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X-Ray Tomography and Infrared Spectrometry for the Analysis of Throwing Sticks & Boomerangs

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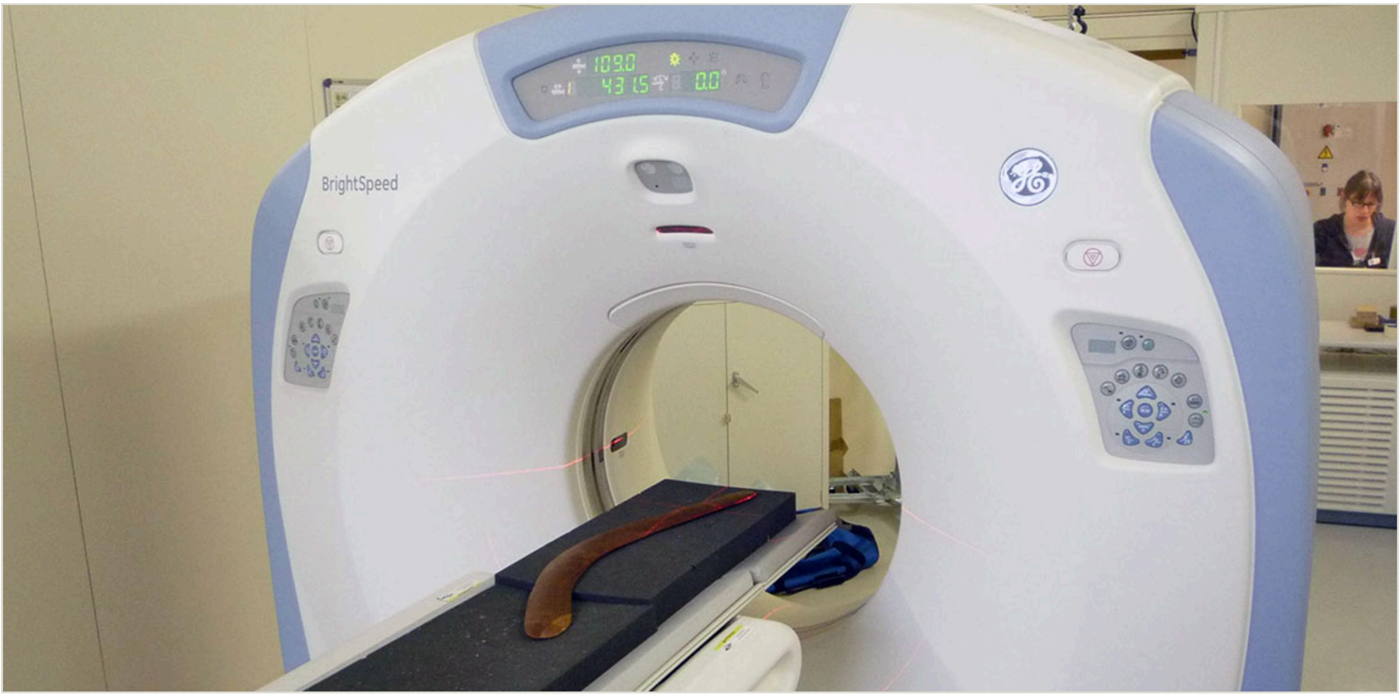

Throwing sticks[1] , including boomerangs[2] as a subclass, are prehistoric objects as old as humanity. They have endured on many continents in different forms, uses, and traditions of manufacture. Numerous different approaches have been used to study them. Many studies of throwing sticks are dominated by morphological determination and focused on Australian objects which have been classified by the origin of their cultural area on this continent (Davidson, 1936; Jones, 1996). However, few authors give importance to a fairly complete record of Australian Aboriginal throwing stick and boomerang features (Turck, 1952; Callahan, 1999).

1 This term is applied to any tool made of one or several wood pieces, or less often from other natural materials, which are set with a angle between 0 to 180 degrees. These wood pieces are called blades, are 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 of very specialized throwing sticks with returning trajectory.

2 The terminology in this article refers to boomerangs as the only objects that have a 180° turning trajectory. Many Aboriginal words (ex bargan, boomari) have generated this artificial name «boomerang» were attached only to light returning type of implements. Later early colonists, confused by the many kinds of sticks assimilated all non-returning heavy throwing sticks under this same appellation. This confusion of terms continues to this day.

> “ Concerning the understanding of throwing stick manufacture and aerodynamics, I was curious to know how the X-Ray tomography technique can bring internal information on their wood section. This would allow me to identify the manufacture technique and to get a better understanding of how the wood have been removed from the raw piece to shape them, and also to achieve an accurate density measurement.

In 2009, confronted to the study of throwing sticks collections from several museums and private collections (including more than three hundreds artefacts) and the need to evaluate their aerodynamic and functions, I developed a throwing stick classification and a methodology to measure their characteristics (Bordes, 2014). This approach is complementary to the gathering of ethnographic or archaeological contextual data to confirm or invalidate hypotheses about theirs functions.

Evaluation of the different features of ethnological throwing sticks, corresponding to their many diverse functions can be critical to assess by comparison, more objectively, new archaeological discoveries, as it has been the case with such type of implement discovered recently in Normandy (Bordes, Lefort and Blondel, 2015). Nevertheless, weight, length, wingspan, thickness or blade twisting measurements give only access to external information, and others information like density and used wood section diameter stay out of reach. Indeed, mean wood density of a throwing stick is difficult to determine as this value can vary with the part of the tree/bush from which the piece of wood had been extracted (branch, trunk or root), which depends of the gathering technique used (wood heart shaping, splitting or trunk/root extraction) (Bordes, 2010). The precise type of manufacture technique, which can show numerous variations depending of the environment, wood resource and specific function of throwing sticks is not elucidated, with only artefact external analysis.

For example, central desert throwing sticks called "kylies" need to be resistant, used both as a melee weapon, multipurpose tool and high impact medium range projectile and need consequently to be made from dense acacia wood with only a slight curvature to keep resistance and weight for maximum range. Splitting technique is chosen for material and crafting energy economy along with cultural reasons. On another hand, Southeast Australian boomerangs can be crafted in medium density wood, using mangrove or casuarina trees, because these projectiles do not need to be resistant against ground impacts and enemy shields, only travelling through air with high trajectory, useful in bird hunting and gaming (Bordes, 2014). They can be made more simply by cutting a branch or even extracting inner bark from a trunk (Bordes, 2010). Regarding the first example, specific manufacture technique like splitting technique used by central desert Australian indigenous people are quite well known during the 19th-20th century (Jones, 1996), but other throwing stick crafting techniques from other cultural areas (e.g., Africa, Asia) are little known. Splitting technique is a particular type of manufacture leading to a pair of throwing sticks that have important technical and cultural implication, truly linking these pairs of throwing sticks as twin objects which were not only used together for hunting or war, but clapped in pairs to rhythm dances, and were even exchanged together without being ever separated (Jones, 1996; Bordes, 2010).

Concerning the understanding of throwing stick manufacture and aerodynamics, I was curious to know how the X-Ray tomography technique can bring internal information on their wood section. This would allow me to identify the manufacture technique and to get a better understanding of how the wood have been removed from the raw piece to shape them, and also to achieve an accurate density measurement. If the type of manufacture and part of tree used can be guessed in some case with visual inspection on fresh made experimental throwing sticks, I found that very often, wood surfaces of aged ethnological museum objects are difficult to read because of the superficial coating (e.g., patina, paint, or resin), and that similar difficulties can be encountered on archaeological objects due to wood surface alteration.

Another aim was to be able to avoid some of the physical measurements by obtaining 3D models of the objects. This can be critical for the study of fragile archaeological artefacts for which it is better to minimise contact. Indeed, even in good condition of preservation, wooden artefacts dating back thousands of years can be degraded, deformed or broken during storage and transportation, which is what unfortunately happened in the months following the study to the Gaulish throwing stick (Bordes, Lefort and Blondel, 2015) with definitive loss of some information. Some neolithic throwing sticks discovered in France have also undergone such decay and are now also in poor states of preservation, preventing any further measurements of their original characteristics to propose new interpretation of their prehistoric functions. Having made 3D models from these archaeological artefacts would have probably saved much information for future study. Additionally, external physical measurements complemented by internal X-Ray tomography allows more complete data, resulting in better replicas for experimentation and flight demonstrations in live museums. Other techniques, such as infrared spectrometry, can enhance complementary surface chemical information, especially in the analysis of layers of pigment, resin, or fatty material which are known to be used traditionally in the manufacture and decoration of these implements.

In 2010, taking the opportunity to gain access to the Xylologic X-Ray tomography platform of Nancy, as well as an infrared spectrometer in my working lab, I set out to check the potential performance of these objects, and what information could be drawn from tomography images. Primarily this would be on experimental objects made of different known woods and manufacture methods, then to try to get the same kind of information from aged ethnological artefacts from a private collection.

My passion for boomerangs started in 1996 and converged with my taste for archaeology to create a strong interest in their prehistoric technology, including more widely their older counterparts, the throwing sticks. Since 2006, I have been able to produce about 200 experimental models of different types, with straight or returning flight. I use my throwing experience to find the optimum method of throwing each style, and observe different trajectories in varying throwing parameters. 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 (Bordes, 2014):

Firstly, experimental models for aerodynamic exploration replicating one or more characteristics of ethnological throwing sticks which are intended to answer aerodynamic questions concerning the type of wood used, choice of airfoil section or the selected blade tuning. The objects were constructed to answer these questions are shaped by a roughing metal tool (machete or axe), to fasten the coarse wood removal.

Secondly, models used were for exploring 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 sticks splitting technique with wood or stone wedges (Bordes, 2010).
Because of the time investment, around only eight percent of the total number of throwing sticks that I produced had been exclusively worked with stone tools from extraction of the 'green' wooden piece to the final polishing. On others, I focused only on the use of stone tools for some crafting steps, but ninety percent of my experimental throwing sticks had their final shaping and polishing with stone tools. These experiments are rich in manufacturing information to assess the wood, gestures with different tools, the manufacturing time and the marks left by tools on wood artefacts.

Thirdly, some of the models are close replicas of archaeological or ethnological models. 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 replicas bracket the original object and can give an good idea of its use. Thus several replicas improve the estimation of a given archaeological throwing stick and comparing relative differences in their characteristics allows to progress in the understanding of the properties and functions of the original. Such replicas are used to mediate research on throwing sticks, and to present models manipulated without using fragile and precious objects.

Information about known Samples

Nine throwing sticks from my personal collection were scanned. These sticks are from experimentation described above. Unless indicated, stone tools have been used for final shaping and finishing.

They were selected to represent different types of wood and manufacture such as the wood heart shaping technique, or splitting into "twin throwing sticks" (Bordes, 2010). Several objects have been chosen as very thin boomerangs[2], in medium-density woods, as well as thicker objects made of denser wood. The interest of working with well-known experimental samples is mainly to know the type of manufacture, starting diameter and the average density of the wood, and will allow to check the accuracy of these data determined from X-Ray tomography images.

Here is a list of objects examined from my collection and manufacturing information about them. In Appendix 1.1-2, details of their aerodynamic characteristics can be found, resulting from the manual measurements already carried out on these objects. The method of measurements and classification of throwing sticks used for the objects listed in Appendix 1.1-2 had been treated in a previous work (Bordes, 2014).

Figure 1. Boomerang in Dogwood (*Cornus mas*) (bo25). It is a boomerang shaped with metal tools from a half of dogwood branch of 7-8 cm in diameter, after splitting it in two halves.
Figure 2. Boomerang in Mulga wood (*Acacia aneura*) (bo11). Boomerang cut with a machete irregularly from the heart of a branch of 7-8 cm diameter.
Figure 3. Boomerang in rock She-oak wood (*Allocasuarina huegeliana*) (bo15) Boomerang cut with a machete irregularly from the heart of a branch of small diameter (5-6 cm).
Figure 4. Throwing stick in jujube wood (*Ziziphus zizyphus*) (bc38). Throwing stick cut with a machete from the heart a dry branch of 9-10 cm in diameter, preferably cutting on a half diameter better spared by insects.
Figure 5. Throwing stick in boxwood (*Buxus sempervirens*) (bc47). Throwing stick of the "lil - lil" type, typical of South East Australia which is made by metal tool on the

heart of a piece of boxwood junction trunk root, the wide head at the extremity of following pale corresponding to the root part, and the attacking blade corresponding to the trunk.

Figure 6. Twin throwing sticks in hornbeam wood (*Carpinus betulus*) (bg32).
Throwing stick carved exclusively with stone tools, including the cutting of the branch with a stone axe, on a half piece of a splitted branch of hornbeam wood (diameter 9 cm) with wooden wedges. This half was reversed in relation to the next so as to keep the internal face of the wood as intrados[3] .

Figure 7. Twin throwing sticks in hornbeam wood (*Carpinus betulus*) (bg33).
Second throwing stick carved exclusively with stone tools, including the cutting of the branch with a stone axe, shaped on a half piece of a hornbeam branch (diameter 9 cm) splitted with wooden wedges.

Figure 8. Replica of a perforated Tun throwing stick, hornbeam wood (*Carpinus betulus*) (bl43).
First replica of an African throwing stick from Chad cut with a machete in one half branch of hornbeam tree, split with a metal axe. Their profile is rectangular and small in front of the original diameter of 7-9 cm. Internal face of the wood corresponding to the intrados.

Figure 9. Replica of a Tun throwing stick, hornbeam wood (*Carpinus betulus*) (bl44).
Second replica African stick from Chad cut with a machete in the other half branch of hornbeam tree split with a metal axe. The section is rectangular and small in front of the original diameter of the wood piece which is 7-9 cm. Internal side of the wood corresponding to the extrados.

Aboriginal Ethnological Samples (private collection Stephane Jacob - Arts Australia)

The detailed characteristics of these three objects are given also in Appendix 1.1-2

Figure 10. Left-handed boomerang, nineteenth century (1109).

Figure 11. Boomerang 1109 details. Black layer & white paint strokes.
Boomerang collected at the beginning of the 19th century from South Australia. My measurements of blade twists on this object shows that it is a left-handed boomerang in perfect working order. It is characterized by an incredible fineness (5 mm thick from one blade to the other) that demonstrates a perfect mastery of shaping in the raw wood. It is covered with an unidentified black layer and traces of white paint.

Figure 12. Central desert grooved throwing Stick of the Early 20th Century (1017).
This asymmetrical, grooved throwing stick with broadened short blade is typical of the Australian central desert region, collected at the beginning of the 20th century. According to ethnological information on the manufacture of these throwing sticks, they were frequently built on diameter halves after splitting to form pairs (Jones, 1996).

Figure 13. Archaic throwing stick (1123).
This "archaic" type of throwing stick with a low curvature and elliptical airfoil section comes from Western Australia, collected at the beginning of the 20th century. It is covered with engraving on both sides: concentric circles, corrugated lines on extrados. A snake on the underside.

Method Used

The apparatus used is the X-Ray tomographic scanner of the Xylosciences platform of INRA Nancy (Freyburger, et al., 2009). Each sample was scanned in its entirely, placed on their intrados, parallel to their wingspan, always in the same direction, i.e., from the extremity of the attacking blade[4] to the following blade. This typically produced 350-650 images depending on the wingspan because of a cut every 1.25 mm. Five sections located precisely, perpendicular to the section of the object, and representative, were also performed by repositioning the object each time, to serve as a referent points. Two of these sections are located on each blade, 3 cm away from each extremity, two other sections located in the middle of each of the blades and the last section is taken at the elbow. Instrument used for Infrared Spectroscopy was a Bruker 22 spectrometer equipped with an ATR (Attenuated Total Reflection) diamond window on which were directly positioned the throwing sticks surface to be analysed (See Figure 14).

Exploiting X-Ray Images Information

(See collected information Appendix 2, and tomographic images Appendix 3.1-14)

Shaping

The visualisation of relative density of wood rings of growth on tomographic images allows circles to be drawn to reconstruct the initial diameter of the worked wood piece, and relate it to the width of the actual object. Marked circles are intending to make an evaluation of the maximum diameter of initial wood piece used and to try to position the section of the carved throwing stick in it. The fact that the rings of a piece of wood often move away from the perfect circle can be a source of inaccuracy. They can be off-centre after an asymmetric growth on a face of the tree.
The position of the section of the objects in relation to the hypothetical centre of the initial piece of wood makes it possible to know the longitudinal position of the curvature of the throwing stick within the natural shape of the branch. Thus, we will be able to observe if the craftsperson proceeded by removal on the outside of the blades, which is frequently used to accentuate the curvature, or conversely inscribed the shape on outside edge of the piece of curved wood to minimize it.

Estimation of the minimum diameter

From the drawing of concentric circles on the images of tomographic sections we can estimate a minimum diameter for the shaped piece of wood. This may be, for example a small diameter when the object has been cut from the heart, or a larger diameter with the object cut on an half, or again an even larger diameter whose object could be cut by extraction or on a previously billed board.

Estimation of the density of wood

It is very difficult to estimate the absolute density directly with the intensity measured on the images because the grey levels of the scanner images do not correspond directly to the density. They are in Hounsfield units, on a scale ranging from -1000 for air, 0 for water, and +1000 for bone. Even if correlation curves exist, we prefer to divide the known mass of these objects by the calculated volume from the 500 section images, using the acquisition software of the machine, which is more accurate.

Calculated density value is given for each object in the Appendix 2.

The Contribution for the Aerodynamic Study

Airfoil section survey

The set of sections obtained in X-Ray tomography not only constitutes crucial internal information but also more simply external contour information that can serve as an ultra-precise aerodynamic airfoil section survey. Indeed, it is a very long process and not always easy to raise the airfoil section of these objects, especially those in museum collections, because contact with artefacts may be in some case restricted for preservation issues. Thanks to the images, the classification of the type of airfoil section of a throwing stick is simplified: round, elliptical, biconvex, almost plano-convex, plano-convex. This also applies to observation of irregularities. This is particularly interesting on some objects that have a different airfoil section on each of their blades and at the elbow, which is sometimes encountered on some Australian indigenous throwing sticks and boomerangs (Bordes, 2014).

Survey of angles of incidence

By drawing an axis through the centre of each airfoil section along one of these objects, we can also observe very precisely the angle of incidence[5] from one end to the other of the object, which expresses the transverse twists of the blades between them and with respect to the elbow. This visualization of the torsions will complete and confirm the manual measurement. These twists are crucial for the flight of these projectiles and in particular for the return of boomerangs (Bordes, 2011).

Results

The detailed results for each of the objects are given on the attached form in appendix (See Appendix 3.1-14) which is based on the series of five sections located and perpendicular to the profile of the objects. We will nonetheless focus on comparing the known information (type and diameter of the wood, crafting technique) on the objects of my personal collection (See Appendix 1) with the information that it is possible to read on the tomographic sections (See Appendix 2). For two pairs of objects (bg32 / bg33) and (bl43 / bl44) a matching test of the two parts compared to the original diameter was attempted (See Appendix 3.8, 3.11).

Known Objects from my Personal Collection

Boomerang dogwood (bo25) (See Appendix 3.1)

The imaged sections on the boomerang in dogwood show that the section of this object is placed on the upper half of the diameter of the wood section with respect to the plane passing through the heart of the piece of wood. It is observed that the intrados surface remains at a relatively constant distance from this plane which confirms a manufacture on a half diameter after splitting. The measured density indicates a piece of wood denser than the average given for this wood. Finally, it is easy to read a marked positive incidence twist at the end of the attacking blade (right blade on figure). The evaluation of the diameter is smaller than the actual known diameter used for the shaping of this object which confirms that this evaluation is a minimum diameter, external wood having been removed during the operation.

Boomerang Mulga (bo11) (See Appendix 3.2), Boomerang in She-oak (bo15) (See Appendix 3.3)

Mulga and casuarina are woods typically used for aboriginal throwing sticks and boomerangs. The images on these boomerangs confirm my construction on the heart of curved piece of wood whose assessed diameter matches the diameter actually used. The shift of the section of the casuarina boomerang towards the inside of the curve is clearly observed, and due to the removal of an opposite part degraded by insects. The boomerang in She-oak has suffered an abduction outside the curvature on the attacking blade, outside the elbow and inside the following blade. The calculated density is in good agreement with the average recorded for this wood, particularly dense compared to European species. With tomographic sections, we can observe accurately the adjustment of the attacking blade (right blade on figures) in positive incidence on both of these boomerangs, while the following blade (left blade on figures) remains fairly neutral. This type of tuning is frequently used on indigenous Australian boomerang (Bordes, 2011).

Jujube throwing stick (bc38) (See Appendix 3.4)

Another object, a jujube throwing stick appears to be carved from the heart of a branch about 7 cm in diameter, shifted to a half section. In fact, the diameter of the branch was about 10 cm higher. This throwing stick required half diameter removal to get rid of some degraded outer wood attacked by insects. One can also observe a manufacture of the attacking blade along the interior of the curvature of the piece of wood while the following blade has been carved rather outside of it. The density is in good agreement with the theoretical value for this species.

Boxwood throwing stick (bc47) (See Appendix 3.5)

The images confirm that this throwing stick is from a heart-centered construction and the evaluated diameter is close to that used. Good agreement of the calculated density with the theoretical value for this wood. Visualization of a positive incidence torsion in the attacking blade (right blade on figure) intended to make the throwing stick hover longer.

Twin Throwing stick in hornbeam (bg32) & (bg33) (See Appendix 3.6-3.8)

The images of these throwing sticks show that their shaping was centred on halves of diameters. They were wedged inside the curvature of the piece of wood. The evaluation of the diameter of the piece of wood was close to that actually used. The density calculated for each of these pieces reflects the value given for this specie and very close to each other since it is actually the same piece cut in half.
If we recalibrate the two pieces with the help of dark growth rings we can see that one of the pieces has been shaped by inverting it with respect to the other, this in order to minimize the removal of material between the two pieces and use a minimum diameter (Bordes, 2010). Nevertheless, it is observed that the removal took place to a certain extent to resize the section convexity of the objects and was more important in the centre for one of the ends of the piece of wood.

Replica of perforated Tun throwing sticks, hornbeam wood (bl43) & (bl44) (See Appendix 3.9-3.11)

We can make the same remarks for these two throwing sticks as for the previous ones as regards their shaping in the starting wood piece. The evaluation of the diameter is less than that used because of outer wood removal. The density is significantly different from the two previous objects, even if it is the same hornbeam wood. This shows the density variability according to the piece of wood chosen for manufacturing. Contrary to bg32 / bg33, we see a lower removal of material on the heart here, because of the choice of a rectangular section having flat extrados and intrados surfaces that did not require substantial retouch of section of both side after splitting. It is also clearly observed that the incidence twist on attacking blade (right blade on figures) is more pronounced for the bl44 throwing stick than for bl43.

Aboriginal Objects whose Manufacture is to be Determined

Left-handed Boomerang from 19th Century (1109) (See Appendix 3.12)

The thinness of this object (5 mm) made it more difficult to read images and wood rings in the sections obtained near the extremities. Despite this, it can be deduced that the object was extracted from a branch of large diameter, at least 10 cm. The density calculation suggests that it is not acacia wood but probably a lighter wood, perhaps casuarina, which is relatively commonly used in South Australia. The positive incidence of the attacking blade (left blade on the figure) is very marked and clearly shows that it is a left-handed boomerang in perfect flight state, if one also considers the orientation of its plano-convex airfoil section.

We have some observations regarding the adhering black layer and the traces of white paints for which a complementary analysis was made in infrared absorption spectrometry. In comparison with the spectrum made on the surface of the uncovered wood, the surface covered by the blackish substance gives rise to new spectral bands which correspond to the presence of resin. This one has a spectral footprint fairly close to what can be obtained on a natural resin (Valis, 1991) xanthorrhea (*Xanthorrhoea sp.*), which was one of the substances used by Aborigines along with the well-known spinifex (Trioda sp.) (Derrick, 1989). Further analysis would be needed to confirm precisely the identification of the natural resin used. The surfaces covered with traces of white pigment gave additional spectral bands which correspond to the presence of clay (Vacullikova, et al., 2011). It is likely that kaolinite or another, similar white clay, which are commonly used prehistoric pigments, was used to decorate this boomerang (See Figure 15).

Grooved Center throwing Stick of the Early 20th Century (1017) (See Appendix 3.13)

X-Ray tomographic images have brought several interesting pieces of information for this type of throwing stick. Since the profile of the object is steadily at a fixed distance from the centre of the piece of wood, included in one half of the diameter, it can be deduced that the object was obtained from a trunk split in two parts. This result was expected for this type of throwing stick called "kylie" and built in the central region of Australia typically by this splitting technique for making "twin" throwing sticks (Jones, 1996; Bordes, 2010). The minimum diameter reconstructed is around 9 cm which seems likely for this type of object. The density gives a higher value than the unit which indicates that it is probably acacia, probably mulga (*Acacia aneura*). In the images obtained, the accentuation of the curvature given to the object during manufacture is also very clearly distinguished. Indeed, the wood was removed preferentially outside the curvature at each extremity and inside of it at the elbow.

Archaic throwing stick (1123) (See Appendix 3.14)

The images show that this object, unlike the previous one, was built more simply, rather on the heart of the wood by removal. It has been shaped following the outside of the curvature of the piece of wood to minimize it or look for the best wood. This observation is consistent with what is ethnologically considered for this type of more massive and rather archaic throwing stick. The reconstituted minimum diameter is 9 cm and the density found is very high (See Appendix 2), probably indicates a particularly dense species of acacia or a choice of a very dense part of the tree.

Conclusions

X-Ray tomography imaging is complementary to the manual survey carried out on each object and the examination and surface analysis of layers of resin, fat or pigment that may have been added on this type of object. This technique brings out the internal information that shows how these objects were shaped to adapt to natural wood pieces, completing the aerodynamic information deduced from measuring mass, surface, profile thickness, and twists made by external analysis techniques. In this way, one can better understand the construction of the object, its trajectory, its use and its cultural value.
The scanning of paired objects shows that the tomographic imaging technique can be used to associate two throwing sticks or boomerangs that have been constructed in this way, which may be useful in case of doubt about certain pairs of objects which have been unfortunately separated in a larger collection of a museum, so as to potentially reform such pairs built from the same piece of wood.

However, an improvement in the reading of wood rings of thin objects, such as boomerangs for example, will require a higher resolution per cut.

The diameters evaluated from the images compared to the real diameters used for the series of reference objects confirm that the value found is always less than, or equal, to the real value, since a peripheral removal may have taken place (debarking, seeking for harder wood in the centre of the piece of wood)

In addition, X-Ray tomography provides a very accurate image of the object in 3D constituting a valuable virtual statement, taking into account the difficulty of conservation of wooden objects in the long term. This allows virtual manipulation, which helps to easily visualize twisting settings and profiles. This 3D survey can also be used to make copies as a resin object, if necessary.
Finally, the internal imaging of these wooden objects complements other surface analysis information that can be obtained for example with Infrared spectrometry (See Figures 15 and 16).

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3 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 For two bladed throwing sticks, the two blades are not aerodynamically equivalent. The blade which needs 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 is 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.

5 The incidence is defined by the angle between the table plane and the medium axe passing in the middle of the throwing stick airfoil section taken in the blade moving direction (See Figure 17).

Attachment(s)

Appendix 1 (2.9 MB)
Appendix 2 (1.99 MB)
Appendix 3 (11.42 MB)

Keywords throwing stick
weapon

Country Australia

Bibliography

Bordes, L., 2010. Splitting twin throwing sticks. *Bulletin of Primitive Technology*, 40.

Bordes, L., 2011. A study of traditional throwing sticks and boomerang tuning. *Bulletin of Primitive Technology*, 42.

Bordes, L., 2014. *Les Bâtons de jet préhistoriques et leurs représentations: Développement d'outils et de méthodes pour la mesure de leurs caractéristiques et l'évaluation de leurs fonctions.* MA. CEPAM/Université Sophia Antipolis. Available at: < http://revedeboomerang.free.fr/Master%20thesis%20-%20Throwing%20sticks%... > (English translation) [24 February 2018].

Bordes, L., Lefort, A. and Blondel, F., 2015. A Gaulish Throwing Stick Discovery from Normandy: Study and Throwing Experimentations. *EXARC Journal*, [online] 2015(3). Available at: < https://exarc.net/issue-2015-3/ea/gaulish-throwing-stick-discovery-norm... > [30 August 2015].

Callahan, E., 1999. How to make a throwing stick. In: D. Wescott, ed. *Primitive Technology* I: A Book of Earth Skills. Salt Lake City, UT: Gibbs Smith. pp.214-217.

Davidson, D. S., 1936. Australian throwing-sticks, throwing-clubs and boomerangs. *American Anthropologist*, 38(1), pp.76-100.

Derrick, M., 1989. Fourier transform infrared spectral analysis of natural resins used in furniture finishes. *Journal of the American Institute for Conservation*, 28(1) , pp.43-56.

Freyburger, C., Longuetaud, F., Mothe, F., Constant, T. and Leban, J-M., 2009. Measuring wood density by means of X-Rays computer tomography. *Annals of forest science*, 66(8), 804.

Jones, P., 1996. *Boomerang: Behind an Australian Icon*. Kent Town, S Aust.: Wakefield Press.

Turck, A., 1952. *Theorie, fabrication et lancement des boomerangs*. Paris: Editions Chiron.

Vacullikova, L., Plevova, E., Vallova, S. and Koutnik, I., 2011. *Characterization and differentiation of kaolinites from selected Czech deposits using infrared spectroscopy and differential thermal analysis. Acta Geodynamica et Geomaterialia*, 8(1), pp.59–67.

Valis, S., 1991. Investigation in the distortion of triodia and xanthorrhoea resins on Australian Aboriginal artefacts in museum collections. *AICCM Bulletin*, 17 (1-2), pp.61-74

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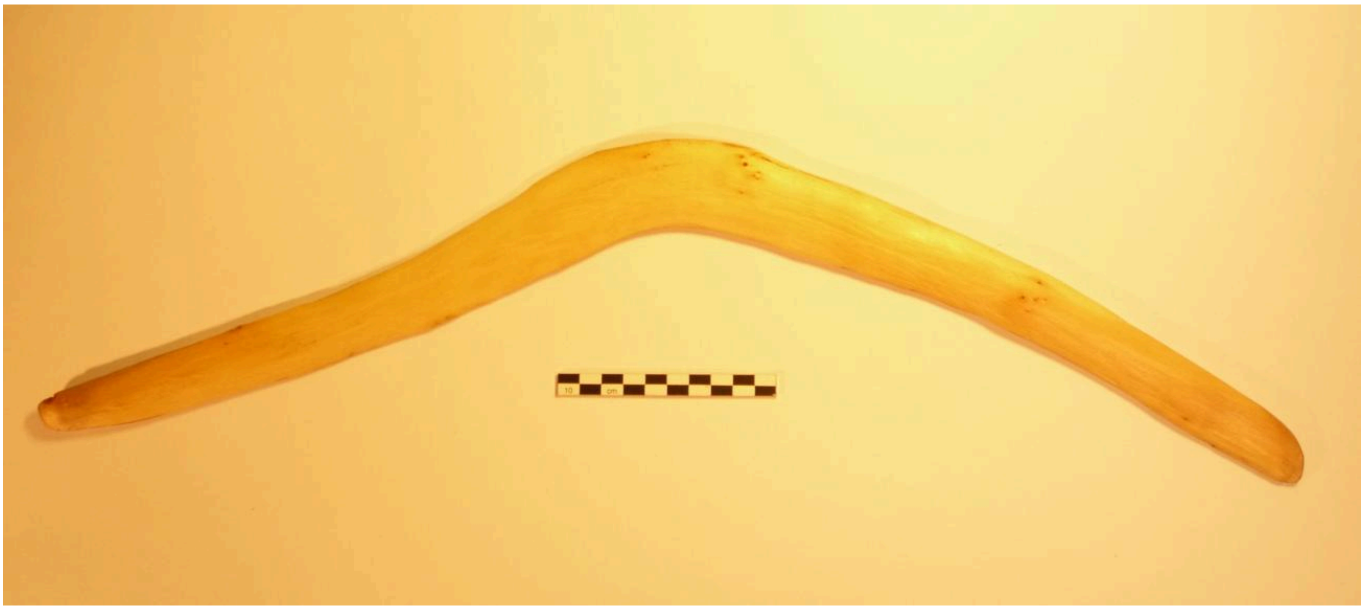

FIG 1. BOOMERANG IN DOGWOOD (CORNUS MAS) (BO25)

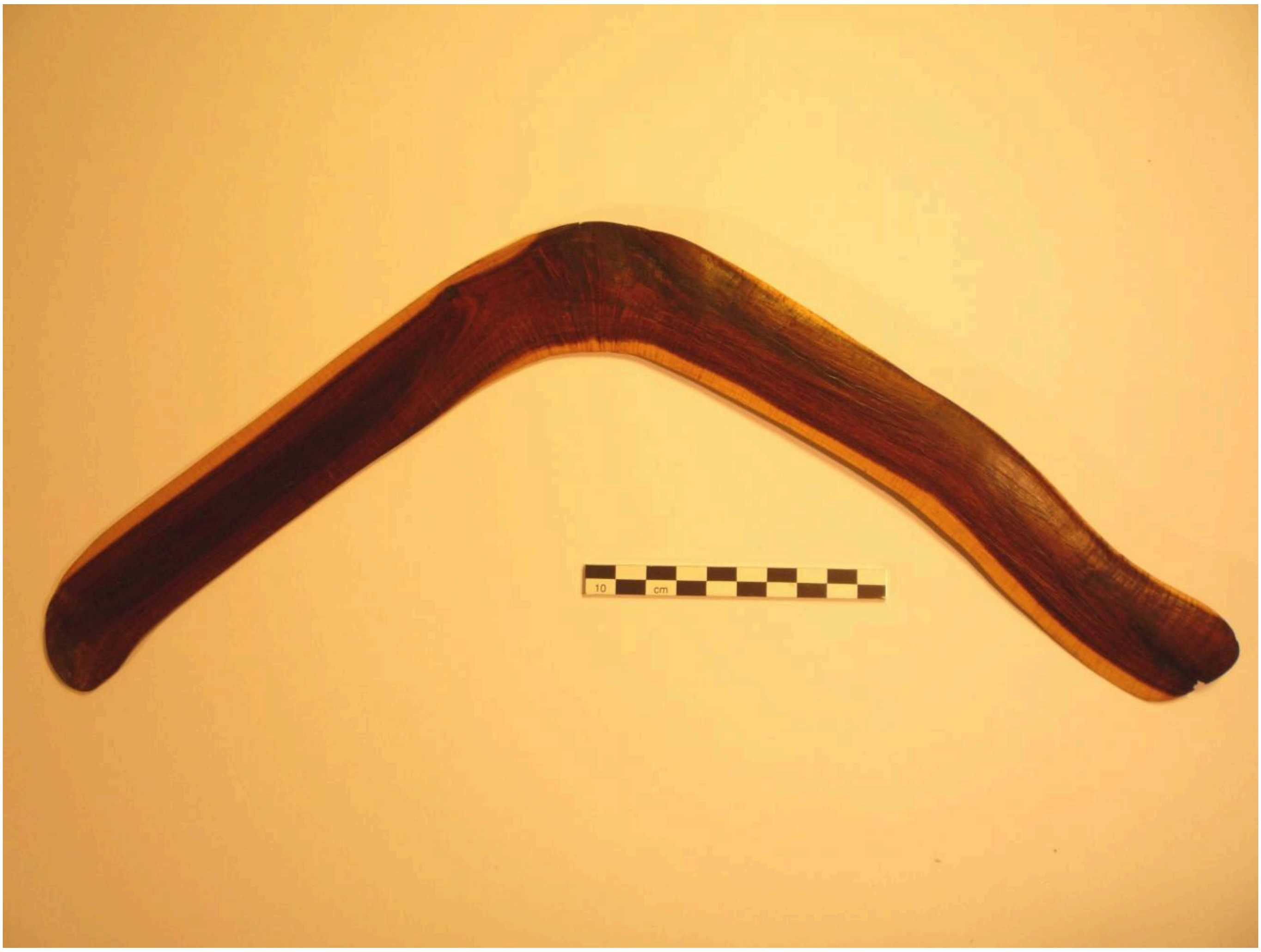

FIG 2. BOOMERANG IN MULGA WOOD (ACACIA ANEURA) (BO11)

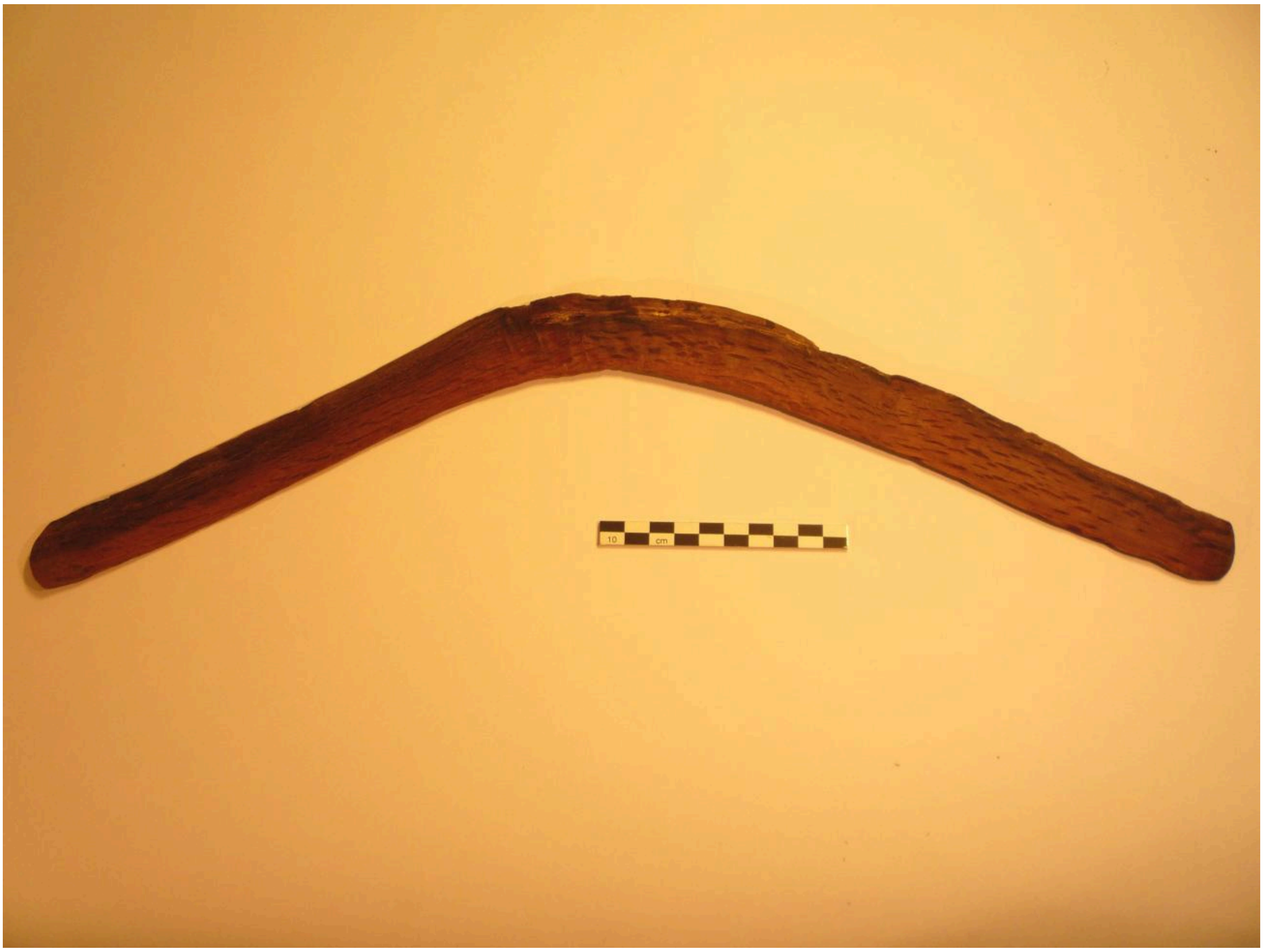

FIG 3. BOOMERANG IN ROCK SHE-OAK WOOD (ALLOCASUARINA HUEGELIANA) (BO15)

FIG 4. THROWING STICK IN JUJUBE WOOD (ZIZIPHUS ZIZYPHUS) (BC38)

FIG 5. THROWING STICK IN BOXWOOD (BUXUS SEMPERVIRENS) (BC47)

FIG 6. TWIN THROWING STICKS IN HORNBEAM WOOD (CARPINUS BETULUS) (BG32)

FIG 7. TWIN THROWING STICKS IN HORNBEAM WOOD (CARPINUS BETULUS) (BG33)

FIG 8. REPLICA OF A PERFORATED TUN THROWING STICK, HORNBEAM WOOD (CARPINUS BETULUS) (BL43)

FIG 9. REPLICA OF A TUN THROWING STICK, HORNBEAM WOOD (CARPINUS BETULUS) (BL44)

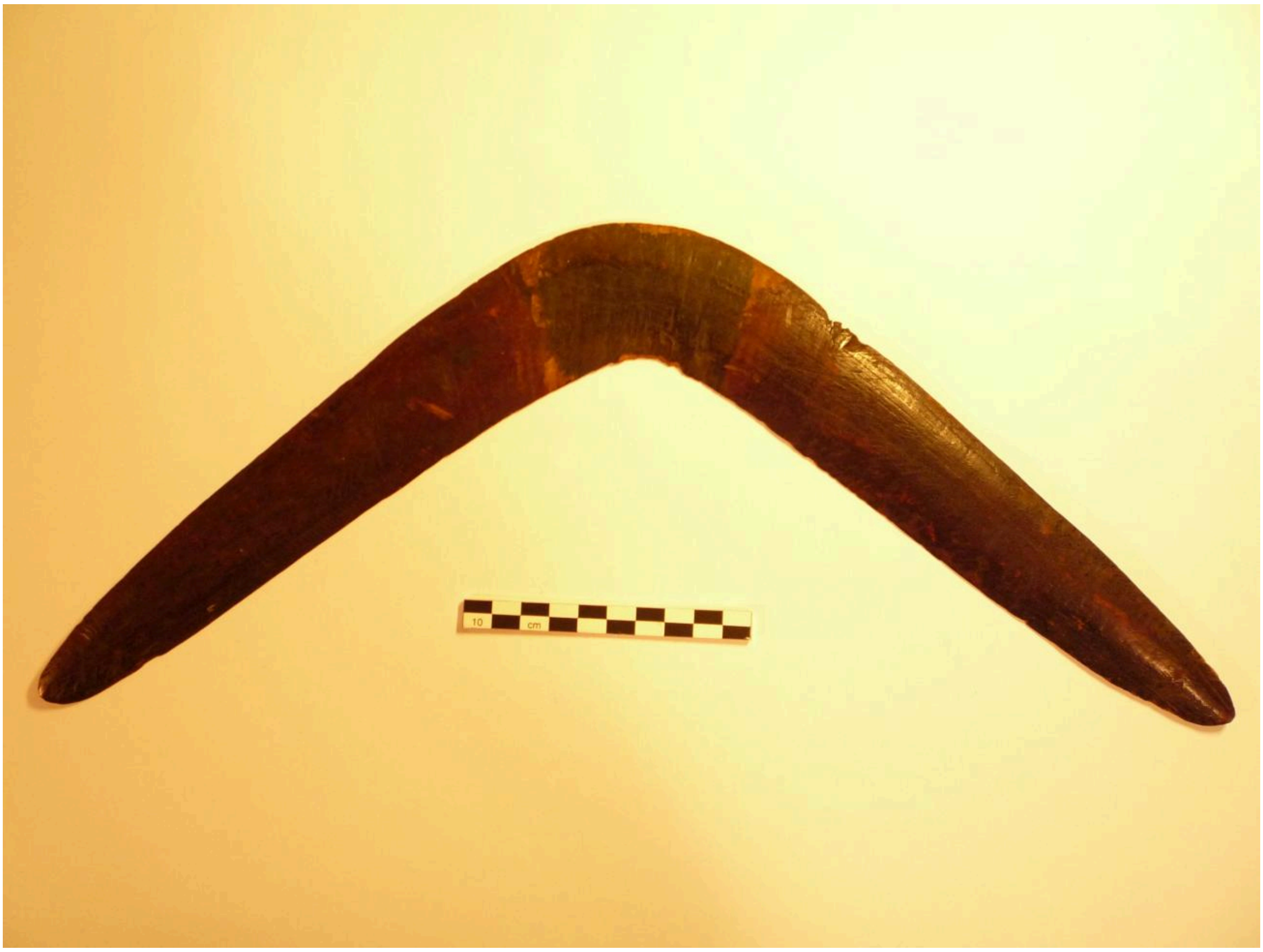

FIG 10. LEFT-HANDED BOOMERANG, NINETEENTH CENTURY (1109)

FIG 11. BOOMERANG 1109 DETAILS. BLACK LAYER & WHITE PAINT STROKES

FIG 12. CENTRAL DESERT GROOVED THROWING STICK OF THE EARLY 20TH CENTURY (1017)

FIG 13. ARCHAIC THROWING STICK (1123)

FIG 14. OBJECT 1017 ON THE TOMOGRAPHY MACHINE TRAY BEFORE THE START OF THE SCAN.

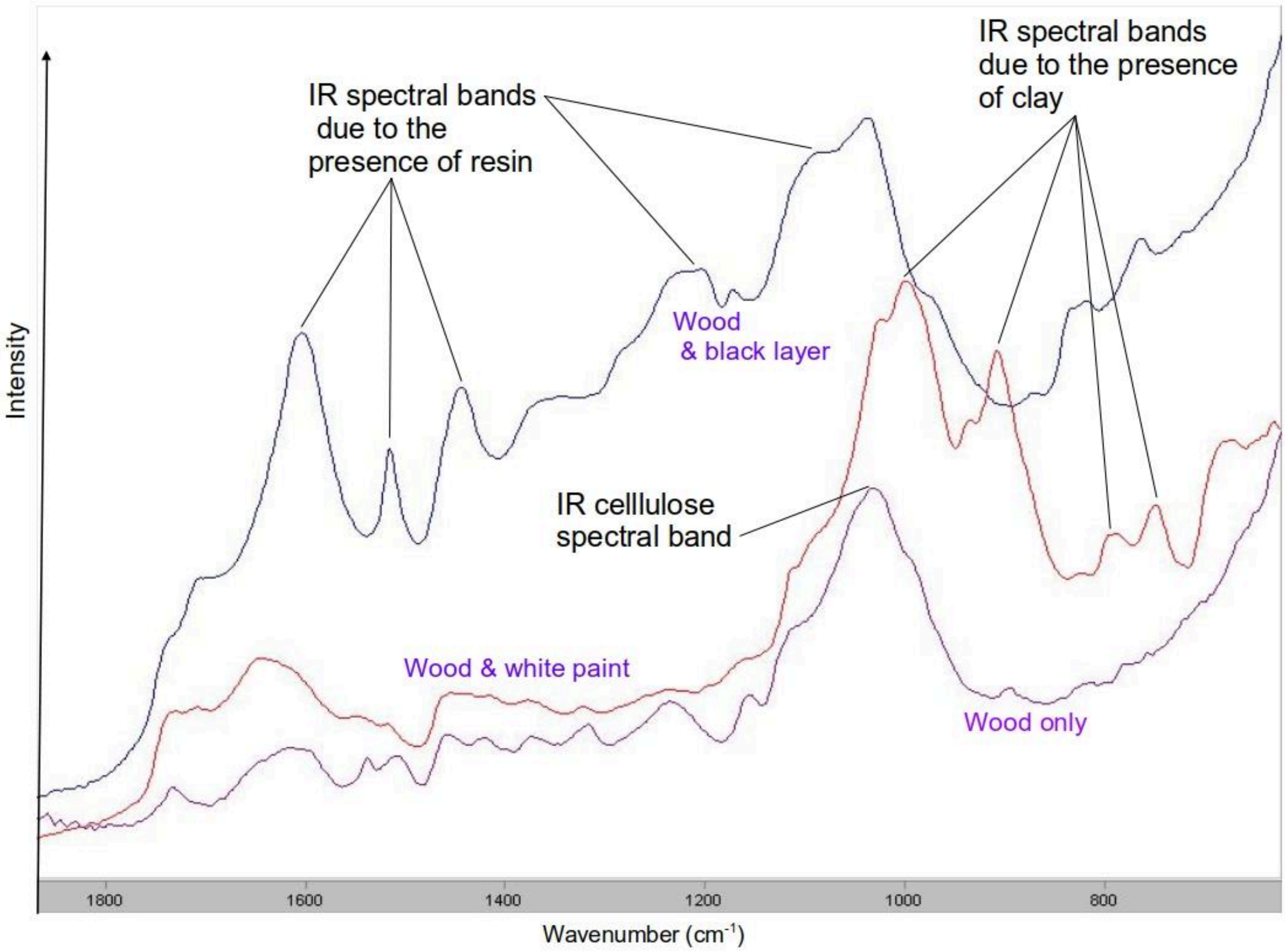

FIG 15. INFRARED ABSORPTION SPECTRA OF THE BOOMERANG SURFACE. FROM BOTTOM TO TOP: ANALYSIS ON UNCOVERED WOOD AREA SHOWING ONLY THE WOOD CELLULOSE SIGNAL, ON WHITE PAINT AREA, AND ON BLACKISH LAYER AREA.

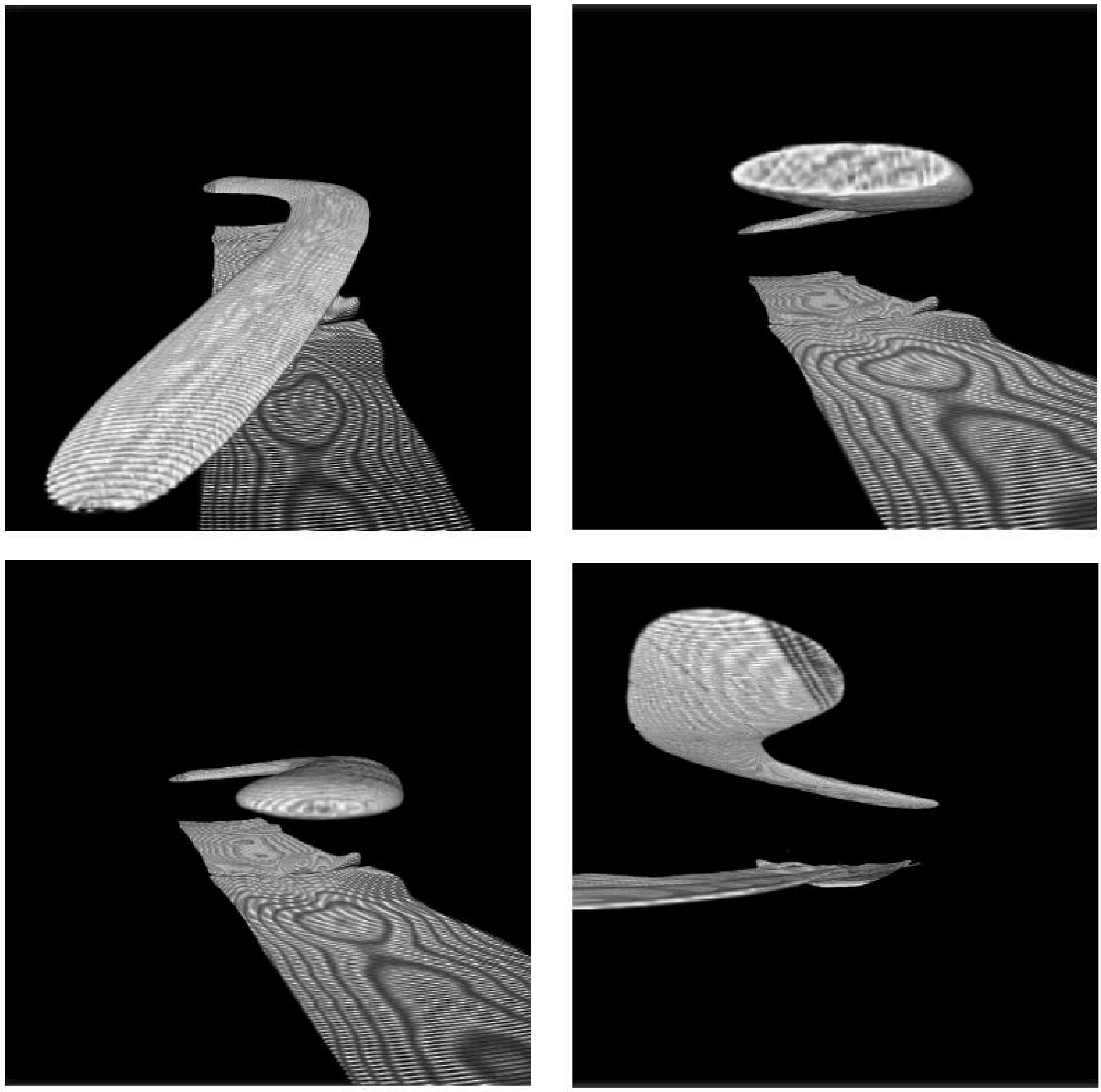

FIG 16. EXAMPLE OF A 3D RECONSTRUCTION ON OBJECT 1107 FROM TOMOGRAPHIC SECTIONS (IMAGEJ SOFTWARE, 3D VIEWER).

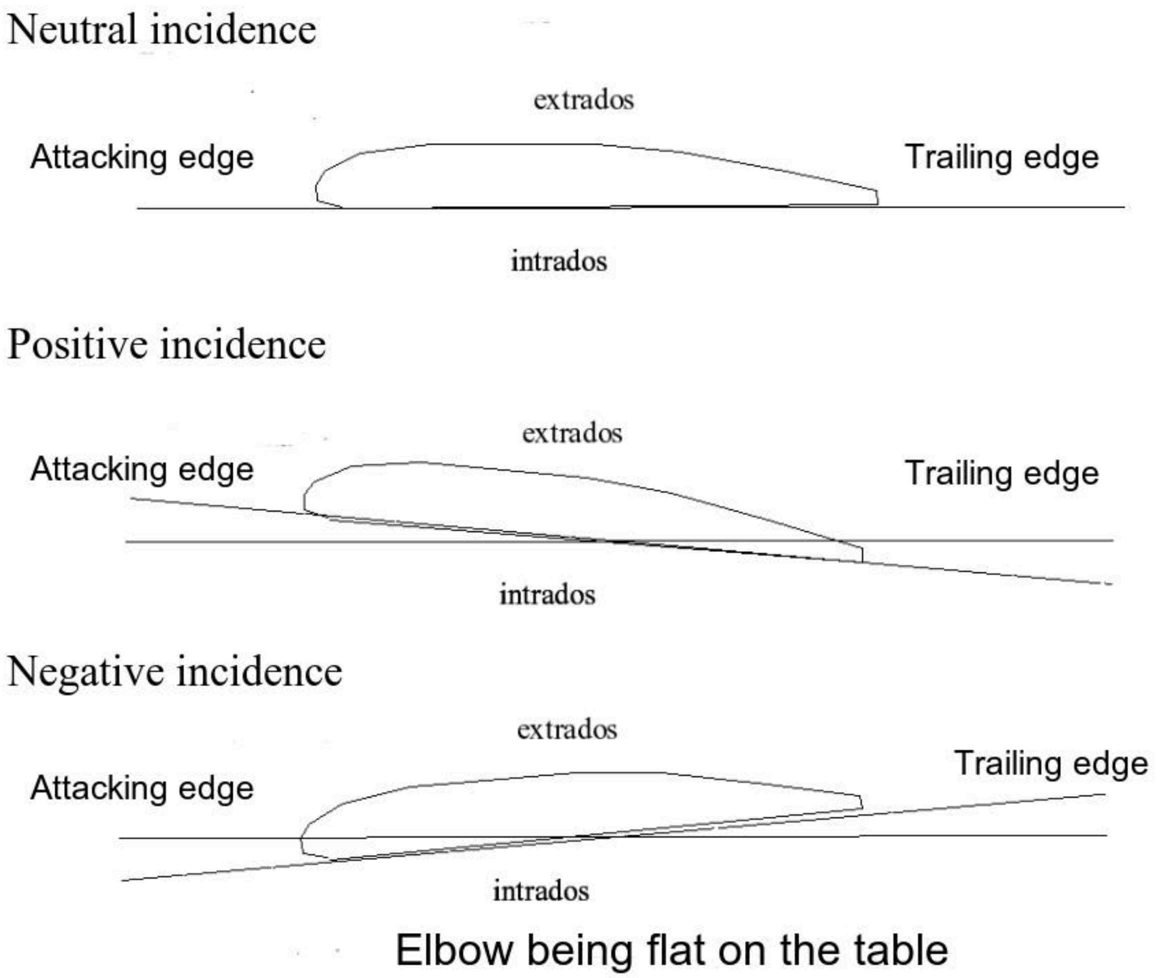

FIG 17. DRAWING SHOWING THREE TYPE OF POSSIBLE INCIDENCE TUNING: NEUTRAL, POSITIVE AND NEGATIVE.