Study and experimentation around a Gaulish throwing stick[1] discovery in Normandy

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Abstract:

In 2010, Archaeological excavations on the pre roman site of Urville Nacqueville, Normandy(France) dig a unknown wooden shaped implement. This boomerang[2] like shaped wood artefact, dated from 120 to 80 BC, has been found in a enclosure trench of a gaulish village close to a ritual deposit of whale bones. The careful study of this implement, aside archaeological and ethnological comparison, show its have been probably used more like a bird hunting throwing stick. To test this hypothesis, some experimental replica crafting and throwing have been conducted, aiming to get more information about its functionality from the different flying trajectories obtained.

Archaeological Context

This artefact has been excavated inside a rustic district, from an enclosure trench protecting a living area where three circular buildings stood. These building are belonging to a Britain isles style. The stick was in vertical position against the external oriental wall of this structure(Lefort 2010). The base of the artefact was on a small built channel made some time after the main trench was filled. This particular position of the artefact tend to interpret it as a deposit on purpose rather than a disposal.

Boomerangs and throwing sticks: how these terms are used in this article

Since its appropriation by European, the term «boomerang» had been used to designate indistinctly all kinds of throwing sticks.
This language abuse, caused by the fascination of these objects returning flight, lead to forget the existence of a larger and diversified group of related objects, including a very small percentage of returning projectiles(Hess 1975. p 24). We tend nowadays as we will do in that article to designate only returning throwing stick as boomerangs, in respect of their Aboriginal etymology(Thomas 2000).

We will give a general definition of a throwing stick as a wood piece with a variable curved shape, having several more or less shaped blades forming a ordinary angle between them. This wood piece is throw by hand in rotation around its gravity centre.

Different use of throwing sticks

Some throwing sticks are capable to reach between 150-200 meters range and break the legs of a big mammal. Tamouls from South India was still using this kind of weapon in the XIX century to hunt hare, but also as big mammal as deer(Hess 1975. p 60).
It was also known in North America by Pueblos people, called « Rabbitstick » and mainly used to hunt rabbit(Heizer 1942). This weapon is also know in ancient greece under the designation « lagobolon » and are represented on several statues and figurative vases. The other main use of the throwing stick is bird hunting. Well documented in Australia(Jones 1996), this hunting practice is also represented on tomb painting representing the daily life of the elite of the ancient Egyptian society. The scene is generally taking place in a marsh where the hunter on a small papyrus boat is waving his throwing stick, followed by his servants. The hunter is aiming directly at a flock of bird and hit often several birds at the same time(Thomas 1991). In Australia, and other continents, throwing sticks were also used in conjunction with nets for bird hunting, but even sometimes big mammals(Hess 1975. p 59). About bird hunting, returning throwing sticks were mainly thrown over a flock of bird to imitate the bird of prey attack and get them down in ground fixed nets. Indeed, being a very light throwing stick weighting generally less than 200 grams and with small wingspan between 40-50 cm, returning throwing sticks tend to be only specialised in that kind of indirect aerial hunting and especially designed for gaming. Some use of throwing sticks for fishing in shallow water are recorded in Nord west Australia(Jones 1996).

Presence of throwing sticks in prehistoric Europe

The older identified throwing stick in the world is dated from 23 000 year belonging to the upper Palaeolithic period. This object, made of mammoth ivory, had been found in the Oblazowa cave in Poland(Valde-Nowak 2000)(Thomas 2000). About the Mesolithic period , an artefact dated from 6000 BP had been recovered in peat land of Brabant in Danemark(Thomsen et al. 1902) whereas the Egolzwil 4 site in switzerland deliver three examples of throwing stick dating from the middle neolithic(Cortaillod culture : 4500-3500 BC.)(Ramseyer 2000). Another example belonging to the final bronze period had been discovered at Möringen, in Germany.
At the same period, this throwing weapon is represented on Nile hunting scene painting in Nakht Theban tomb in egypt dating from the XVIII dynasty. However the more spectacular discovery of throwing stick had been made in Toutankhamon egyptian tomb which give more than twenty of these decorated projectiles in wood and ivory among the others treasure of the young pharao. Experiments with replica had show that some of these throwing stick had returning capability(Thomas 1991).
Two retuning throwing sticks found at Elbschottern near Magdebourg in Deutchland and at Velsen in Netherland dated respectively from 800-400 BC and 300 BC are the only example know for iron age(Hess 1975).

Fig 1: Europe map with localization of throwing stick archaeological discovery discussed here

Throwing stick in ancient texts : The cateia from Virgile and Isidore

The « cateia » is a throwing weapon quoted by ancient authors in the Eneide of Virgile(*Enéide*, VII, 740 et III, 274), Silius Italicus (*Les Guerres puniques*, III, 274) and Valérius Flacus (*Argonautiques*, VI, 83). Ferguson is the first to recognise a boomerang like weapon in these texts and make the relation with this latin name(Ferguson 1838). In these texts, « cateia » is designed by lexical terms compatible with a throwing stick in a warlike context. This particular term is associated with « torqueo » verb which mean « throwing a object in rotation » and with the adjective « pandus » which mean curved. Finally in his *Etymologies* written during the VII century, Isidore de Séville quote the Cateia as a gaulish throwing weapon with some returning capability. In a synthesis of information extracted from these ancient text Salomon Reinach is describing this object as a short heavy blunt weapon with a wooden flexible handhold (Reinach et al. 1894, p. 192). Servius(ad Aen, VII, 741) also tell that the cateia have a maximum length of 1.5 cubit to keep manoeuvrability and that it is thrown at very short distances because of its weight, sometimes returning to the thrower.
Other proposal for interpretation of the term cateia as a throwing axe or javelin have proven to be wrong and confusing with another javelin like weapon named « aclys ». The cateia term is probably designing at the same time, in a confusing way like what have been done by European in Australia. Indeed, several different categories of throwing stick are described in apparent contradiction sometimes like a heavy war version and other times as a light returning version. But more importantly, this latin term convey the fact that throwing stick were in use during the second iron age in Europe and was included in gaulish war outfit, and this kind of projectile was enough important to be quoted by several ancient authors.

General Description of the artefact

The stick appear like a curved wooden piece of 54 cm wingspan and 1 cm thickness. The wood analysis show it was crafted as a whole from a single wood branch of an apple tree(Pomoideae sp). Urville Nacqueville stick was carefully crafted and polished to erase any woodworking tools traces. Three centred narrow parallel grooves have been carved along both surfaces of the artefact. Five iron strips have been fixed around its extremities, elbow and mid part of each blade. For each of these strips, the metal is overlapping and fixed with a small nail. At time of discovery, one of these strip had been lost and one blade was found without it, but a nail hole attest to its presence.

Fig 2 & 3: Pictures of the artefact discovery along the enclosure trench

Detailed features of the artefact

The listed detailed characteristics of the artefact could be found in appendix 1. The measurement, evaluation and database referencing of these parameters had been developed in a previous work(Bordes 2014)

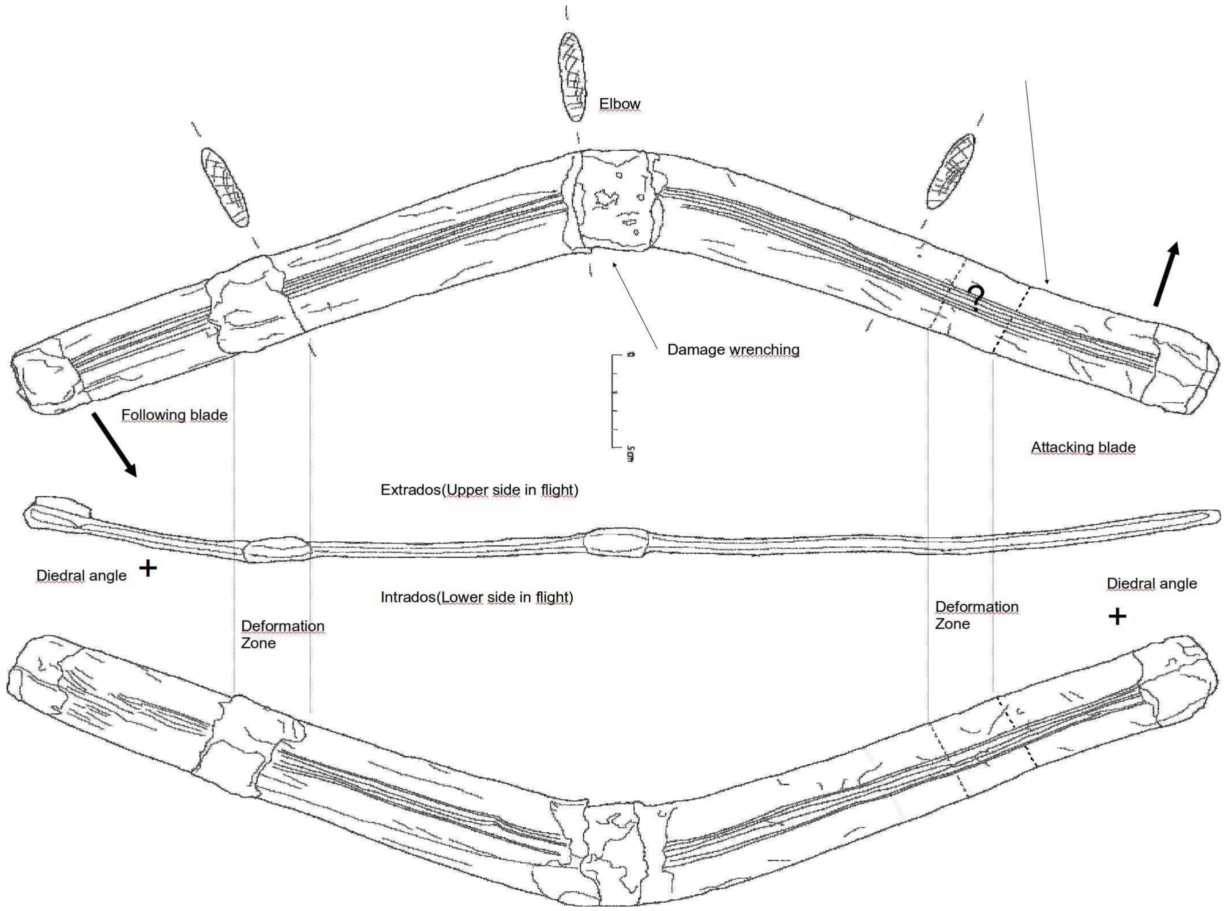


Fig 4: Drawing and interpretation of the Urville Nacqueville stick by François Blondel. Wrench and wideness reduction of the right blade is interpreted as a the right handed holding. Arrows indicating the anticlockwise way of rotation.

Blades:

The actual object wideness is maximum at the elbow with 5.3 cm. Taking in account the wrench of wood visible on the interior edge of the elbow, the wideness could have been more around 5.6 cm at the start.
The wideness is decreasing from the elbow to the extremity of the left blade until 3.8 cm. The same thing is true for the right blade which extremity wideness is finishing with 4.2 cm. However, 10 cm from the right blade extremity, a sudden shrinkage was probably caused by an impact on this exterior edge. It seem that this part had been reform to be used as a holding. This reformed hand held help us to determine the laterality of this object , considering the orientation of the dihedral angle deformation on both blades. Indeed, if this object was used as a throwing stick like projectile these dihedral angles were related to the upper face(extrados[3]) to allow stable flight.
Considering this orientation reference, we will refer as the attacking blade[4] for the right blade and the following blade for the left blade.

Section:

The section of the object is symmetric between the lower face(intrados)[3] and the upper face(extrados), though it vary between a rounded rectangular type for the left blade to a biconvex type for the right blade. So the section will be qualified as a mixed type. The consequence of this difference of blade section is that the biconvex attacking blade is slightly lighter and take more aerodynamic lift than the left blade with a rectangular rounded airfoil, equivalent to a gravity centre shift. This effect reinforce the difference of aerodynamic applied between the two blade by the curvature angle(Bordes 2011) and contribute to the aerodynamic lift to give the projectile a curved trajectory like boomerangs. Mixed section are often encountered among throwing sticks around the world.

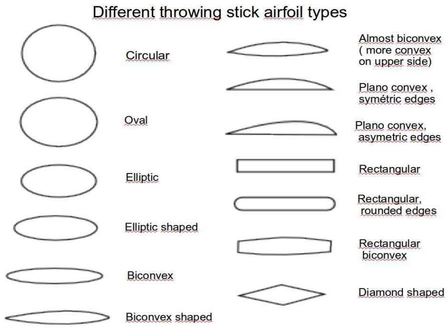


Fig 5: Different sections encountered for throwing stick and boomerangs

Dihedral angle deformation:

Two very accentuated dihedral angle create a space of 1.5-2 cm between the blades extremities and the elbow plane. These dihedral angle symmetric deformations are starting around 13 cm of the blades ends and are not the consequence of the artefact burial. These deformation could not come from a withering process during a neglecting state in the trench at gaulish time because the object had been buried quickly which explain its well conservation. It's relevant to notice that these dihedral angle deformation are localised on the blade at the same position of the iron strips. In consequence, they are probably du to metal oxidation in a wet environment which increase the volume of metal strip and locally pinch the wood section to induce these deformations. Consequently, these dihedral angle could have been less accentuated in the past and closer to those we could observe generally on throwing sticks: some dihedral angle showing gap less than 1 centimetre. This hypothesis had been confirmed by experimentation.

Height/Wingspan ratio

The height on wingspan ratio is a good indicator of the stability of a throwing stick against the risk of flipping in flight. More this value is close to 1 and more the projectile is stable. Under the value of 0.2, this risk of instability in flight is greatly increased. This ratio measured on the Urville Nacqueville stick is 0,33 which mean a pretty stable projectile in rotation.

Grooves

Three centred longitudinal grooves had been engraved on each side of the artefact with a chisel. They are 1 mm wide and deep and spaced from each other of 1 mm. The central groove is slightly deeper. These grooves is only decorative in function.

Extremities

The artefact is made of a single wood branch. The extremity are truncated with rounded angles are worked and well finished. Consequently, the object is a whole and seem to not be apart of a larger broken wooden artefact.

Nail hole of the lost iron strip

A nail hole had been observed on the intrados of the attacking blade. The position of this nail hole is nearly symmetric compared to the fixed position of the iron strip on the other blade.

Fig 6: Observation of a Nail hole on the intrados of the attacking blade

Iron strips

We could observe four oxide iron strips positioned on the elbow, and at each extremity and after the middle of the following blade(left blade). These iron strips are meanwhile 2.5 cm wide and around 0.5 mm thickness and were fixed by small iron nails. A lost fifth iron strip was positioned just after the middle of the attacking blade. It presence is confirmed by the symmetric deformation of this blade at this position as the one fixed on the following blade, and a nail hole left by its fixation.
Additionally, to set the corresponding iron strip, the elbow had been reworked to carve a notch which cut into the decorative grooves while the others strips are simply fixed over the grooves. This mean that these strips hadn't been fixed on the object all at same time but at different step along the lifespan of the artefact.

Indeed, with the observation of the strip fixing and losing it's possible to explain the following steps:

First initial step of the object without any iron strip, decorated with set of grooves without dihedral angle deformations(step 1)

Second step after the fixing of the central elbow iron strip, without dihedral angle deformations(step 2)

The fact that the elbow strip had been fixed in a reworked notch that cut the grooves show this fixing was a repair and was not planned at the beginning on this artefact. Indeed the elbow is the more fragile zone for throwing sticks and breakage very often happens there. The trace of impact and wrenching located inside the elbow reinforce this interpretation(cf impact traces)

Third step with five iron strips with increasing dihedral angle deformations(step 3)

To prevent future breakage, the object is reinforced by four others iron strips fixed directly around the blades on the grooves. Two at each extremity and two others after the middle of each blades, 13 cm away from extremities. These iron strips are probably reinforcement to prevent breakage, without playing any decorative role because iron material is almost not used for decorative purpose at gaulish time.
After that, the object undergoes some deformation of the blade, probably du to the humidity and starting iron oxidation. This phenomena start to create two important dihedral angles on each blade. The same upward orientation of these symmetric deformations angle could indicate that the object was laid on a flat surface during this period. The artefact is probably also under used during this step.

A fourth step with only four iron strips with full dihedral angle deformation(step 4)

Later, the object could have been used once more as a projectile and endure damage which explain the lost of an iron strip on the right blade(attacking blade)

Finally, at this step, the artefact is deposited in the trench. The process of oxidation goes on to contribute to the state of the recovered archaeological object.

Impacts traces

Careful observation of the Urville Nacquevile object surface reveal some small wood wrenching on the edges which could correspond to some damage impact of this artefact consequence of its usage as projectile on ground or against obstacles.

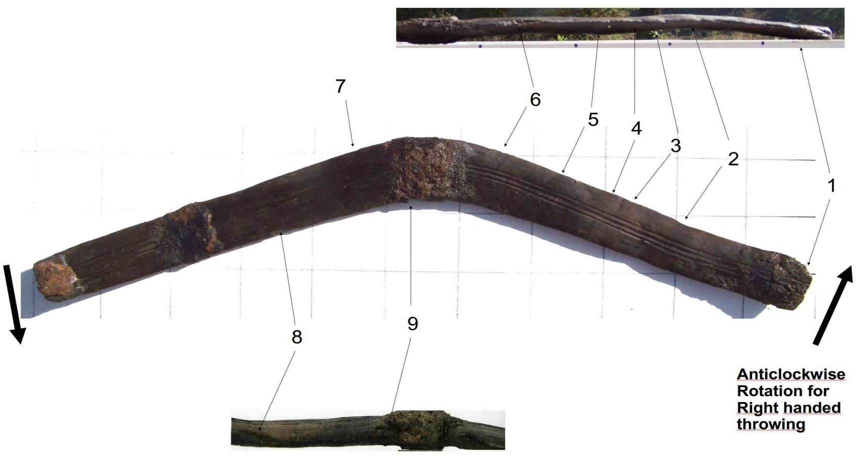


Fig 7a: Impact traces observed on the edges(extrados view)

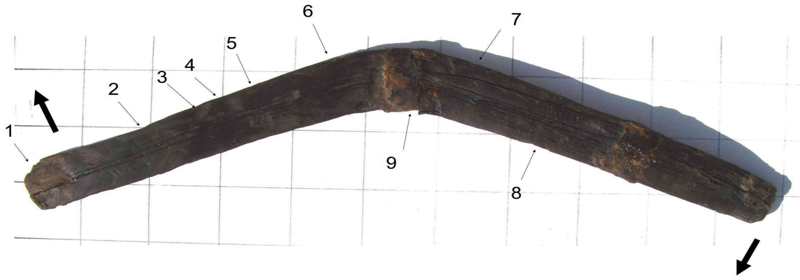


Fig 7b: Impact traces observed on the edges(intrados view)

Except the wrenching n°1 and n°9, the damages around oxided iron strip hadn't been taken in consideration. Indeed, these wrenching could have been the result of oxided iron fragment losing from the strip attached with wood bits. However, the corner breaking n°1 is relatively important to be noted. The wrenching n°9 is related to an important damage underwent by the object elbow which lead the first central elbow iron strip repair. The wrenching n°2 seems to have been repaired and the edge reworked decreasing the wideness of the blade and making a better holding. This major wrenching damage is probably the cause of the losing of the fifth strip.
Wrench damage n°3 to n°7, smaller, are mainly localised on the outer curvature and the supposed attacking edge[5] and could be compared to impact observed on ethnological models of throwing sticks (Fig 7). Consequently, These impact traces could confirm the way of rotation of the object used as a projectile as well as the awarding of the holding blade. The wood wrenching n°8 located on the inner curvature and also on the attacking edge of the following blade reinforce the idea about the projectile use of this artefact.

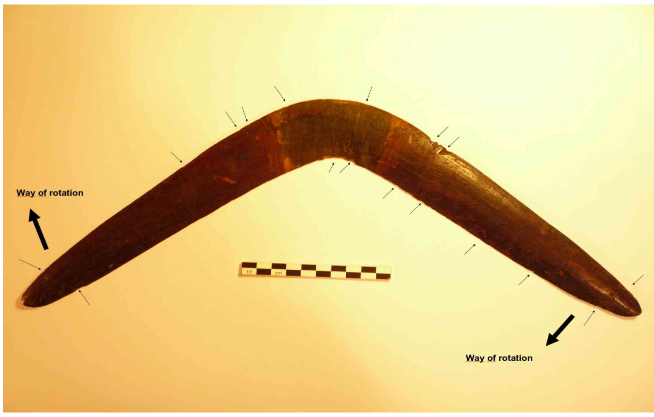


Fig 8: Example of localisation of impact damage on an South Australian Aboriginal boomerang: Impact are in majority on the outer curvature and attacking edges.(South Australian Museum)

Mass evaluation and mass on surface ratio

A mass evaluation had been done with the accurate drawing of the artefact. If we take in account the fact that the mean airfoil shaping is 16% less in surface compared to a rectangular section, we found a 210 cm³ volume estimation. Calculating the mass with a mean density for apple tree between 0.657g/cm³ – 0.833g/cm3, we found a mass ranging from 138 g to 175 g for the object without any iron strip(step 1)

Evaluation of iron strip mass

Even if the iron strip aren't all identical, the estimation can be done taking a mean wideness of 2.5 cm and circumference of the blade section. It gives a ballast of 8.5 gr per strip using the iron density(7.8) and the mean strip thickness of 0.5 mm. If we suppose all iron strip almost identical, it gives finally a range of 172-209 gr object with four strip and a range of 180 - 217 g with five iron strip.

Mass on surface ratio is an important parameter for throwing stick flight. A low mass on surface ratio throwing stick will undergoes more aerodynamic lift and if this force is stronger than its weight, it will follow a curved trajectory. At the opposite a throwing stick with a higher mass on surface ratio will have its weight winning on the aerodynamic lift force and follow a straight line trajectory. In function of a experimental database it was possible to establish mass on surface limit which could separate different throwing stick

class related to this parameters(Bordes, 2009). For example the very light throwing sticks class corresponding with boomerang like projectile having a returning trajectory often show ratio under 0.7 g/cm2. Over this value, another throwing stick class with ratio in a range between 0.7 et 0.9 g/cm2 have a curved but not strictly returning trajectory.
For Urville Nacqueville artefact, the calculated mass on surface ratio without iron strip is between a range of 0.55 to 0.7 g/cm2 and between 0.69 to 1.03 g/cm2, depending of the number of strip(1-5).

incidence tuning

No incidence torsion[6] was observed on the archaeological object, but in absence of a accurate plot of this parameter after the discovery, slight incidence torsion tuning are probable as flight experimentation showed.

Useful Archaeological and ethnological comparisons

Two archaeological throwing sticks found in Europe could shed light on Urville Nacqueville stick: Firstly, The boomerang like throwing stick found in Velsen(Netherland)(Hess, 1975) which is a returning projectile. Velsen Boomerang like projectile is belonging also to the middle iron age period(300 BC) and less than 600 km away from Urville Nacqueville.

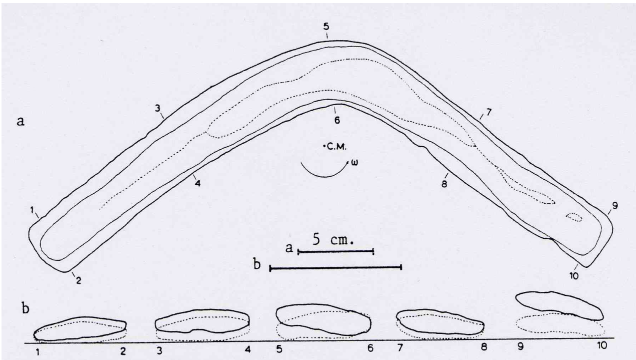


Fig 9 : Drawing of Velsen boomerang like throwing stick(Hess, 1975)

Velsen throwing stick have a 39 cm wingspan giving a 0.35 height on wingspan ratio. Its mean wideness is 3.5 cm . Its thickness is varying from 6 mm from the extremity to 8 mm at the elbow. Its mass evaluation give 72 g and its mass on surface ratio calculated around 0.47g/cm². This object is made of oak tree which is a favourable wood to craft light throwing sticks and boomerang. Its shape, rounded with constant wideness and truncated ends is close to those of the Urville Nacqueville stick. However its height on wingspan ratio is a bit higher and it is a lighter and finer object compared to the object studied here. Its characteristics are therefore belonging to the very light throwing sticks class(mass/surface ratio< 0.7 g/cm²) and with its conserved positive incidence attacking blade tuning, confirm its returning capability and its right handed laterality.

Magdebourg returning throwing stick, found at Elbschottern near Magdebourg in Germany is another archaeological discovery close to our studied object. This throwing stick is belonging to an older period with a datation ranging from 800 to 400 BC. The wood used is ash wood. Its better conserved blade has a 22.7 cm length, its thickness is between 0.7 and 1 cm and its wideness ranging from 7.35 at the elbow to 4.25-4.4 cm at the extremity of blades. Its rendered wingspan is 37 cm giving a height on wingspan ratio of 0.67. From its drawing, it's possible to calculate its surface around 182,6 cm² and make an estimation of its weight between 76 and 109 g considering the ash wood mean density. Finally it's possible to obtain its mass on surface ratio ranging from 0.4 to 0.6 g/cm2 which show this projectile is belonging to the very light throwing stick class and predict its returning capabilities as boomerang like object.
Indeed, experimentations lead on replica had showed a returning trajectory and left handed laterality.
Compared to the Urville Nacqueville stick, its a smaller and lighter object. Similar to Australian Aboriginal boomerang, Magdebourg throwing stick have a widened elbow though Urville stick have a constant wideness. Its rectangular airfoil is close to those of our object of study although its has a slightly different attacking blade airfoil with a concave intrados. This feature aim to increase dramatically aerodynamic lift on attacking blade to accentuate the returning trajectory. This mixed type airfoil is commonly encountered on throwing sticks in Australia and also existing on Urville Nacqueville artefact.

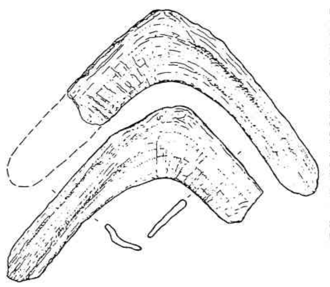


Fig 10: Boomerang like throwing stick found at Elbschottern near Magdebourg in Germany. Dated between 800 and 400 BC(Evers, 1994)

Ethnological comparisons are also rich in information for our study. Indeed Urville Nacqueville artefact have common feature with the famous American pueblos throwing sticks(Heizer, 1942). These specialised throwing sticks were used in rabbit hunting and have often curved shape, truncated end and rectangular airfoil, but could have elaborated carved holding. Nevertheless these rabbit sticks are designed for ground hunting and are generally thicker, larger and heavier than Urville Nacqueville stick. This comparison allow to think that the Urville Nacqueville artefact could be too fragile for ground game and be more adapted for bird hunting.

But the more striking common point between our artefact and South west American throwing sticks is the presence of centred grooves, also coming by set of three or four, frequently encountered on Anazasi Throwing stick which precede pueblos rabbit sticks(fig 10).

Fig 11: Example of archaeological pueblos rabbit sticks dated from 500 BC to 500 AD grand Gulch, Utah. National Museum of American Indians, New York. Note the gap between set of grooves to attach binding which reinforce this throwing stick.

Indeed, throwing sticks in south west America are coming from a ancient central American tradition and were used by Mayan people as fighting stick and to deflect incoming enemy darts(Heizer, 1942). They are frequently showing centred set of grooves on both faces similar to those observed on Urville Nacqueville artefact. These set of grooves are regularly interrupt by gap allowing binding of the stick by sinew or vegetal fibre cord. This system of throwing stick reinforcement could have been used also on the gaulish artefact, but using iron material for binding strip which was the more common new material for iron age period.

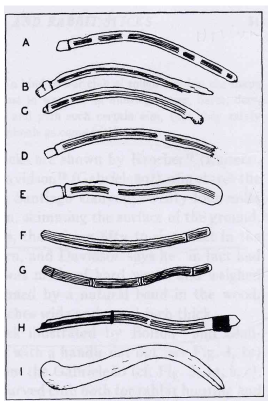


Fig 12: Serie of simple or double curvature grooved throwing stick found in South west of America in Texas, New Mexico and Utah(Heizer, 1942)

Another Ethnological comparison with reinforcement and repair are iron strips used for valari Tamoul throwing sticks which could shed light on this particular use of metal on Urville Nacqueville stick. Indeed iron strips are used for south Indian throwing sticks called Valari dating from XIX and XX century, used for hunting and war. Additionnaly, valari bonded with iron strip are sometimes not any more thrown but are playing a ritual and symbolic role in temple or are exchanged for wedding.
Some of these throwing sticks have a type of wide iron strip carefully fixed on the extremity of their short following blade and have around 2,5 cm wideness close to our gaulish artefact strips, but are thicker(around 1 mm). This type of strip planned at the making of the throwing stick, being set in carefully carved notch and welded.

Fig 13a & 13b: Valari carefully finished with an iron strip at the end of the following blade. Wideness of strip is 24 mm, thickness 1 mm.(Pitt river museum, Oxford UK)

Another type of iron strip on valari Indian throwing sticks is the repair strip. Others valari shows narrower iron strip, with a wideness around 8-9 mm and 0.5-1 mm thickness fixed by a small iron ring on the edge, mainly for repair. Indeed valari with this type of strip are always damaged or have wood splitting .

Fig 14a &14b: Example of valari showing the two different type of iron strip encountered: A wide welded iron strip at the short following blade extremity and several narrower repair strips fixed with rings.(Pitt river museum, Oxford UK)

A last ethnological comparison could be done about the dimensions and airfoil shaping of our studied archaeological object with some light throwing stick and boomerangs from South Australian region of Lake Alexandrina:

In this region its exists some curved light throwing stick and boomerang for bird hunting which have a biconvex airfoil, thickness between 6 and 10 cm, wingspan ranging around 50 cm and truncated blade ends. Their only distinct feature is a widened elbow for more resistance. This point allow to understand better how the main default of Urville Nacqueville gaulish artefact is lacking widened elbow and needed to be repaired by a iron strip in a reworked notch after a breakage. These common feature shared with Aboriginal light bird hunting stick allow to favour the bird hunting use if we identify our gaulish artefact with a throwing stick like projectile.

Fig 15: Example of Australian Aboriginal bird hunting stick form lake Alexandrina region (Quai Branly Museum). Mass 260 g, wingspan 57 cm. Despite its appearance, this object is not a boomerang with a returning trajectory, because of his weight and could be compared in term of projectile use with the gaulish artefact of Urville Nacqueville.

Arguments for the throwing stick hypothesis

Here is a summary of arguments reinforcing the hypothesis which identify Urville Nacqueville gaulish artefact with a throwing stick:

Its dimensions are compatible with those of throwing stick:

As we see above, if we compare its wingspan, thickness and wideness with those ethnological throwing stick examples like Aboriginal Australian, Its dimensions well fit with the mean value encountered for these projectiles.
Its rectangular cross section on following blade is commonly encountered for American rabbit stick and its biconvex attacking blade section is the most common airfoil for throwing stick around the world. Among Aboriginal Australian throwing sticks, mixed type of airfoil on each blades of the same projectile are frequently observed.

Stable in flight :

Its height on wingspan ratio of 0.26 show that it is a stable projectile in flight, without risk of flipping.

The wood used is compatible and favourable for light throwing stick and boomerang crafting:

Apple wood as a medium density and resistant wood is still used today to craft moderns boomerangs as an excellent quality wood. Medium density and resistant wood are also used around the world for light throwing stick like rabbit sticks in Oakwood made by pueblos Indians in Arizona or Casuarina wood in South Australia.

Set of grooves are common on throwing sticks

Several type of throwing sticks are partially or totally covered by grooves like the «kylie» grooved throwing stick crafted in arid central Australia or Anazasi throwing stick in South west America.

Reworked notch and strip fixing strip is used for throwing sticks

Repairs by binding with sinew and vegetal cord strip after carving a notch is commonly encountered among Aboriginal traditional throwing stick and boomerangs. Anasazi throwing stick are reinforced by vegetal and sinew strip too, and in a same pattern by interrupting centred set of grooves.

Iron strip are found on certain type throwing sticks for reinforcement and repair

South Indian valari throwing stick display this feature, as well as some archaeological egyptian prestige throwing sticks similar to those of the serie found in Toutankhamon tomb displaying gold covering(Thomas et al. 1991). Dimensions and thickness of iron strips found on Urville Nacqueville gaulish artefact are compatible with those observed on Indian Valari.
Use of such reinforcement and repair on throwing sticks enhance their prestige and could change their primary projectile function to a more symbolic role in ritual and social cultural event.

Experimental replica crafting and throwing

The replica crafting with hand traditional or even prehistoric tools is a deliberate choice aiming to evaluate an object produced by very simple crafting ways and keep aware of the resulting crafting defaults on the throwing stick obtained, that could drastically affect its aerodynamic. Indeed, these informations could be missed by using more modern crafting leading to a more «perfect» results.
Indeed, hand crafting method has the drawback to do not lead to an «exact» replica(if it may exist !) of the archaeological object but have the advantage of staying close to the wood surface real natural irregularities which are a slowing rotation factor in flight that could being underestimated with a more perfect surface modern crafting(replica in resin for example). Differences between replica and the archaeological object had been offset by creation of three replica(A, B , and C) to flank the archaeological artefact characteristics. In this approach, differences are turned in advantage because they are discussed and help to get a better view of the use of the object studied.

Making of the replica A

A first replica had been made by Luc Bordes using a plain curved branch of apple wood. The coarse shaping had been done by hand cutting tool(machete), followed by a shaping stage made by scraping with a flint scraper block. The finishing and polishing stage have been made with a hand-held sandstone. Grooves had been done with a hand steel chisel without hammer.
Dihedral angle deformation were produced by steam and dry heating.
This replica, made after a early drawing of the archaeological object was slightly thinner and lighter than the archaeological artefact. Summary of replica A characteristics could be found in appendix 2

Fig 16a & 16b: Replica A with produced dihedral angle deformation, extrados(a) and intrados(b) views

Flight experimentation without strip(step 1)

The throwing experimentations had been done trying with both successive orientation of the object, extremities dihedral deformation pointing upward or downward. The replicated projectile had been thrown in different directions relative to the wind.

Extrados/intrados orientation: Orientation of the diedral deformation

Throwing vertically the object with diedral angle deformation pointing downward lead to an uncontrollable trajectory turning right at the end, because of the gyroscopic precession effect. Throwing it horizontally lead to a more straight trajectory but difficult to master and subject to flight instability.

Obviously, the trajectory obtained with dihedral angles pointing upward is far more stable, but because of the rotation, small wingspan and light weight of the object, the flight is not straight, but rather «S» shaped. Nevertheless, this first serie of throwing experimentation show that the extrados could be assigned to the side where diedral deformation are pointing.

Determining throwing inclination

With this extrados/intrados orientation, different throwing inclinaisons had been tested, from a nearly vertical throwing(typical throwing for boomerangs) to a more horizontal throwing(typical throwing inclination for heavy throwing sticks) passing by different intermediary inclinaisons around 45°.

Throwing near an horizontal plane worsened the «S» shaped trajectory, which render it even more inaccurate and useless. This result could be planned, as symmetric light throwing sticks acquire quick rotation and strong gyroscopic effect that turn the rotation plane inducing a systematic right curved end of trajectory for a right handed projectile.

The best trajectory were found for a medium inclinaison around 45° which delay the gyroscopic rotation plane turning effect and lead to more straight trajectory, but the object is still flying too low and with low accuracy.

Determining projectile twisting tuning and enhancing its flight by positive incidence tuning on attacking blade

Twisting tuning for throwing sticks and boomerang are critical. Apart the main positive diedral deformation, no incidence twisting was noted on the archaeological object. Indeed they could be altered and difficult to observe on a two thousand years old artefact. This parameter wasn't measured accurately at the time of discovery, so this is allowing to propose hypothesis about incidence tuning existence on Urville Nacqueville stick by experimentation.

Urville Nacqueville artefact is close to a light throwing stick and Aboriginal boomerang by its mass on surface ratio which lead to test similar tuning for its experimentation. For example positive incidence tuning on attacking blade frequently use for Australian Aboriginal boomerang and light throwing stick category(Bordes, 2011).
Additionnaly, considering the object thickness, size and weight, it would be not adapted to ground hunting, because of the impacts with ground and obstacle would break it. Used as a hunting stick, it would be rather used as a bird hunting stick.

The trajectory obtained by using a slight positive incidence tuning, done by heating, are far much satisfactory, showing more diving and distance, with a more stable flight, in a slight curve(fig 17).
The trajectory could be kept low with a vertical throwing allowing to aim birds when they take off, or in a more high climbing route by leaning the object at 45°. The end of trajectory initiate a slight return if the object is thrown with a lot of rotation energy, more or less marked, depending of the relative wind.
The maximum distance is 35 m for climbing high trajectory and reach 45 m for low trajectory(fig 17)

Even if this object doesn't show a true returning capacity, the observation of the initiation of this effect at the end of its trajectory allow the throwing stick do not get lost and can sweep away a larger aimed zone increasing its chance of hitting a fowl.
Another main point, is that this flight allow the throwing stick to lean horizontally at the end of its trajectory and fall parallel to the ground with less chance of being broken, which is the main risk of others type of trajectories tested before(without tuning or with a strict vertical throwing).

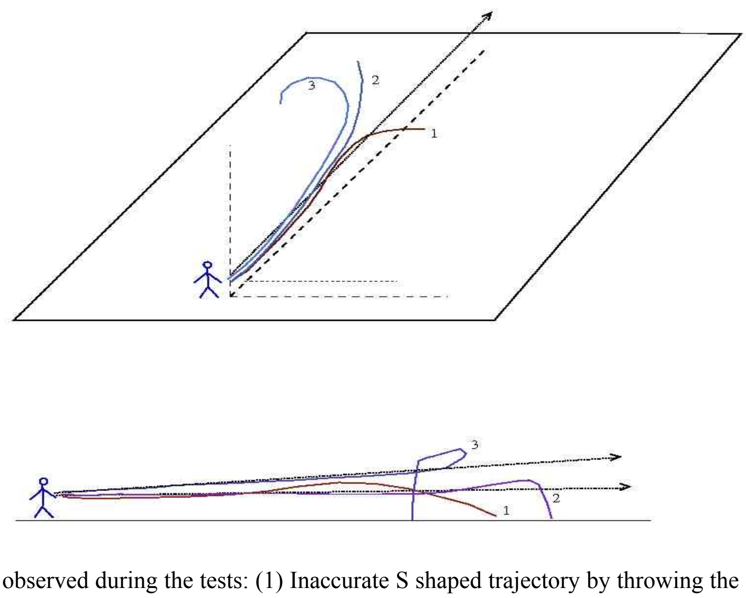


Fig 17 : The different trajectories observed during the tests: (1) Inaccurate S shaped trajectory by throwing the object horizontally, without incidence or diedral angle toward the ground(2) Optimal low trajectory by throwing near vertical plane (3) Optimal higher trajectory by throwing with a 45° angle from the vertical.

About the curving trajectory in standard condition with a low relative wind, its happens too far from the thrower to get a chance of a complete return back to the thrower. Indeed, it seem that returning completely wasn't the aim of this throwing stick because along its stages, the artefact had been weighted by an increasing number of iron strip ballast, decreasing progressively its chance to experience a returning flight.

Experiments with addition of ballast equal to iron strip, with presence of both diedral positive deformations

To make the ballast 1 mm thick lead was fixed with adhesive tape. This way of temporary fixing was preferable for the throwing experiments, to allow setting and removal as required. Three tests was done with 1,4 and 5 eight grams lead ballasts.

With a single eight gram ballast at the elbow, the projectile have its trajectory little shortened and higher. This effect is predictable and frequently observed on modern boomerangs weighted at the elbow(the gravity centre is shifted toward the elbow). In this way the artefact is the state two gain in stability and climbing capability and stay very efficient for bird hunting(trajectory type 3).

With four eight grams lead ballast, the distance was increased by ten meters, to a maximum between 45 and 55 m. The thickness increasing at the strip position tend to brake the projectile rotation, decreasing the aerodynamic lift and gyroscopic precession effect.
Adding three additional lead ballasts change dramatically the object flight. The projectile don't generate enough aerodynamic lift to counter balance the increased mass, and the inaccurate trajectory is straight and low, describing a S figure because of the clockwise rotating plane du to the gyroscopic effect(trajectory type 1).

Experiments with addition of ballast equal to iron strip, without diedral positive deformations

If we restart the same kind of experiment with little or no diedral positive deformations, it possible to throw the replica with full five lead ballast with a better trajectory(trajectory type 2). Indeed Without diedral positive deformations which brake the rotation movement, the projectile recover faster rotation and superior aerodynamic lift leading to a more stable slightly curved trajectory.

Fig 18: Replica weighted with lead fixed by adhesive tape(prepared for four strip test)

Making of Second «B» and third replica«C» after archaeological artefact examination

Two others replicas had been done to flank the archaeological artefact characteristics, more specifically thickness and mass. They have been done the same day with slightly different crafting techniques by Luc bordes and François Blondel. Replica B has been crafted with cabinetwork techniques(wood chisel, file and grinding paper) from a curved plank extract from a apple tree branch core. This replica move apart the archaeological artefact by its airfoil which tend to be flatter on the intrados(almost flat convex airfoil).
Replica C has been made by manual more simple techniques (machete, flint scraping hand tools grinding stone) from a curved plank extract from a apple tree branch core. Its has a wingspan little shorter than the original. Central grooved lines hasn't been done on this replica.

Tests with addition of ballast equivalent to the iron stripes, with diedral positive deformations

For these tests, replica B has been equipped with four lead eight grams ballasts fixed with adhesive tape to simulate the fourth state of the artefact. Replica C is equipped with four steel strips of identical mass to simulate the same state.
These replica, whose mass was closer to the original artefact, have been thrown the same way as replica A, in the same conditions of wind and under different wind directions. Trajectories obtained are almost straight, low or driven down to the ground, following inaccurate flight in a « S » shape(trajectory type 1, fig 17). In these conditions, replica B flights were worst, because of its airfoil producing less aerodynamic lift than replica C.

The steel strip located at the extremity of replica C attacking blade appear to be comfortable to hold the object, sometimes doing harm(a little cutting at the finger), because at the opposite of the central strip set at the elbow in a notch they are set on the surface of the artefact hence proeminent from it.

Another serie of tests was tried with removing all ballasts from replica B to simulate the first state of the archaeological object, keeping the incidence tuning neutral. The same useless trajectories were observed.
A third serie of tests was attempted on the same replica changing the incidence tuning to positive on the attacking blade as done for the replica A. The flight obtained was far improved, being stable and accurate. The object keep its rotation until the end of its trajectory and lay down flat, without risk of breaking. On the other hand, the curvature of the flight is less accentuated or absent compared to the tests done with the replica A.

Experimentation with replica without diedral positive deformations

The main observation about Replica B and C is that they don't reach enough rotation speed for efficient flight. This is because of their diedral positive deformations and increased thickness. Indeed, these diedral positive deformations that were less critical on Replica A tend to have more accentuated negative influence on the flight of replica B and C.
This remark lead to wonder if these accentuated diedral positive deformations have been really existed on the functional gaulish object as a throwing stick and try a last serie of test removing all diedral tuning on replica B and C like that have been done on replica A.

The results are very convincing : replica B and C recover a very correct flight, with slightly climbing and curved trajectory end. It could be noted that the Replica B fly with less climbing and increased range compared with replica C.
In conclusion, it can be said that the three different replicas, even with not having an identical flight are showing the same general flight behaviour.

Replique	Appliques	Diédres	Incidence positive	Type de vol	Etat de l'objet
A	0	oui	oui	3	1
A	1(coude)	oui	oui	3	2
A	4	oui	oui	1	4
A	5	oui	oui	1	3
A	0	non	oui	3	1
A	1(coude)	non	oui	3	2
A	4	non	oui	2	4
A	5	non	oui	2	3
B	4	oui	non	1	4
C	4(acier)	oui	non	1	4
B	0	oui	non	2	1
B	0	oui	oui	2	1
B	0	non	oui	2	1
C	0	non	oui	3	1

Fig 19: Summary of experimental tests on replica A, B, C with indication of the stripes number, diedral deformation, and positive incidence tuning. The type of flight obtained is indicated along with the corresponding state observed on the archaeological artefact.

Restitution of the Urville Nacqueville artefact use as a throwing stick

To get an insight of the use of this artefact as a throwing stick, we need to take in consideration all its characteristic and experimental tests results:
Without iron strip the artefact mass/surface ratio is in between 0.52 and 0.66 g/cm² which categorise it in the very light throwing stick class(M/S<0.7 g/cm2)(Bordes et al. 2014). This is the group where boomerangs type projectiles are found. This mean that in the archaeological state one and two, it is not surprising to obtain on the replica a curved trajectory with a proper incidence tuning on the attacking blade.

On the other hand, adding five iron strip bring the ratio of mass/surface between 0.66 and 0.8 g/cm², which change its classification to light throwing stick category(0.7<M/S<0.9 g/cm²) with no potential of complete return. Indeed, the limit of these two category is fixed around the value of 0.7 g/cm² in function of my personal experimentations. I observed that It is very difficult to craft and tune returning projectile with mass on surface ratio over 0.7 g/cm2. In the state three, the object is obviously a projectile with a straight trajectory or following a slight «S» shape, but with no accentuated curve, its mass winning on its aerodynamic lift in standards relative wind conditions(light breeze 10-20 km/h)

The low shaped rectangular or biconvex airfoil of the artefact, bring less aerodynamic lift than a true plane convex airfoil encountered frequently on the boomerang type projectiles. This aspect confirm that this artefact had been crafted more like **a light throwing stick** than a playing object designed to return to its thrower, as experimental tests shown.

Considering the artefact mean thickness(between 9 and 10 mm), its reduced dimensions and the medium density of its wood, this projectile would be not very efficient on ground targets and would break easily. This consideration allow to infer that It has been made rather to travel by aerial trajectories probably to hit only fowl as a weapon specialised in bird hunting. However two different trajectories are possible, a low flight aiming to intercept bird on take off or a higher flight to hit a flock of flying birds.
Indeed, one of the main advantage of a throwing stick is the potency to bring down several fowl by a unique throw, one impact on a target not stopping the projectile rotation movement, that will kill it, go around, and hit other targets without too much loss of energy.

The strips, especially the central elbow strip, testity the archaeological artefact several different states. Their presence show that the artefact needed reinforcement and has been probably exposed to important contraint and shocks.

Another thing to take in account is the additional mass of these strips simulated by the ballast added to experimental replicas which tend to increase the range of the artefact used as a projectile. This increasing mass along the different state of the artefact life confirm that these modifications were aimed for a throwing stick use, fitted to hit target, rather than a gaming toy use, modified to accentuate its curved trajectory, like the famous boomerangs.

Nevertheless, this light throwing stick which could be classified in its state one, without iron strip or in its state two with the unique central elbow iron strip, in the group of very ligth throwing stick, close to boomerang precursor. This category of projectile are capable of having accentuated curved flights with strong wind which mean that the gaming use of this gaulish artefact couldn't be totally excluded and may have existed aside the hunting main use.
In the state three, the artefact become less functional as a projectile, after the adding of iron strips at both middle and blades ends over the decoratives grooves. Theses news four strips have ben added as reinforcement. Indeed iron material is seldom used as decorative purpose at gaulish time.
These new iron strips have so weightened the artefact, that its was in this state probably not used anymore for real hunting, but more kept as a prestige item. Iron strips at blades ends also render the object less confortable to hold for throwing. Additionnaly, these final strips are not fixed inside notch with render them a little more proeminent from the surface and accentuate the rotation braking and holding unconfortable.

States four and five with lost of one iron strip and repair show the difficulty encountered by the gaulish users with this additionnal strip weight which lower the flight to the ground increasing the risk of breaking the artefact not designed to be enought resistant against solid obstacles. This loss of function as a projectile could have been the reason of it deposition as a votive item in the trench where it have been discovered.

Conclusions

Urville Nacqueville throwing stick reinforced with iron strip, is unique in europe for the second iron age period. Its different states reflecting the transition between a really used hunting projectile to a prestige item assuming a more symbolic function, increase even more its archaeological value.
This throwing stick used probably as a bird hunting stick, give evidence of an ancient tradition of making and use of light hunting stick in the north of Europe. This tradition seem to have been perpetuated from the first iron age. This discovery indicate the great continuity of throwing sticks usage in Europe from Palaeolithic, as the evidence of the ivory throwing stick found at Oblazowa(Walde-Nowac, 2000), through the Mesolithic period with wood like artefacts found in north of Russia, until the neolithic with Egolzwil throwing stick found in Switzerland(Ramseyer, 2000). Despite of more modern and efficient weapon for hunting like bow, people continue to use throwing sticks as a reliable weapon for hunting during iron age, and at gaulish period, enhance this primitive projectile by using on it this metal.

This hunting weapon was especially adapted to swamp and coastal area rich of fowl, as showed by the discoveries of Elbchottern boomerang like object along the river Elbe(Evers, 1994) and Velsen boomerang like object(Hess, 1975) found on a coastal site in Netherlands**.** Urville Nacqueville throwing stick was also found in a swamp and humid coast which are favourable environment for specialisation of these weapon in bird hunting, often living in large number in such environment. This is confirmed by numerous birds bones remains found in gaulish layers on the Urville Nacqueville archaeological site.

If we take in account archaeological excavation data from the site of Urville Nacqueville, people were living there around 80 BC in a flourishing town as showed by several gold coins found, which was commercially connected by channel boat crossing to the Dorset region in the British isles. Moreover, because of the animal bones found in archaeological excavation including many birds remains we know that the hunting activity was practised on this site and that during the second iron age hunting was reserved to the gaulish elite.

Bird hunting sticks were already obsolete as main weapons at the second iron age, because these implements weren't any more primary hunting weapons probably since the neolithic period during which they seem to acquire different new symbolic functions. Even so, This discovery show that its usage has been perpetuated until gaulish time with increasing symbolic value. Were throwing stick used at this time like in ancient Egypt for bird hunting by noble egyptian in the Nile delta ? The evidence collected during this study and experimental test converge toward this conclusion. This prestige hunting use could explain at the same time the fine crafting of the functional artefact and care for its repair, followed by its conservation as cultural significant item which lead to the votive depot in the trench where its has been found.

Finally, it seem that the north of Europe kept a living tradition of throwing sticks and boomerang use during the second iron age, but unlike Australian continent where these implements were passed through millennia by Aboriginal people, this tradition has been since forgotten...but now partially recovered !

Appendix 1

Archaeological artefact characteristics

Typology: Symmetric rounded shape, truncated ends, biconvex/rounded rectangular airfoil
Wingspan: 54 cm
Height: 15 cm
Mean thickness: 10 mm
Airfoil: biconvex/rounded rectangular
Surface: 250 cm²
Volume : 210 cm^3
calculated mass without strip: 138 - 175 g
calculated mass with four strip: 172 - 209 g
calculated mass with five strip: 180 - 217 g
Mass with four iron strip after conservation treatment: 135 g
Wideness: 3,8 et 5,3 cm
Height/Wingspan: 0,27
Mass/surface ratio without strip: 0,55 à 0,7 g/cm2
Mass/surface ratio with strip: 0,69 à 0,83 g/cm2
Attacking blade airfoil: biconvex
Following blade airfoil: rounded rectangular
Attacking blade diedral angle/Following blade diedral angle +16/+18
Attacking blade incidence angle/Following blade incidence angle 0 / 0

Replica A caracteristic

Typology: Symetric rounded shape, trucated ends, rounded rectangular airfoil
Wingspan: 52 cm
Height: 15 cm
Mean thickness: 8 mm
Airfoil: rounded rectangular
Surface: 236 cm²
Volume : 158 cm^3
mass without strip: 135 g
mass with four strip: 169 g
WidenessWidthnes 5,3 cm
Height/Wingspan: 0,27
Mass/surface ratio without strip: 0,57 g/cm2
Mass/surface ratio with four strip: 0,72 g/cm2
Attacking blade airfoil: rounded rectangular
Following blade airfoil: rounded rectangular
Attacking blade diedral angle/Following blade diedral angle +16/+18
Attacking blade incidence angle/Following blade incidence angle 0 / 0

Replica B caracteristic

Typology: Symetric rounded shape, trucated ends, Quasi biconvex/rounded rectangular airfoil
Wingspan: 54 cm
Height: 15 cm
Mean thickness: 10 mm
Airfoil: rounded rectangular
Surface: 244 cm²
Volume : 216 cm^3
mass without strip: 165 g
mass with four strip: 199 g
WidenessWidthnes 5,3 cm
Height/Wingspan: 0,27
Mass/surface ratio without strip: 0,68 g/cm2
Mass/surface ratio with four strip: 0,83 g/cm2
Attacking blade airfoil: rounded rectangular
Following blade airfoil: rounded rectangular
Attacking blade diedral angle/Following blade diedral angle +16/+18
Attacking blade incidence angle/Following blade incidence angle 0 / 0

Replica C caracteristic

Typology: Symetric rounded shape, trucated ends, Quasi biconvex/rounded rectangular airfoil
Wingspan: 52 cm
Height: 15 cm
Mean thickness: 10 mm
Airfoil: rounded rectangular
Surface: 248 cm²
Volume : 208 cm^3
mass without strip: 182 g
mass with four strip: 199 g
WidenessWidthnes 5,3 cm
Height/Wingspan: 0,27
Mass/surface ratio without strip: 0,68 g/cm2
Mass/surface ratio with four strip: 0,73 g/cm2
Attacking blade airfoil: rounded rectangular -biconvex
Following blade airfoil: rounded rectangular-biconvex
Attacking blade diedral angle/Following blade diedral angle +16/+18
Attacking blade incidence angle/Following blade incidence angle 0 / 0

Notes:

1 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 degrees.
These wood piece are called wing, 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.

2 Boomerang

My terminology in this article 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. The classification of throwing sticks and boomerangs is a difficult issue that I'm trying to deal with, however it remains a subject being far beyond the point of this article.

3 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.

4 Attacking wing :

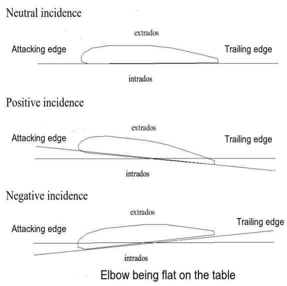
For bipale throwing sticks, the two wings are not aerodynamically equivalent.
The blade which need to travel a greater angle before being at the same position of the other one is called the attacking wing.
The other is called following wing.
The attacking wing travelling through a much more greater angle of air behind the slipstream of the following blade, get intrinsically more of aerodynamic lift, all other parameters being the same.
This is the wing which is handled in common Australian aboriginal style of throwing, curvature facing the target, but could be sometimes not.

5 **Attacking edges:**

Edge of a pale going directly against the relative wind created by direction of throwing stick rotation. On the contrary of the trailing edge being in his slipstream.

6 **Incidence torsion**

The incidence is defined by the angle betwen the table plane and the medium axe passing in the middle of the throwing stick airfoil taken in the blade moving direction.



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