australia but also in Africa. As for the shape with broadened blade, it may have mixed airfoil section which show that the long blade remained often cut for handling in order to use both the object from distance or in upon contact use. This "L" shape (Fig. 61) is very stable and can sometimes be found in natural branches and thus have an ancient origin in the technology of throwing stick. This is a shape that can be a relatively effective projectile with very little airfoil shaping and tuning. One can say that it is a "easy" shape of throwing stick to manufacture and control.

Figure 61: “L” shaped throwing stick, Darfur, Sudan. 78 centimetres wingspan. Pitt River Museum.

Class: Hoe shaped

Shapes having a straight attacking blade, one acute angle, with a value of symmetry is less than 0.5

Symbolic notation:

This shape of throwing stick (Fig. 62) is probably made after hoe or adze shape. Indeed, the handle of some tools like axes handles, disassembled from the active stone part, can serve sporadically as a projectile. It is produced easily from a branch and trunk junction. Although less stable and less resistant than the "L" shape, it is attested for throwing sticks on the African continent.

Figure 62: Hoe shaped throwing stick. Dogon people, Mali. Musée Quai Branly.

Class: Crozier shaped

Shapes having a straight attacking blade, a following blade curved inward and a value of symmetry less than 0.5.

Symbolic notation:

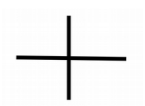
Although somewhat less effective in terms of projectile with respect to the L-shape, this form is stable as throwing stick if the handling or attacking blade does not exceed a certain length. This shape is mainly used outside of Australia within crop breeders or farmers. This seems to indicate his developing relationship with one or more new functions. Indeed, the curved shape of the short blade provides no significant gain in the use of the object as a projectile against a shaped "L", but adds a contact use more or less predominant. The latter, with its curved extremity, seems to be related to the idea of catching or catching a plant, animal or symbolic concept. The object in question here is a short stick (Fig. 63) (height/wingspan > 0.2 for stability), it should not be confused with gambling crooks and walking sticks whose handle must lie to adapt to these new uses, and then completely losing the throwing function.

Figure 63: Crozier shaped throwing stick, Zuni, Arizona, 51 cm wingspan. Musée Quai Branly.

Class: four-bladed:

Form consists of two superimposed pieces of wood and fixed perpendicularly with respect to each other.

Symbolic notation:



Obviously from a different making than throwing sticks made of one piece, this shape is essentially found for four-bladed boomerangs of the Queensland region of Australia or the central region of the island of Sulawesi, Indonesia. This object, seemingly simple, is actually unknown first order of an innovation in the field of throwing sticks, in terms of stability and producing aerodynamic lift. This is indeed the first principle of the helicopter, long before the plans drawn by Leonardo da Vinci during Renaissance. In the central region of the island, is also described the use of such objects of type "four-bladed boomerang" bamboo called Motela (Fig. 64), able to return and intended solely to be used in games.

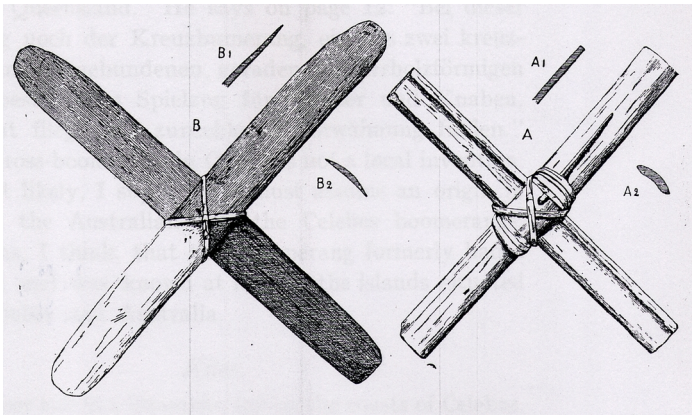


Figure 64: Bamboo four-bladed called " Motela ". Sulawesi Central Region (right). Comparison with a four-bladed wooden Aboriginal Australian (Kaudern, 1925).

Kaudern stated that some four-bladed boomerangs from Queensland have concavity beneath their blades that mimic natural bamboo concavity. This is an important clue to indicate that these objects were probably imported into Australia from Indonesia under the influence of the culture of Macassan fishermen at an unknown date. I could not yet verify this detail on the subject of this type found in the collections. But the fact that the use of this type of object is restricted to the region Cairns (Queensland) (Fig. 65) appears to confirm that these objects have not had time to spread to other parts of Australia, and rather correspond to a recent external contribution to the continent.

Figure 65: Four-bladed shape, Queensland, Australia. 49 centimetres wide, Pitt River Museum.

Class: Arc Shape

Shapes having a progressive curvature from one end to the other, with a constant width.

Symbolic notation:

This is a very old form of throwing stick as naturally curved branches can in this case take the place of projectile. However, this form is rare compared to the crescent shape, because of it lacks resistance at the elbow if the airfoil section is shaped. Consequently, this type of shape often keeps a circular or elliptical section because of this reason, limiting its aerodynamic range capabilities.

Figure 66: asymmetric arc shape, Sudan. 102 centimetres wide. Pitt River Museum.

Class: Double curvature

Shape with a double curvature

Symbolic notation:

Despite its singular appearance, this form is very archaic and it seems that it existed from the beginning of the evolution of the throwing sticks. It is possible to find natural branches that have this double curvature which significantly increases the stability and range of the projectile. The condition is, however, able to obtain two bends in the same plane. The section of this shape remains circular or elliptical general for keeping resistance. We find this shape in the Anazasi culture in the form of double curvature throwing stick with central groove (Fig. 67).

Figure 67: Double curvature throwing stick Anazasi. Museum of Mesa Verde National Park, Colorado.

Sub-class: Asymmetrical double curvature

Shape having a double curvature with a non-similar extremity heavier

Symbolic notation:

This shape is a variation of the previous one, completed by a mass at one extremity, which creates an increased rotational inertial effect. Because of this advantage, it is encountered more frequently than before. This type of shape is sometimes called "snake stick" and it can found the most famous examples in ancient Egypt represented in scenes of hunting birds (Fig. 68).

Figure 68: Hunting scene representative Egyptian noble hunting birds with a "snake" throwing stick.

2 Types of extremities:

We define different types of extremities and their symbolic notation:

- **Pointed**

Extremities obtained by a progressive convergence of opposite edges of a blade.

Symbolic notation:

This type of extremity for throwing sticks is probably inherited from digging stick to digging function and which was also used to attack or defend. The pointed extremities provides thus a more offensive to the projectiles, but doing so limits the airfoil section shaping and the section at the blade extremity, which reduces the aerodynamic lift of the object at that point. The extremities in this case tend to have more drag and slow the rotation of the projectile. A little rotational inertia is further lost by removing the mass of the furthest points from the centre of gravity of the object.

• **Beveled**

Extremities obtained by the sudden convergence of opposite edges at the blade tip.

Symbolic notation:

This solution ends is a very good compromise between conservation of the pointed feature of the object without much loss of mass, and the conservation of the blade extremities width as explained above.

• **Rounded**

Rounded extremities are obtained by converging edges of the blade without creating any point.

Symbolic notation:

This type of end is characterised by the loss of pointed extremity related function and an optimisation of the aerodynamic blade extremities which promotes the rotation of the projectile. The rounded shape allows for maximum of airfoil section shaping for extremities. It is an extremity type gradually adopted by boomerangs since it can produce more spin and aerodynamic thrust to overcome their own mass and enhance their returning property. It should be noted that the throwing sticks with rounded ends may continue to have shovel function in soft or sandy soil (see Appendix II)

• **Truncated**

Ends obtained by cutting the blade, without convergence of opposite edges of the blade.

Symbolic notation:

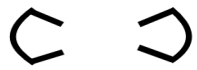
This type of extremity gives no particular function to the object and seems fairly neutral aerodynamically. The truncated extremities seem rather recent developments in throwing stick since they require additional work to saw the piece of wood or its flattening by grinding. It probably denotes a working tradition of wood with relatively advanced tools, since it is an

additional expenditure of energy without functional benefit or improvement of the projectile.

- **Fan**

These type of ends are obtained by divergence of blade edges and rounded terminations

Symbolic notation:



The function of this type of extremity has two advantages:

The first is to add mass at the end of a blade of a throwing stick to increase its moment of inertia. The second is to prevent the gripping hand from slipping off the blade by being blocked by the protrusion. This type of extremity is peculiar for throwing sticks in ancient Egypt.

- **Spherical**

Symbolic notation:

Termination formed by a rounded protuberance or thicker material ball and wider than the extremity of the blade. In handling or attacking blade, this type of extremity's volume plays the same role as the fan extremity type but allows the addition of greater mass. The influence of this ball device is somewhat slowing the rotation of the projectile by its volume. This effect has the advantage to regulate the rate of rotation during the flight as for Indian Valari. On another hand, located on the following or distal blade , it is especially useful to add a offensive mass in close combat.

Throwing sticks with mixed extremities:

It can be found in throwing sticks equipped with identical extremities, but also extremities of different kind. It will be noted in this case as follows: extremity of attacking blade/extremity of following blade

Eg: Pointed/truncated

Symbolic notation:

The first symbol designating the attacking blade extremity and the second the following extremity. It could be found extremities whose shape is between two types among the four boundaries shape described above: In this case we cite the blade with a hyphen, for example: sharped-rounded

Grooving

Some throwing sticks have grooves on one or several surfaces. These include fully grooved Aboriginal throwing sticks of central desert or partially grooved Anasazi throwing sticks of the American Southwest people. This grooving can be more or less coverage, more or less regular and with specific grooves section. The spacing and number of grooves may also be characteristic of a cultural group. The grooving can have a functional or symbolic aspect or both simultaneously. For this reason we distinguish this feature from decoration further described (Fig. 69).
Regarding the explanation of grooves on throwing sticks of the Australian central desert, an assumption of an aerodynamic effect associated with the lift has been advanced by Nelson (Nelson 2001). But the fact that this grooving is found on other objects that are not projectiles (eg shields, containers, close combat maces) cast doubt on that explanation. The use of grooves to produce sounds by rubbing two throwing sticks one against the other, shows that this feature may have others purposes. Another working hypothesis could connect the grooves to improve quality resistance wood and to the prevention of splitting. Finally if we consider some Anazasi throwing sticks used in conjunction with spear thrower, it can be suggested that heir role can be possibly in deflecting better enemy spears and blows.

Figure 69: Detail of the grooving of a throwing stick "wilki". South Australian Museum.

Decoration

Although the decorative aspect is not the essence of our approach, we take care to save the decorative treatment of objects. The decoration of throwing sticks does not play a significant role in aerodynamics about their use as projectile but a symbolic role. In Australia, it consists of either painting or engraving.

Painting:

The indigenous Australians prepare the paint from iron oxide or hydroxide mineral pigment in the range from red to yellow, and from white clays for white. It can also be made from vegetable dyes. To apply it on the piece of wood, you can mix the paint with animal fat, which enables it to penetrate the wood and fix it. This fat, systematically applied, even in the absence of pigment also play a protective role for wood and keeps the blade tuning settings of throwing sticks against further twisting. The painted decoration (Fig. 70) often has a more ceremonial use than the engraving as it is more ephemeral than the latter, wiping itself with the intensive use of the object. It is often produced especially for a particular occasion. Painted decorations are also known on throwing sticks in the cultures of the Anasazi Indians and Pueblo descendants.

Figure 70: "V" shaped throwing stick with double side grooving from Kimberley region coated with red ochre and painted with white clay bands. South Australian Museum.

Engraving:

In Australia, throwing sticks are often traditionally engraved with sharp possum teeth within the entire jaw of this animal for a better grip in carving task. The ancient carved symbolic motifs are usually abstract to the Pre-colonial period (Fig. 71), then become more figurative in the exchange perspective of these objects from the nineteenth century. The etching unlike painting, is perennial on the objects and is often produced on objects that are used daily and resist their use as projectile. In this sense, one can see the same difference between painting and engraving on throwing sticks between scarification and body painting. Indeed, these weapons are tools of course an extension of the human body and are symbolically treated similarly.

Figure 71: Details of an engraved throwing stick. Australia (NSW), Museum Quai Branly.

Laterality

Some throwing sticks are ambidextrous, but many have clear laterality. This choice done by the maker or tuned by its owner, gives a better performance as a projectile used as such. Laterality can be determined mainly by traces of handling, airfoil section orientation and by observing the blade tuning settings.

Reinforcement or repair

Throwing sticks may have reinforcement or repair in the form of rings (Fig. 72) enclosing their cross-section, manufactured in different materials. Tendons or vegetable fibres for prehistoric times, and iron for historical periods. In Africa there are also animal skin sleeves (see appendix I, Fig. 61), appendix II, Fig. 75).

Figure 72: Example of jet Tamil Indian stick (Valari) having steel reinforcement rings. Pitt River Museum.

Traces of shaping tool

It is possible to identify at archaeological throwing sticks and ethnological traces of shaping. In the study of museum collections and experimental production, I could observe shaping traces as marks of cutting tools, traces of file or scraping action (Fig. 73a, 73b), the use of gouge etc .

Figure 73a, 73b: Example of shaping traces: left: wrinkling from scraping on an ethnological object (Quai Branly Museum) right: wrinkling on an experimental throwing stick.

It will not be possible to talk in more detail of throwing stick shaping and its traceology within this memory.

Traces of use

Traces of use can be detected on some throwing sticks. Among the most obvious are traces impact of observed (Fig. 74a, 74b), and marks from use with fire and gripping. When they are in the majority on some edges, traces of impact can provide information on the direction of rotation of the object and confirm its actual use as projectile. Traces of handling when to inform them on the proximal or attacking throwing stick blade. Associated with traces of impact, they can confirm laterality of the object.

Figure 74a, 74b: Example of impact marks at the elbow and on a blade extremity, on edges, visible on a boomerang from Western Australia. Quai Branly Museum.

It will not be possible to talk in more detail about traces of use in the context of this memory.

Deducted characteristics:

Probable trajectory

It is possible to make a rough prediction of the trajectory of a throwing stick from the previous measurements.

We will distinguish three types of path:

Straight:

Trajectory which does not have a pronounced curved part, and which is adapted to reach accuratly a target.

Curved or S:

End of trajectory in slight turn with or without tilting in reverse curve, to form an "S". The curved trajectory born with the increasing aerodynamic lift on the object during its flight and provoke titling in "S" curve is due to the phenomenon of gyroscopic precession (Thomas, 1985).

Returning:

Full returning trajectory which bring the object to its starting point under standard conditions (low wind 10-20 km/h wind, at the zenith of it). This is noteworthy, because if hurricane conditions are considered, even the anvils can become boomerangs ! Indeed, number of authors do not cite the experimental wind conditions under which they observed returning flights, putting in some case doubt about these observations.

Likely range:

In the same way, it is possible to estimate throwing sticks range. Different range classes will be distinguished as follows:

Very short range: 5 to 30 meters

Short range: 30-50 meters

Average range: 50 -70 meters

Long range:80 -100 meters

Very long range: over 100 meters

The distance estimate is made by performing several thrown in different directions relative to the wind under the conditions of a gentle breeze (10 to 20 Km/h) and by averaging. The fact that in hunting conditions the game will preferably be approached with a headwind or through, these likely experimental wind directions are close to "real" throwing wind conditions. Be cautious with the validity of the throwing sticks maximum ranges obtained in windy days with wind blowing in the back !

Appendix II Detailed functions of throwing sticks

Uses as a projectile

Terrestrial hunting uses:

These uses have in common the high resistance requirements of the projectile which is designed to hit the ground violently, an obstacle or target. When shooting, the ground can be used to make rebounds to increase the chances of hitting the target, especially on small game in the case of throwing into the legs. On large animals, kangaroos, deer, buffalo, throwing sticks are commonly used in conjunction with other hunting weapons like spears or lances and other clubs by a group of hunters, as hunting strategies.

Small game hunting

This is an opportunistic small game hunting practised with a throw along the ground at very short range (5-30 meters) and preferably on groups of animals. In Australia, for example, small lizards and marsupials are slaughtered in this way. In western countries, we still find today a modern version of this activity with hunting cats wild perched in trees that are dropped twirling crowbars (Lowe, 2002).
The projectiles suitable for this purpose did not need a lot of airfoil shaping, but especially resistance to impact with ground and other solid objects potentially encountered on their way (trees or rocks). So it can be simple straight throwing sticks, pointed or not. More sophisticated throwing sticks suitable for large land game can also shoot small game.

Hunting rabbit/hare

This is a close function as the one described above, but specialised in hunting lagomorphs. It is characterised by collective hunting strategies. This practice is widely attested in the South western United States, but also in many other parts of the world. So much so that one can say that the throwing

stick is the ideal weapon for hunting this type of game. The traditional rabbit hunting practised by Anazasi and later by the Pueblo cultures that have succeeded them, like Zuni peoples, Hopi, and Moki is often a collective hunting folding (Devereux, 1946). To do the hunting, hunters going by foot use Mozikho, a very simple straight double-pointed throwing stick with circular section, while hunters mounted on horses use Packeho which are curved throwing sticks having much more sophisticated handle (Devereux, 1946). Together, they surround the hunting area, flush out animals and fold them to other hunters for the kill (Devereux, 1946). Then, throwing sticks are called the "rabbitsticks" in this region. These collective hunts rabbits are also attested in South India (Thurston, 1907). Some descendants of Indian Pueblos recently still using the rabbitstick for this hunting instead of firearms to save ammunition (Campbell, 1999). An experimental study in rabbit hunting showed that the throwing stick was more effective on animal flushed out of cover and being moving targets than still animal which may be masked partially by vegetation (Allen, 2001). This point shows the complementarity of this weapon with the bow that is in contrast rather a lookout weapon or approach a stationary animal, or being slow because not alerted. The effectiveness of the throwing stick on lagomorphs is such that people in Africa continue to use them, as Dassanetch in Northern Kenya (Chick, 2007). We find this use also on the Australian mainland since the introduction of the rabbit.

Hunting kangaroo/emu

Aborigines use throwing stick for hunting kangaroo and emu. It can be a hunting approach, the hunter hiding behind a mobile screen of vegetation until the shooting distance around thirty meters. Another hunting strategy involves a group of hunters who will use projectiles directly or for the folding of these animals to large capture nets. Emus, quite curious animals, can be lured and be stunned as directly in contact with these weapons. The throwing sticks for this purpose therefore tend to be heavy, large and very resistant. Macropods tend to be tough and fast animals, projectiles intended for them must gain enough speed and have airfoil enough shaped. This use is almost as demanding for throwing sticks as those used for ranged combat (see below). This involves use of objects provided with airfoil shaped section, fast and heavy enough to have an efficient impact.

Deer hunting

Practiced in India, deer hunting is attested for throwing stick use (Hornell, 1924). Despite the size of this game, this type of animal has fragile legs that can be easily broken by impact from a throwing stick. This, however, involves a airfoil shaping development that gives them enough speed, in addition to their mass.

Hunting buffalo

This use is attested by a series of crozier shaped hunting sticks of Mali and Burkina Faso (Fig. 75). These heavy objects sometimes reaching 870 grams are very resistant. These animals had to be hunted at rather short distances to maximise the impact of the weapon on the legs.

Figure 75: African throwing stick attested to hunt buffalo. Quai Branly Museum.

Ranged combat

In Australia, Aborigines different groups used their throwing sticks to attack or defend against an enemy or rival. Some testimonies are reporting this warlike use can literally "mow" a target by putting it to a minimum, out of action (Jones, 1996). In this continent, the tapered side edges of the throwing sticks and the frequent presence of pointed extremity accentuate the piercing effectiveness on enemy. Indeed, testimonies exist about piercing impact crossing through the body of the enemy (Jones, 1996), which shows the energy attained by these projectiles yet only made of wood. The throwing sticks used for ranged combat are frequently used in conjunction with a shield, as in the case of close combat (Basedow, 1925). The use of poison on throwing sticks pointed extremities is attested in Australia (Clark, 2012). The ranged combat have higher performance requirements for a throwing stick in terms of resistance speed, and range. Nevertheless, a compromise between mass and ease of grip is often found to use the same object in melee. This is for example the case of the typical throwing sticks of the central desert. These opposite constraints reflect the throwing stick paradox in that it must be optimised as a projectile but also to meet requirement for contact uses. Nevertheless, one can find some “V” shaped like throwing sticks typical of the Kimberley region, who seem to have chosen a more exclusive ranged combat function, to the detriment of combat use in hand to hand. They have very shaped airfoil, small wingspan and are thin to increase their speed, while increasing their width at elbow to keep their impact resistance required for this purpose.

In Africa, it is certain that many of throwing sticks have also served this purpose. Examples include the Maba, in eastern Chad, the people of the eastern Ouaddai, using the throwing stick called Safrouk for ranged combat. We must remember though that societies of hunter-gatherers such as Australian Aborigines however didn't not practice real organised wars, incompatible with their social organisation, but conflicts in the form of vendetta and reprisal against theft of women or for example in response to witchcraft.

But in other historical societies much more hierarchical, for example war uses of the throwing sticks

are known in India (Hornell, 1924). The Valari who was a type throwing stick used by the Tamils, designed to a stun shot to the lower limbs or a lethal shot to the head. It has been used as well for the war until British colonisation. Some have sharp edges and are murderers. Special daggers double-edged called kattaaris could be fixed on the blades of some models. Using Valari by the Indian army of Maradus during a battle against a British expeditionary force in 1789, illustrates this war use (Hornell, 1924).
In California, the use of throwing sticks at ranged combat is also attested by the Hopi, Ute and Walpi, who used this weapon against enemy archers. The projectile was launched towards the archer during its preparation in shooting, for hurting or disorienting enough to charge him with a melee weapon before it come to its senses (Heizer, 1942).

Fishing

This use is attested mainly in secondary use of Kimberley throwing sticks mentioned in the previous use section. One of this "V" shaped throwing stick with pointed extremities modified in fishing throwing stick with rounded extremities shows that this type of hunting stick did not need to have pointed ends feature for this function, being designed to stun fish (Jones, 1996). This fishing takes place in shallow waters and low current, the throwing stick being projected toward the surface of the water (Fig. 76). It enters with enough speed to knock the fish swimming near the surface, in fifteen centimetres maximum depth (Clement, 1904). This tactic has been well observed for fishing fish trapped in the water holes at low tide, but also along rivers and beaches. For this, it seems that the Aborigines of the region have taken advantage of the low thickness and increased width of the throwing sticks to get greater penetration in water. The throwing sticks that are used for this purpose are rather heavy and have generally small wingspan.

Figure 76: Baadi Aboriginal man holding a fishing throwing stick. Kimberley Region (Jones, 1996).

Livestock

Use of throwing sticks by pastors/hunters populations is attested in Saharan Africa including Chad as shown by two throwing sticks the quay Branly Museum originating from this region (Fig. 77). These throwing sticks have good performance as projectiles and were used not only as throwing sticks to hunt game, but also to fold the stubborn beasts from a distance back to herds. Presumably for this use the shepherd was simply regulate the force of the shot to make it safe for the animal to his herd. In most cases, these objects could also guide the livestock by stick contact too (see guidance herd contact use).

Figure 77: Throwing stick used by Zaghawa people in Chad to fold the livestock and hunting. Musée Quai Branly.

Aerial hunting uses

Hunting birds/bats

This is throwing the projectile in a compact flock of birds or bats from a vantage point to shoot as much as possible. In the case of small birds, a throwing stick potentially allows stun or kill more volatile successively during a single shot (Jones, 1996). Indeed, the experimental launch of these projectiles show that their energy, their recess circles, allow them to hit the target by its extremities without hindering its movement completely bypasses to the next, especially in the case of light and small sizes targets, like birds. In this use, the throwing sticks are rarely used to hunt a solitary target (Jones, 1996). A signal or a shout allows to fly the birds before firing (Jones, 1996) to avoid a throwing close to the ground that could damage the object. In Australia, as in Egypt, people also used frequently captured birds calling to attract other birds for this kind of hunt (Jones, 1996) (Thomas, 1991). Bird hunting can be done as close to the ground or to the body of water surface (lake, swamp etc.) or with the hunter on the shore or in the water.

This use had been observed for Australian Aborigines in river environments, wetland or lake shorelines or hunting birds in Egypt attested from antiquity until 1950 (Thomas 1991). Personal experiments show that this loose soil environment allows not risking breakage of the projectile playing in this function essentially an aerial role. In this case, it does not need too much resistance and a short-range

average between 30 and 70 meters. Returning projectile like boomerangs can be used too, but not always (Jones, 1996). Indeed, it has also been observed for this use throwing sticks having non returning straight flight. In Sulawesi, such objects are used by children to hunt birds above the rice fields (Kaudern, 1925) with a lower likely range around 30-40 meters maximum and not returning (Bordes, 2009).

Pulling down birds

This function is using throwing sticks which have the property to have curves flights, enough light to have a high trajectory and can be easily thrown up. These features are preferred particularly by Aborigines from South East Australia or the use of pulling down birds was prevalent (Jones, 1996). The projectile is launched over a flock of birds which fly instinctively toward the ground thinking that they are under the attack of a raptor. Hunters sometimes mimic the cry of a bird of prey like hawks at the same time. Holes may be made to the extremities of the blades of throwing sticks and boomerangs to make them whistle and accentuate the surprise (Jones, 1996). The flock of bird is generally pulled down to nets or toward other hunters equipped with throwing sticks are posted (Jones, 1996), often in river bed corridors lined with big eucalyptus (Fig. 78). The curved path is in this case utilised to scan a surface above the flying volatile and for easier recovery of the object limiting its range and preventing it to get lost. Concerning other regions of Africa, light and very curved throwing sticks from the region of Lake Chad having holes at the blade extremities are emitting a sound in the air, could have been used also in this function (see Fig. 29).

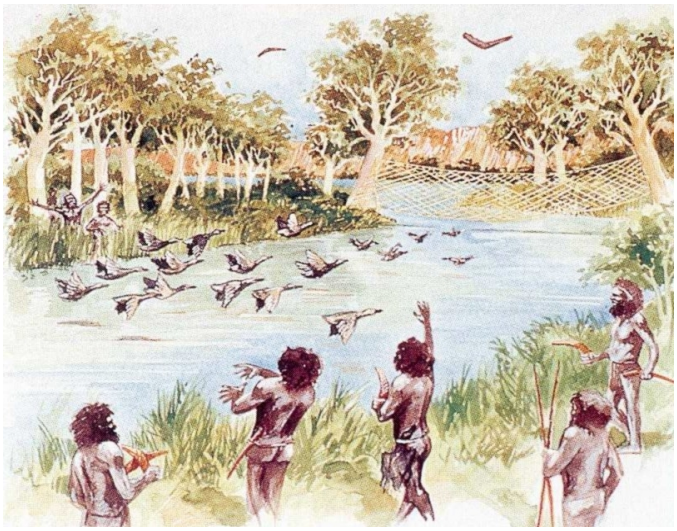


Figure 78: Evocation of Aboriginal men pulling down birds with throwing sticks and nets (Jones, 1996).

Game (return)

Paradoxically, throwing sticks designed as boomerangs with returning flight are best known, while they filled only a particular purpose in the lives of some Aboriginal groups (see part I 2 terminology, the term boomerang). This is certainly due to the fascination that Europeans have maintained on this property and continues to feed to this trajectory (Thomas, 1985).

Boomerangs are lighter objects compared to throwing sticks used for hunting purposes especially about their the further airfoil shaping and which possess a particular twisting tuning (Hess, 1975). The games played by the Aborigines with the boomerang, were quite different from the current modern sport since it was for these people less to catch object in his return, but more to how to guide effectively in its path. The games were so oriented is to describe a particular path with several loops, or to the accuracy of the return, or get the boomerang through arches made of branches etc. In principle, all boomerangs high trajectory that served for the game, can also be used to pull down the birds. On may be noted that Australia does not seem to be the only continent where returning throwing sticks were used for game. There are known returning four-bladed objects from the central region of the island of Sulawesi, not to mention also the objects in that category and linked to this use found in Europe at the age of iron (see part II 1). It should be noted finally that the returning trajectory, while strengthening the gaming use, occurs at the expense of accuracy, resistance and range of the projectile. In fact, testing shows easily enough that this is very difficult to throw and make return to the thrower, a boomerang built using traditional methods, at ranges greater than 50 meters.

Contact uses

Hand to hand Combat

Since the origin of the projectile, the throwing sticks are an adaptation of single sticks and clubs that were used in hand to hand combat. This usage is still very present among these weapons. It exists in all cultures as an ambivalent use, with the exception of objects which became too light or too little resistant by specialising as a projectile. The throwing sticks for use in close combat is often done in conjunction with the use of a shield. In close combat, these objects are used as clubs, and can take advantage of their sharp edges and pointed ends or simply by impact effect of their mass. A wingspan of 60 centimetres seems an advantage for this use and a high resistance is needed, which excluded too much curved shape and throwing sticks having a too narrow elbow. We do not find this use simultaneous use with aerial hunting use, though some birds hunting sticks could still be used to defend against an attacker, but are not designed primary for that.

Parrying

Some throwing sticks can be used to effectively ward off other projectiles such as spears or adverse throwing sticks (Heizer, 1942). Aborigines grooved throwing sticks of the central desert are attested for this defensive use against spears, when the defender has no shield or in areas where we did not produce shield (Clark, 2012). Some Anazasi throwing sticks double curvature in the South West of the Americas could also include this dual use. This use tradition, along with their characteristic grooves

would be of Mesoamerican origins (Heizer, 1942).

Digging action

Digging stick

This practice uses one or two pointed ends of the throwing stick to dig to find water, or digging for food such as yams, or again to dig a burrow in order to ferret out an animal hiding there (Jones, 1996) (Clark, 2012). The digging sticks are short enough to be launched and often have pointed extremities which make them well designed to couple digging function with hunting use on small game. The use of throwing sticks as digging stick requires objects having great resistance and small curvature for practical reason.

Shovel digging

This use is a variant of the previous one, but uses the rounded blade ends that can be used to dig loose or sandy soils (Fig. 79). For Australian Aborigines, although it is the digging sticks, women quintessential attributes, which are preferred for this work, but men can also sometimes use their "Kylie" to dig the ground, using the blade extremity as a shovel (Clark 2012).

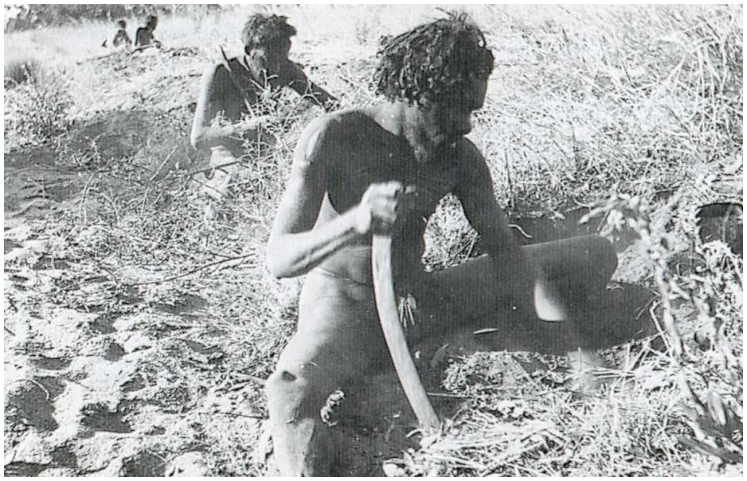


Figure 79: Aboriginal men using their "Kylies" as shovel to dig up wild onions, Yuendumu, central desert (Jones, 1996).

Uses with fire

Fire saw

Some Aboriginal throwing sticks can be used as fire saw to produce a ember (McCarthy, 1961). To do this, intense heating need to be created by friction sawing the edge of the object on a slotted dormant wood piece or provided with a perpendicular groove loaded tinder (Fig. 80) .This dormant piece can be a shield softwood sacrificed for this purpose (Clark 2012).

Figure 80: Wangkangurru aboriginal man lighting a fire with a throw stick by sawing on a shield. Lake Eyre region. (Jones, 1996)

Fire Management

Certain throwing sticks have burning traces (Fig. 81) that attest to their use for the domestic fire management practice to place or remove food or other object in the hearth (McCarthy, 1961). This usage also reflects the relationship of throwing sticks with fire used as a tool which heat is used to manufacture them. Indeed, in turn, heat treatment enhances resistance properties of these objects, and therefore, increases their durability (Callahan, 1975).

Figure 81: Throwing stick with its distal extremity (right) carbonised by contact with a fire. Private Collection Stephane Jacob.

Uses with herds

Livestock guidance

Some throwing sticks were used simply to move the animals in a herd by contact. This usage is often in conjunction with the distant cattle folding, but not systematically. It is likely that this use of the throwing stick and crozier shaped throwing which transformed progressively these objects toward the long pastoral staff who gradually loses its projectile function, since we can see that herd management is the only function that includes at the same time a projectile use and a contact use.

Figure 82: Asymmetric arc shaped throwing stick used for guiding the cattle but not for distant livestock folding, Sudan. 102 centimetres wide. Pitt River Museum.

Other

Disarticulation of game

AboriginalAustralians used the sharp edges of their throwing sticks for the disarticulation of kangaroos (McCarthy, 1961). This use is attested only on this continent and could explain this feature on Australian throwing sticks. It is possible that some particularly sharp sticks were used to roughly share pieces of meat or use as skinning knife as they took the place of stone knife (Jones, 1996) (McCarthy, 1961). This function promotes heavy objects to be effective in this, and slightly curved like the famous Kylie from the centre of Australia (McCarthy, 1961).

Flint knapping hammer

Aboriginal Australians used sometimes their throwing stick to retouch the stone sharp edge of their woodworking adze (McCarthy, 1961). This may be an opportunistic use, since these adze themselves are used to make such wooden weapons.

Crozier shaped stick to launch stones

This usage seems specific to crozier shaped sticks that are used in this case indirectly:
The object is no longer use as a projectile itself but is used to hit by its distal curved extremity stones on the ground towards a target . Often under the influence of the purpose, the gripping blade extended to a longer handle and the object partially loses its biconvex airfoil section for a circular section, or rectangular, more resistant. This usage is illustrated and described by Serge Cassen in his study of Neolithic crozier shaped signs of Morbihan (Cassen, 2012)

Harvesting

In this case throwing sticks are used to harvest fruit in a tree that are too high to reach (Cassen, 2012).

Symbolic & social use

For these uses in Australia, there are often engraved or painted decorations on the throwing sticks. The engravings are generally intended to be permanent, while the paintings in red ochre and white clay are executed for the occasion, similar to that prepared the bodies of the participants. Indeed, the paintings tend to disappear quickly during their practical use and must be renewed frequently. Australian Aboriginal throwing sticks are also tied to symbolic practices often covered with red ochre pigment that is more resistant to everyday use. Symbolic uses of throwing sticks often coexist with more utilitarian uses. For example, in the region of the central desert in Australia or men decorate the extremity of their throwing stick with strips and points of white clay for a funeral, then leave the pattern to fade when the event ends. When an object as to be nothing more than ceremonial, it also seems to lose its utilitarian functions, which is accompanied by the loss of quality requirements that is brought to the construction of the object. This can go up to change some of its characteristics, size or shape. This evolution can be observed for example in throwing sticks of northern Australia, a region where people are not longer using the throwing stick as a projectile but only for ceremonial purpose when Europeans arrived on the continent.

Music

Aboriginal Australians often use their throwing sticks to mark the rhythm in dances by hitting them in pairs or against the floor as clap sticks (Fig. 83). It seems that throwing sticks, wider than these, have a higher pitch. Two techniques are used to produce a rhythm with a pair of throwing sticks. A simple clapping with the central parts of objects against each other and a quick and continuous clapping produced by the clashing of their extremity (Van der Leeden, 1967). The grooving Kylies of central Australia were also used to produce rhythmical scraping sound between two throwing sticks (McCarthy 1961).

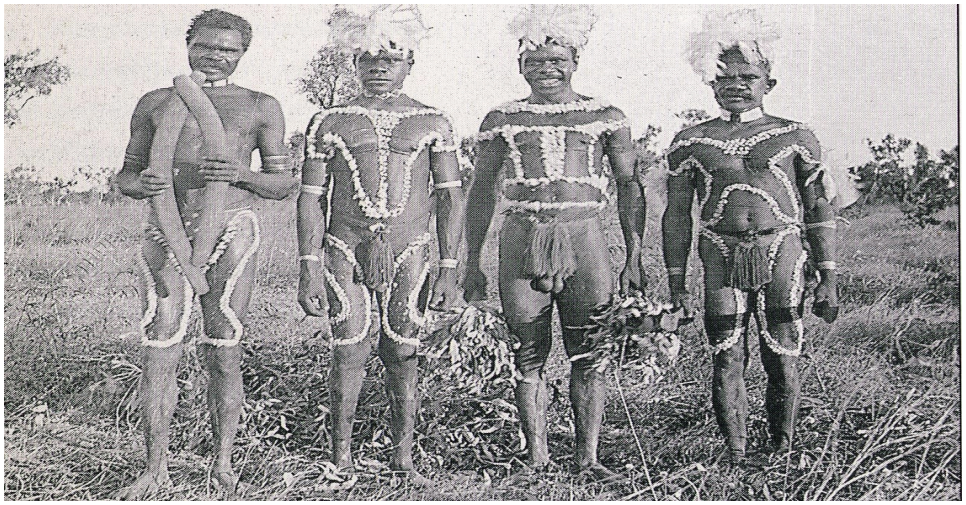


Figure 83: Aborigines ready for a ceremony. A male collides a pair of throwing sticks to rhythm dances. Roper River region (Jones, 1996).

Dances

Many aboriginal dances include throwing sticks or in the dance moves or as part of the costume. In southern Australia, it can be seen on engravings of the eighteenth century queues dancers who have placed their throwing stick in their loincloth rearwardly as a kangaroo tail (Fig. 84). Another example might be the use of four-bladed boomerangs Queensland region attached to the end of sticks and are rotated by hands to rotate like propellers in certain dances (McConnel, 1935).

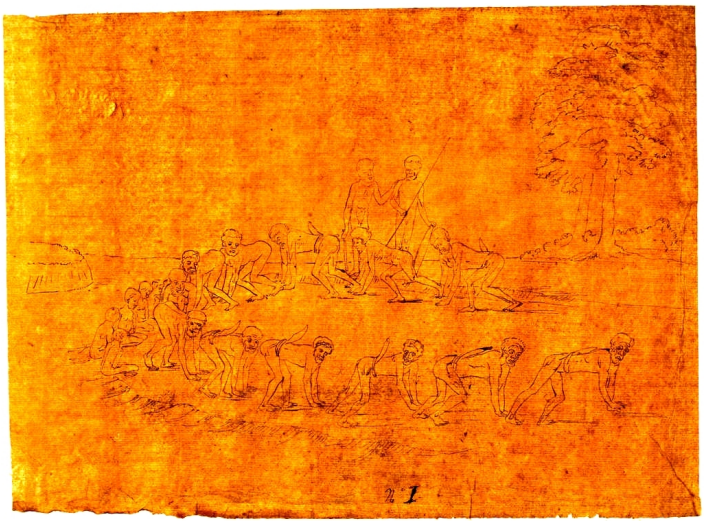


Figure 84: Drawing of the eighteenth century showing a male dance in which throwing sticks are made belt to mimic the tail of an animal (Natural History Museum of Le Havre, Lesueur collection).

Ceremonial

The throwing sticks planted in the ground can delimit ceremonial circles or part of a ritual (Fig. 85). Also known the throwing stick to use for ritual deflowering of young girls before the ceremonial intercourse (Berndt, 1951).

Figure 85: Ceremonial usage of throwing sticks over an ancestral spirit figure (Bora ceremony). Southern region of Australia (Jones, 1996).

Exchange

Throwing sticks that have gained prestige and are of high quality, were used as currency. It seems that boomerangs were traded to a lesser extent than the straight flying throwing sticks (Roth, 1897)
For Australia, trading was known in the Lake Eyre region where "kylie" type throwing sticks from the centre of the desert were exchanged for stone axes or for pituri, a hallucinogenic plant (Mulvaney et al., 1999).

Appendix III Table function-characteristics

Reading the table:

At the top, horizontally, criteria or features which could have been exploited in this study. On the left column, functions or function groups. The numbers in parenthesis indicates the number of objects involved.

For part about functions summary (Fig. 86):

An entry indicates either a range in which lies the throwing sticks which have the function concerned, or a positive or negative value. A positive value indicating a growing object number with the higher criterion value, or negative, meaning decreasing number of objects with low value of the criterion.

For range indication, for example, the input "fine-medium" at the intersection of thickness and small game hunting according to Australian objects, meaning objects that have this function are divided pretty near equal numbers in fine to medium range.

For another example, the negative value at the intersection of major criterion and fishing function according to Australian objects means that objects that have this feature spans the entire range, but that there is a growing number of objects with decreasing wingspan.

For the bottom part of the table (Fig. 86) about comparison between group of function:

The sign expressed indicate the change between the first function group compared to the second group associated.

For example the negative value entrance at the intersection of the mass/surface ratio and comparing terrestrial hunting uses/ contact use for Australian objects means that throwing sticks that have been observed for terrestrial hunting uses have a tendency for lower value of mass/surface than throwing sticks observed for contact uses.

Function summary											
	mass/surface	Wingspan	Height/Wingspan(curvature)	Thickness	Wideness	Blade tuning	Edges	Extremities	Symmetry	Trajectory	Range
AUSTRALIA(214)											
Contact uses											
Melee fighting(58)	Medium-Heavy	Medium	Light-Medium	Fine-Medium	Narrow-broad		+Rounded	+Rounded	-	Straight	medium-Very long
Fire saw(40)	Light-Medium	Medium	Light-Medium	Medium	Medium-broad		+Tapered	+Rounded	-	Straight	medium-Very long
Desarticulation(38)	Light-Medium	Medium	Light-Medium	Medium	Medium-broad		+Tapered	+Rounded	-	Straight	medium-Very long
Digging stick(36)	+	Medium	-	Fine-Thick	Very narrow-Medium		+Rounded	+Pointed		Straight	
Digging shovel(46)	Light-Medium	Medium	Light-Medium	Medium	Medium-broad		+Tapered	+Rounded	-	Straight	medium-long
Terrestrial hunting uses											
Small game hunting(84)	Light-Heavy	medium	Light-Medium	Fine-Medium	Narrow-broad		+Tapered	+Rounded		Straight	Very long
Kangaroo/emu hunting(80)	Light-Medium	medium	Light-Medium	Very Fine-Medium	Narrow-broad		+Tapered	Pointed, Rounded		Straight	medium-Very long
Ranged combat(131)	Very light-Heavy	Small-medium	Light-Medium	Very Fine-Medium	Narrow-broad		+Tapered			Straight,curved	medium-long
Fishing(36)	Very light-Light	-	Medium-Accentuated	-	Narrow-Medium		+Tapered	+Pointed		Straight,curved	medium-Very long
Aerial hunting uses											
Birds/bats hunting(108)	-	-	medium	Very Fine-Medium	Narrow-Medium	+	+Tapered	+Rounded	+		short-Very long
Pulling down birds(106)	-	Small-medium	medium	Very Fine-Medium	Narrow-Medium	+	+Tapered	Pointed, Rounded			
Game uses											
Game(returning)(45)	-	-	Medium-Accentuated	-	Narrow-Medium	+	+Tapered	Pointed, Rounded	+	returning	short
AFRICA(35)											
Contact uses											
Melee fighting(7)	+	medium	Light-Medium	Thick-very thick	Very narrow-broad		+Rounded	+Rounded	-	Straight	very short-medium
Terrestrial hunting uses											
Small game hunting(30)	+	medium	Medium	+	Narrow-Medium		+Rounded	+Truncated	-	Straight	
Deer/broad ongulates hunting(21)	+	medium	Medium	+	Narrow-Medium	+	+Rounded		-	Straight	short-long
Buffalo hunting(6)	+	medium	Medium-Accentuated	+	Medium-broad		+Rounded	+Truncated	-	Straight	short
Ranged combat(1)	Medium	medium	Light	Thick	broad		+Rounded	+Rounded	-	Straight	medium
Cattle breeding(3)	+	Medium-large	Light-Medium	Thick-very thick	Very narrow-Medium		+Rounded	+Rounded	-	Straight	medium-very short
Aerial hunting uses											
Birds/bats hunting(3)	Light-Heavy	-	+	Medium-Thick	Very narrow-Medium	+	+Rounded	+Rounded	-	Straight	very short-medium
INDIA(21)											
Ranged combat(19)	+	-	Medium-Accentuated	Medium-Thick	Narrow-Medium	+	+Rounded	+Rounded	-	Straight	long-Very long
Small game hunting(21)	+	-	Medium-Accentuated	Medium-Thick	Narrow		+Rounded	+Rounded	-	Straight	Very long
Deer/broad ongulates hunting(21)	+	-	Medium-Accentuated	Medium-Thick	Narrow-Medium	+	+Rounded	Truncated,rounded	-	Straight	Very long
Tiger-hunting(19)	+	-	Medium-Accentuated	Medium-Thick	Narrow	+	+Rounded	Truncated/rounded	-	Straight	long-Very long
Aerial hunting uses											
Birds/bats hunting(19)	+	-	Medium-Accentuated	Medium-Thick	Narrow	+	+Rounded	+Rounded	-	Straight	long-Very long
INDONESIA(11)											
Birds/bats hunting(11)	Medium	medium	Medium-Accentuated	Medium-Thick	Narrow-Medium		+Rounded	+beveled	-	Straight	very short-short
AMERICA(10)											
Rabbit/hare hunting(10)	Light-Heavy	Small-medium	Light-Medium	medium	Narrow-Medium		+Rounded	+beveled	-	Straight	medium
AUSTRALIA											
Terrestrial hunting uses/contact uses	-	-		-			+Tapered		+		
Aerial uses/ Terrestrial uses	-	-	+		-	+			+	Curved	
Game/aerial uses			+	-						returning	
AFRICA(35)											
Terrestrial hunting uses/contact uses			+								
Aerial uses/ Terrestrial uses	-	-	+	-	-	+					

Figure 86: Tables of results characteristic/functions relationships.

Notes:

Throwing stick:

This term is general here and is applied to a tool made of one or several wood pieces, or less often others natural material which are set with a angle between 0 to 180 degres. These wood pieces are called blades, more or less shaped and this object is thrown in rotation in the air, in a rotating plane.Boomerangs are only a particular sub category and very specialised throwing sticks with returning trajectory.

Boomerangs:

My terminology in this work is to call boomerangs only objects that have a 180° turning trajectory. In fact many Aboriginal words (ex bargan, boomari) which have given later this artificial name «boomerang» was attached only to light returning type of implements. Later early colonists confused by the many kinds of sticks assimilated non returning heavy throwing sticks under this same appellation. This confusion of terms continues to this day.

Attacking blade:

For two bladed throwing sticks, the two blades are not aerodynamically equivalent.The blade which need to travel a greater angle before being at the same position of the other one is called the attacking blade.The other is called following blade.The attacking blade travelling through a much more greater angle of air behind the slipstream of the following blade, get intrinsically more of aerodynamic lift, all other parameters being the same. This is the blade which is handled in common australian aboriginal style of throwing, curvature facing the target, but could be sometimes not. The attacking blade is finally defined aerodynamically with the direction of rotation of the object, by its largest angle swept, independently of the gripping of the object at the time of launch.

Extrados/Intrados:

The face of a throwing stick that is directed toward the ground or the outside of trajectory during the flight is called intrados or lower face.The other face, the upper face, that could be seen by the thrower is called extrados or upper face. The extrados is more often decorated.

Attacking edge:

Edge of a blade going directly against the relative wind created by direction of throwing stick rotation. On the contrary, the trailling edge is in its slipstream.

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