Reviewed Article:

The Modern Reproduction of a Mongol Era Bow Based on Historical Facts and Ancient Technology Research

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This bow was a concept, commissioned from Ulrich Velthuysen, a Swedish archer. This horn bow could be classified as a post-conquest design from early 14th century AD Mongolia. In this article, I will describe, step-by-step, the gathering and processing of materials, and the construction of this design of horn bow. Unfortunately, there are only a few pictorial representations of what bows may have looked like during 14th century AD Mongolia;

although, there are many other variations of bows during this time period with similar characteristics. Bow styles varied from bowyer to bowyer, so while bowyers duplicated basic fundamentals of construction, there were many different methods of construction, and individual styles of bow-shaping. This article also aims to provide a historical background to a modern 2016 reproduction of a composite horn bow dating from the period of the Mongol expansion. The overview of the bow design includes all types of available and valid sources that speak in favour of its construction and other historical solutions these construction decisions were based upon.

> The process of constructing this bow with the use of multiple horn strips was very challenging and time consuming to say the least. With the use of modern hand and measuring tools, one can only imagine the sort of ingenuity and skill the bowyers from the past possessed along with their patience and conception of the time it took to manufacture this type of bow.

Composite bow concept and terminology

Unlike self bows (which are made from a single piece of wood), or sinew-backed bows (which are made from two materials: a single piece of wood and a laminate of sinew), the concept of a composite bow is based upon using three or more materials during its manufacturing. The materials for a composite horn bow primarily include wood and animal products such as sinew, horn, and glue. Depending on the historical period and methods of construction, other animal products, such as bone and antler were also included. Each one of these composite bow materials contain certain technical and mechanical characteristics, whether the bowyer is considering the tension, compression, juncture, shape or stability of their bow, or strengthening its construction. In view of the sensitivity of certain materials used, especially the organic glue, the composite bow was commonly covered with different materials such as birch bark or animal rawhide in order to ensure protection from weather conditions that affect its durability and performance. Depending on the climate zone, as well as the characteristics of the materials, the composite bow production itself demanded higher precision and a longer period of time than other bows, such as a self bow. A disadvantage in composite bow making, is that each aspect of bow construction, whether big or small, must be performed during a specific season of the year.

The concept of a composite horn bow exists in many variations from a diversity of cultures through the millennia. The most common variation was the recurve bow, in which the limbs bend away from archer in an unstrung position. The advantage of composite recurve bows, lies in the combination of materials. The materials provide the ability for the limbs to quickly retract once released back into their starting position, providing additional arrow speed at a smaller draw weight than a self bow. Their shorter form makes them especially convenient for mounted archery. For these mechanical characteristics to function properly, composite bows must be constructed with two elements in mind: the working flexible limbs and the static recurves (Kooi 1994).

Self bows require long limbs, as shorter limbs would break. A wooden self bow has to be long enough and match the archer's height as well as draw length. In contrast, the short limbs of composite bows require the addition of other materials against the wood to bend it without breaking. Examples of materials are sinew (which is good in tension) and horn (which is good in compression). As Adam Karpowicz (Karpowicz 2008, p.16) stated '' horn and sinew can take enormous amounts of deformation without failure''. The longer rigid ends of the Hunnic and Mongol composite bows serve as levers that allow a longer draw-length, stores more energy into the bow, and increases the speed of the arrow. Wayne and Menes (1995, p.75) state that the Turco-Mongol bows are improved designs as they do not require the *siyah* reinforcement of bone or antler. This increases the Turco-Mongol bow's speed and performance as the *siyahs* are lighter in mass. In contrast to Ottoman bows, which are perceived as the ultimate design, these bows have no reflex in the grip, short bending sections, and short reflexed tips. Because of this design they could shoot lighter weighted arrows, as older bow types had set back handles and required longer and heavier arrows for good performance. Having a set back in the handle, and longer *siyahs*, allowed a shorter brace height for the bow to cast arrows faster. The long *siyahs*, acting as levers, allowed the bow to draw without any "stacking", which means it has a smooth draw. An increased reflex in the *siyahs would* require string bridges. String bridges keep the string from contacting the working limb and keep the bow stable without the string detaching. (See Appendix)

Even with the preserved traditions or written historical documents, there is a problem with the nomenclature pertaining to the elements/parts that comprise composite bows, as Adam Biro (2013, p.9) indicated. The literature uses different terminologies, and in order to avoid confusion in research, Biro (2013, p.10) suggests the terms *rigid tip*,*rigid grip*,*flexible limb* and *wooden core* be used for the bow parts. This article, alongside the suggested nomenclature, will use Arabic and Turkish terminologies that also are used in English literature.

Brief overview on the evolution of static recurve composite bows up to the Mongol era

The first indications of bows that were of composite construction are depicted in reliefs dating from the end of the fourth millennia B.C. in the territory of Mesopotamia. Angular composite bows and their complex inner constructions used in Mesopotamia and ancient Egypt were discussed in detail alongside pictorial evidence by Balfour (1889; 1897), McLeod (1970), and Wachsmann (1987). This provides researchers with a starting point for the development of composite bows. The type that is recognized today as the Mongol bow comes from the conquest period originating from the Hunnic type (Farrell 2010, p.60). The Hunnic type, according to archaeological findings, replaced the Scythian type of bow. For a long time, the Scythian bow was the most recognizable composite bow to researchers due to Scythian art. The same type of bow is also seen in presentations of Ancient Greek, Etruscan, and Persian art, as well as in numismatics. Soviet archaeology, notwithstanding fragmentary findings in Scythian kurgans across Russia and Ukraine, failed to procure a clear understanding as to how they were constructed. From the findings of fractured bow remains from kurgan, Tri Brata indicated that west-Scythian bows were composed of three wooden segments, and were not completely made of horn (Черненко 1981, pp. 7-22). A very clear picture of Scythian bows was provided by finds from the Yanghai cemeteries in the province of Xinjang, China at the beginning of the 21st century. One of these specimens was analysed by Stephen Selby and was reconstructed by Adam Karpowicz (Karpowicz & Selby 2010) who detailsa very complicated construction. Continuous horn strips comprise the central core sandwiched by wooden laths made of numerous pieces. The whole thick construction of the ridged belly with narrow bending sections and working tips was wrapped with sinew and covered with birch bark (Karpowicz & Selby 2010, pp. 94-102).

The Hunnic type, most likely originating from the Xiongnu period, as part of the nomadic tradition, had a huge impact on military technology up to the sixth century AD, especially through military-trade connections. The concept of the asymmetrical Hunnic bow spread from the Far East up to Hadrian's wall. The Hunnic's style of linear development continued for the whole millennium (Emeneau 1953; Paterson 1969; Coulston 1985; Худяков 1991). During the period from the third century B.C. there were significant structural changes that could have influenced the functions of bow parts. The first appearance of bows with rigid tips, as indicated by bone or antler plates, are found until the end of the Turkic-Khazar period, during the beginning of the 12th century AD.

These bows are contained in the subject matter of many literary works, primarily Soviet, Russian, Ukrainian, Hungarian, Chinese, German and Mongol. Given the familiarity of these bows from literature, it comes as no surprise that many bone and antler plate artefacts have been discovered in archaeological digs from the territory of Eurasia. Andrew Hall (2005) emphasized that it is difficult to reconstruct bows based only from these particular finds. Considering the earlier intact finds, he focuses on the artefacts from the territories mostly covered by present day China and Russia (Hall 2005, pp. 28-36). Hall discusses only the basic characteristics of the intact finds of bows. The dimensions, intersection and different forms of joining construction were taken into consideration. Hall was able to establish that this type of bow was characterized by an emphasized set-back in the handle. He also states that the bone and antler plates played a twofold role: (1) to reduce twisting and warping of the rigid tip or *siyah*, as was concluded by Hall in his next article (2006, p.73), as well as, (2) to strengthen parts of the complex construction of the wooden core of bows of this type. During the period of Avar domination, Turkic-Khazar and Hungarian types of symmetrical bow are also characterized by a large number of bone and antler plates. The bone and antler plates vary in dimensions, shapes, and in quantity of constituent parts, in accordance with the construction of that style. The appearance of bone and antler tip overlays intensifies in the period from the ninth to the 11th century AD, and it introduces a new method of joining the wooden core, with the V-splice principle.

Pre-Mongol and Mongol Empire era bows in written and pictorial evidence

The Mongol type composite bow is perceived as an intermediate stage in the development of composite reflex bows, as later bows perfected the form. Literature touches on the problem of bows from the so-called Mongol era. Despite mentioning archery, the primary sources of the time do not describe the bows' construction. There is no manual to indicate their structure or dimensions, as is the case with the Islamic realm between the 12th and14th centuries AD. Although they were mentioned by contemporaries of the Mongols, there are no details as to the construction of these bows. Armenians, for instance, refer to the Mongols as "The Nation of Archers", (Blake & Frye, cited in May 2006, p.623).

It is only after the death of Genghis Khan that Europe faced planned Mongol invasions. In the period from 1236 to 1242 AD, the Mongols, led by Batu and Subatai, devastated Russian principalities, Poland, Silesia and Moravia, finally inflicting a heavy defeat to the Hungarian army in the Battle of the Sajo/Tisa River. After all these events, the Papacy was very interested in obtaining more information about the Mongols, and therefore the first significant data on composite bows are from reports written by the missionary ambassadors, who were Italian and Flemish Franciscan friars, John Plano de Carpini and Willemvan Ruysbroeck.

Carpini (1996, p.70) explains that each Mongol horseman carried multiple bows, or at least one good one, with three large quivers filled with arrows; however, his information lacks detailed descriptions. Nevertheless, the descriptions of quivers and arrow tips allow for the conclusion that these were composite bows from a nomadic heritage. Aside from the mention of bows, the scriptures of the Venetian traveller Marco Polo do not offer any descriptions of their nature nor anatomy. He states that ''their arms are bows and arrows, sword and mace; but above all the bow, for they are capital archers, indeed the best that are known'' (Polo 1921, p. 260).There is also no detailed description of archery equipment in Atâ-Malek Juvayni's voluminous History of the World Conqueror (*Tan̄kh-i Jahān-gushā)*, or in the descriptions of the Mongols in*Jāmiʿ al-Tawārīkh*, by Rashīd al-Dīn Hamadānī, vizier of the Il-khanid ruler Gazan.. In contrast to the lack of details in written form, preserved copies of Rashīd 's work and Ilkhan school Shanhama abound with illustrations that perfectly detail examples of archery equipment. The art sources, therefore, offer far more data from both the pre-Mongol and Mongol era than the written documentation. This article focuses selectively on those resources which can be used as a comparison to the modern reproduction made in 2016.

According to the pictorial evidence the bows from the pre-Mongol period were static, non-contact, recurves with long straight ears. As in the case of earlier Hunnic bows, the long, rigid tips forming a very low angle served as a lever to flex the short bending parts of the bow. Apart from this characteristic, McEwen (1978, p.194) stated that earlier bows did not completely achieve the ability of later specimens to avoid stacking and that the arrows used with static non-recurved bows were of average weight. Peter Dekker (n.d.) states that "'their main advantage is that because the ears point backwards towards the archer, the bows have a natural tendency to correct their ear alignment by the natural tension of the string".

Pictorial documents show that the bows of the Khitans and Uyghurs apparently shared some characteristics with the bows used by the armies of Southern and Northern Song Dynasties. (Figure 1). We find the same characteristic in the presentation *Archer and Horse* by a Khitan prince who escaped to the court of the Tang dynasty, Li Ts'an –Hu, dated to the tenth century AD. The low angle of non-contact *siyah* is partly visible, due to the fact that the archer has slung his bow over his forearm, while the closed quiver is decorated with tiger's hide and the hide of the wild boar, as noted by Bede Dwyer (1998, p.83).   *Four Generals of Zhongxing* by Southern Song Dynasty artist Liu Songnian (1174 – 1224) shows the same features. Not only is the low angle of the rigid tips a striking feature, but also their narrowing, starting from the base to the very tips, as well as a deeper set back than in later bows of the Mongol era. There are no indicators of any bone or antler plates, and we may rightly assume that the construction was joined in theV-splice manner.

Apart from the pictorial artefacts where the people presented were Khitans, Uyghurs, or members of some other nomadic people who were roaming through the Song states, it is not certain that we can conclude the objects in the pictures, bows included, belonged to them. One can only assume that the Song painters presented them based on what they observed in their surroundings.

The miniatures from the Mongol period depict many changes to the design of bows compared to the presentations mentioned above. In Il-khanid Persia, the scenes from Shahnameh are one of the most important sources. Although the subject of these works of art was not contemporary for these painters, they skilfully expressed the objects they observed. In this case, archery equipment was the most frequently painted object with great detail, and uniquely displayed as each style allowed for it. The general characteristics of bows disclose a more perfected form than the earlier nomadic examples. The ears of the bow were formed with a much sharper angle forward, but still in the same measure where the bowstring rested on one part of the ears. The set back of the handle is still present, but less aggressive than in bows of the previous period. The handle was often covered by the archer's hands or was placed in the bow bag making it impossible to draw a set conclusion whether the back of the handle is expanded as in the case of bows that are shown in art presentations of the Seljuk and Mamluk realm, and especially from a later period of Timurids and the Ottoman Empire.

In modern day attempts to reproduce the bow, one can only consider copies of manuscripts from the end of the 13th and the first half of the 14th century AD/BC. Later copies show signs of inserted details that were contemporary to illuminators and calligraphers of those times (Hasanzade and Afandiyev 2011). If we take into account Rashīd al-Dīn 's chronicle, we see particularly good presentations of bows in a compilation of copies in the Edinburgh manuscript, as well as in the so-called Diaz's album. In a great number of chapters, the bows are shown, to a lesser or greater extent, with a similar outline. The angle of the ears is conditioned by their curve, and the lower set back of the limbs. The presentations indicate a more complex inner anatomy of the bow, and all of the bows in illustrations from the Il-khanid period point to the same structure and method of joining parts of construction.

In the images of a version compiled in the Edinburgh manuscript, the points of the *siyahs* appear rounded (See Figure 2). A very distinctive feature of bows from the miniatures in Diaz's album shows sharp pointed tips. In *Cavalry Pursues Enemy* the artist even emphasised the mechanics of a bow. Similar bow characteristics are also found in Diaz's album from the scene of *Kublai Khan Hunting* by painter Liu Guandao, dated around 1280 AD and held in Taipei National Museum.

Regarding other cultural spheres of the same period, we find exactly the same bow characteristics in Serbian medieval mural paintings from the reign of King Stefan Uroš II Milutin (1282-1321 AD). Zoran Pavlović (2013) in his work on the composite bow, specifies two bows painted on two fresco paintings in the first two decades of 14th century AD (See Figure 3). Both coincide with a design which appears in the illuminations from Il-khanate and the 14th century Mongol realm. Another similar bow representation is found at St. George in St. Demetrios Basilica, Thessaloniki, Greece, which likely belonged to a Tatar mercenary in the army of Byzantine Emperor Andronicus II Palaeologus. The picture of this particular fresco from 1303 AD is published in a book written by Gligor Božinoski (2013). Furthermore, the illustrations in *First Small Shahnama* from Baghdad, painted in 1300 AD, shows bow outlines very similar to the replicated model (See Figure 4).

Intact composite bow findings from pre-Mongol and Mongol Era

When it comes to well preserved archaeological discoveries, intact bow finds are the ultimate evidence. The scope of this part of the paper, will include examples of intact bows from the eras before and during what will be known as the Mongol Empire whose foundations were laid down by Genghis Khan.

Intact preserved bows from the pre-Mongol and Mongol eras exemplify diversity in structure and design. The pictorial representations of partial bow discoveries however allude to the opposite conclusion. The best example for researchers was the Žagarlant bow from the pre-Mongol era.

Usually, one can speak of asymmetrical non-contact *siyah* design with a slight asymmetry due to minor differences in the lengths of the rigid tips. According to Becker and Rutschke (2005) the wooden core of the Žagarlant bow was constructed in multiple parts. The core was formed by overlapping 2 wooden strips, additional wooden laminated pieces are glued to the belly of the handle section, and another wooden piece is provided on the back. Through this construction, there is a deeper set back without an expanded and bulbous section on the back of the handle. The *siyahs,* appear to be joined using a V-splice. The Čonot Uul bow from Khovd aimag (See Figure 5), also has *siyahs* connected to the wooden parts of the working limbs by V-splices which are 13.2 cm. (Becker & Rutschke 2005, p.85). The string nock is located at the front section of wooden overlays which are 80 mm in overall length. Bone frontal tip overlays are also shown in the Duguy Cakhir bow (Erdenebat 2012, p.304; Biro 2013 p.203). Bone and antler frontal tip overlays of the Saltovo type from the Turkic-Khazar period were the subjects of Russian and Ukrainian archaeology and literature (Медведев 1966; Савин and Семёнов 1998; Флёрова 2000; Аксьонов 2005; Круглов 2005). Very detailed observations and systematisation of non- abundant bone and antler frontal tip overlays from the Carpathian basin were described by Biro (2013, p.143).

Certain materials, usually birch bark, were used to cover the bow on both the back and belly portions, as well as the sinew wrappings. These covering materials do not provide a clear insight into the construction of the bows' inner-most structure. Most likely,the rigid handle is formed by laminating two wooden pieces on a wooden core, and later brought to its final shape. It is likely that the partially damaged Arcat Del bow consists of a frontal bone or antler grip plate (Erdenebat 2009, p.309) which could have served as a substitute material due to insufficient length of the available horn or as a reinforcement for the wooden core. The wooden core was composed of wild cherry (Žagarlant), willow, and beech (Čonot Uul). These woods would also be used for the cross-section of the bow in the rigid handle portion, working limbs, and *siyahs*, and the wood species vary from specimen to specimen. The wood core ranges from oval, slightly triangular, rectangular, or even sharp triangular cross-sections, which are similar to the kasan ridgeof Ottoman bows and later bow types from the same lineage.

The intact bows of the Mongol era point to a new model and advanced form in terms of structure, functionality, and stability. However, as in the case of the afore-mentioned bows of pre-Mongol era, there is an absence of a large number of finds that could talk about all bows of that period with reliability. The authors had access to the photos of both artefacts published in the literature and unpublished sources. Only the most important features were addressed by the authors. One particular bow from the Yuan dynasty period, provides more details, and will be discussed in the next section about constructing the bow.

The wooden core of the Tsagaan Khad bow excavated in Övörhangay aimag, Mongolia, indicates the adoption of a more complex wooden structure. According to CT scanning, the wooden core of the handle and *siyahs* was joined using the V-splice method. However, the bow was deformed due to its long burial time and there are hints of its detailed reconstruction. (Ahrens et al. 2012, pp.330-334; Becker and Rutschke 2012, pp.86-89). The limbs of the bow indicate a smaller angle, which suggests an expanded handle. The expanded handle is the striking feature of the 13th century pictorial evidence in Seljuk and Mamluk realms. It is also featured in subsequent representations of bows in Islamic art, found in well preserved artefacts of the Ottoman Empire, and those derived from the same lineage between late 15th and 19th centuries AD. The working limbs of the bow in its widest sections are 50 mm and they narrow down the limb to the transition of *siyahs*. *Siyahs* are joined to the limbs by V-splice at an angle of 35 degrees, although the splice length varies both in the area of the handle and in the transition from the working limbs to aggressive curves of the *siyahs* that are triangular in cross-section. The leather pads are set in the string contact area of the tips, but this is not recorded in the pictorial evidence. Sharp pointed tips match the pictorial representations in Il-khanid miniatures and the outline of the bow shows similarities. The core's wood species is likely, Elm while transparent 0.5 mm thick strips of grey cattle horn are visible in some damaged sections (Ahrens et al. 2015, p.685). The bow itself is covered by birch bark in its entirety except the wooden *siyahs*. Overall, the bow is 141.1 cm long measured along the curvature on the back of the bow (See Figure 6).

The next observations come from the Omnogov bow which was constructed in 1720 AD. According to experts from the Japanese laboratory, the bow type, according to its outline, is from the 14th century AD or a bit later, but not after the 15th century. Erdenebat (2009, p.74) suggested typological dating of the intact bow and other inventory within the tomb complex to the 12th - 13th century AD. The bow itself is 51 inches in length measured along the curvature. More detailed dimensions of this bow are provided by Wayne and Menes (1995, pp.71-75). The bow has a slight set back on the handle where 4 inches of belly bone plate is located. The working limbs taper from the arrow pass area, the entire width of the transition limbs to *siyahs*, and all the way to the very tips. The *siyahs* are elegantly carved and triangular in cross-section which is similar to the *kasan* in late Ottoman Turkish bows. The core is constructed with 5 pieces and appears to be joined by the V-splice method. Since buffalo horn most likely was not available to contemporary nomads of the area, it was assumed that shorter pieces and strips of sheep or yak's horns were glued to the belly of wooden structure. The bow is wrapped in birch bark, other than rigid wooden tips that end up with very sharp pointed tips (See Figure 7).

Conceptually, a bow found in the Shiluustei district of the Zavchan aimag province dated to the 13th to 14th century AD (May 2009, p.196) is very close to the afore-mentioned pictorial evidence. The authors relied on Jack Farrell's examination of this bow during an exhibit in Houston, Texas, USA. Farrell's sketches included measurements of the bow's construction and are provided within the publications and proceedings of the Academic Seminar of World Traditional Archery Festival in 2009. Farrell also included photographs with his sketches. The bow's working limbs are shorter in length, wider, and lower in reflex. The handle appears to be expanded. There is no indication that the arms are connected to the handle by V-splice. It was impossible to detect the connective areas due to the fact that this part was covered by sinew layers and birch bark (J Farrell, pers. comm., 20 January 2012). The bow's sharp pointed rigid tips, almost 50:50 in relation to the length of the working limbs are joined by V-splice. These splices appear to be 4 cm deep. According to estimations given by Ulrich F. Wellner, there is a striking aggressive reflex of the *siyahs* that roughly range from 40 to 30 degrees, bringing the total range of reflex to 70 degrees. In the area of the nocks for the bowstring there are 2 horn inserts, one on each tip. Horn strips were reportedly formed by 4 wide, short, grey, ibex horn pieces arranged in a row by using butt-joints to cover the distance of the limb. This is a different variation of adjoining horn as opposed to the side-by-side long thin strip method. The entire bow is covered by birch bark.

Considering there are no published sources of this well-preserved bow from the cave burial in Murui Am, the authors derived their information from the information and pictures received from Luvsanorov Munkh as a primary source who had access to this artefact (L. Munkh 2017, pers. comm., 18 January 2017).

The bow was reportedly unearthed in Murui Am, Bayankhongor province, Bumbugur Sum, Mongolia. According to photographs, the bow was discovered within a cave excavation and it absolutely matches many of the pictorial representations of bows from the period of Il-khanate and Kublai Khan's China. The bow's core appeared to be composed of five pieces using the V-splice method. Even though the bow parts are separated, it is evident that the V-spliced handle is expanded as in the case of the Tsagaan Khad bow. It is assumed there was a slight reflex in the working limbs when the bow was in the strung position. The bow narrows in width in the area that transitions between the working limbs and sharp pointed rigid tips. This transition area was most likely shaped to be triangular into rectangular within the cross-section. Like most finds, the intact bows are still fractured as this discovery contains one damaged *siyah*. The dimensions are still unknown as the bow is not published nor observed in academic detailyet. However, we do know it consists of wood, horn, sinew, and a birch bark cover. It is currently residing in an undisclosed museum vault.

Manufacturing the bow

To start manufacturing this bow, specific materials needed to be gathered and processed. Wood from a sugar maple was cut and shaped into laths consisting of five separate pieces, two laths for the limbs, or working sections of bow, two for the tips (*siyahs*-static rigid sections) and one thick enough for the handle. All of these pieces of wood were joined together with v-splices, creating the core of the bow. For the tips (*siyahs*) wood could be found using the crotch of a tree limb to get a slight curve or bend naturally occurring in the wood to make up the recurvature of the outer extremities of the bow. This was a common practice, but finding wood in a large enough diameter to split and get two equal halves having the same shape can be difficult. I decided to make a form and heat bend the shape I needed to form these parts. The two laths for the *siyahs* were soaked in water for 3 weeks and then boiled in water for one hour. Once hot enough, the wood was plasticized enough to bend safely over a form without any grain rupture and clamped to cool and dry for one month.

During the time while the wood was curing, glue, horns and animal tendons needed to be gathered and processed as well. Two separate animal glues were made with different working properties. The dried deer and cow tendon glue lends itself to gelling quite fast, making wood joinery much easier for putting the individual parts together with ease. The Yellow Croaker air bladder fish glue has a longer set time allowing for other more difficult operations of construction to be completed safely without risk of setting up or gelling.

The same steps and processes were used to make both types of glue. The materials were soaked in water in a large double boiler. It was then heated to 76.66 degrees Celsius for 20 hours. This lower heat slowly extracted the collagen from the materials without degrading the quality of the glue allowing the collagen to gel or set when cooled. After the 20 hours of cooking, the batch was then strained thoroughly through cheesecloth to remove any debris of left over tendons or bladders that did not dissolve. The solution of glue had a very low viscosity due to still having too much water in the mixture. It was then cooled to 60 degrees Celsius to remove the excess water leaving the solution more viscous. Once reduced enough, the solution of glue was set aside to cool for 3 hours. Once cooled, the glue was gelled to a solid mass allowing it to be cut into small pieces and placed on cooking trays to dry for later storage and use.

The next material to be processed was the animal horns. One pair of black Asian water buffalo horns and one pair of white ram's horns were selected. Typically, most composite horn bows are constructed with long and wide single horn strips taken from the outside curve of the horn itself. Some bows however, were constructed much differently using multiple horn strips on each limb. This practice could have been done for a number of reasons, perhaps the materials available did not failitate the bowmaker in making the limbs wide enough, or it is possible that using actual scraps of horn became more economical to produce more bows. There is no current evidence or references reproducing this technique available except for examples of other bow's cross sections showing the use of these multiple horn strips. The methods of processing and techniques of gluing are completely unknown.

To reproduce this method of using multiple horn strips it was decided to experiment and use three narrow horn strips on a scrap of wood. The horns used for the experiment were scrap pieces of water buffalo horn approximately 30 cm long and 9 mm wide. The sugar maple wood was approximately 40 cm long and 5 cm wide.

Cross sections of old bows revealed the gluing surfaces of horn to wood to be concave and convex. Meaning, the natural roundness of the wood taken from a sapling and the hollowness from the inside of the horn were utilized when joining these two materials together. Not all composite bows were made like this however. There are examples of multiple horn strips being made flat and glued to a flat wooden core surface. This is very evident in bows with very wide limbs. For this experiment, the wood was shaped in a convex manner. The horn strips being as narrow as they were had to conform to this convex shape when glued without any gaps when mated together side by side. This issue became apparent when first placing the strips together on the convex wood surface because the sides of the horn strips were cut and shaped at an approximate 90-degree angle.

It also became apparent that the mating sides of horn needed a change in angle to mate correctly to this round convex wooden shape. A slight 4-degree angle was made on the side mating surfaces of the strips. The centre horn strip was made trapezoidal. The pieces fit together very well. After a dry fit, the wood and horn were lightly scored and given around 30 coats of very thin fish glue. The glue had been reconstituted in water and heated to 65 degrees Celsius. Once the pieces were sufficiently sized with thin glue, the horn strips and wood were warmed over a hot plate. A thick solution of fish glue was reconstituted to join the pieces together. Once the pieces were sufficiently warm making the horn very pliable, they were placed side by side on a strip of masking tape to hold them in place. A thick solution of glue was applied to both wood and horn and the horn strips applied to the wood core. Flagging tape or construction ribbon was used to wrap around and secure the horn into place. The ability of this material to stretch aided in squeezing the horn strips together without any slippage. It is possible that any form of cordage with any amount of stretch would work just as well. It would need to be covered in a wax to avoid making the glue stick to everything.

The next step was to securely clamp the horn down to the wood. Tremendous pressure is needed for this and a traditional clamping method was used. A Turkish Tencik tool was used (Klopsteg 1947; Karpowitz 2008). There are other similar forms of this tool used wherever composite horn bows were made. Rope is wrapped around the wood core and around this tool creating a large amount of tension and pressure. As the rope is pulled around the core, glue squeezes out of the joints indicating that enough force has been applied making the glue joint very tight. Once clamped and secured, the mock up limb was set aside to cure for 3 weeks.

After 3 weeks, the rope and construction ribbon were removed. The model was cut in two to view the cross section and glue lines. It was a success and looked very similar to cross sections of old bows. By the end of the experiment, it was time to assemble the previously shaped wooden laths and bent *siyahs* making the wooden core of the bow.

The wooden core consisting of five separate pieces of wood needed to be assembled in stages. First, gluing the two limbs to the handle section and then gluing the *siyahs* to the limbs. This process aids in keeping the bow aligned. The handle section was cut to 34.5 cm long. Making the handle itself 10.16 cm long and leaving 10.16 cm to make up the male ended V-splice that would mate to the female sided V-splice in the bows limbs. Once the V-splices were cut, both the male and female mating sides were lightly scored using a small toothed saw blade. The handle section and limbs were then coated with a very thin sizing solution of fish glue multiple times. Once dried, the pieces were assembled using a thick solution of tendon glue. The fast setting property of this glue aided in keeping the joints together without sliding apart while clamping. After the handle and limbs were assembled and clamped, it was left to cure for two days. The next stage was to roughly shape the *siyahs* and cut similar V-splices to join to the limbs. The V-splices were made 7.6 cm long, making the *siyahs* the male joining part and the limbs again the female joining part. The same process of scoring and sizing were applied. Once dried they both were glued and set to dry and cure.

For this design of bow, the limbs were to be made fairly wide. Wider limbs aid in later stabilization of the bow once the bow is completed and strung. The previous experiment of making the wooden core convex and bevelling the sides of narrow horn strips to conform to the cores convexity would not be ideal for this bow in particular. If the core of the bow were to be made that way, the limb thickness would be very thick resulting in a very heavy draw weight. The individual who commissioned the project requested a lighter draw weight of bow so using flat gluing surfaces would allow more options for controlling total limb thickness to achieve the desired draw weight.

Preparing the wooden core for the horn was a very important step. The flat surface on the belly side of the core - the side that faces the archer - where the horn was to be mated, needed to be made perfectly flat perpendicular to the plane of bending. Once both limbs were made this way by rasping and sanding, the horns needed to be processed. The outside curve of both the water buffalo and rams horn were cut using a bandsaw. The rough outside surface was ground down and the pieces made flat using dry heat and clamping to a flat surface. When the horns cooled, they retained the new flat shape. A true flat gluing surface was made to the strips of horns by temporarily gluing them to a long block of wood and sanding them on a large glass table with 40 grit sandpaper. After the surfaces were made true, they were removed from the blocks of wood and cut into narrow strips. A colour variation of horn was chosen making each limb have two strips of black water buffalo horn and one strip of white ram's horn as the centrepiece. The horn strips were shaped by tapering their thickness and checking the stiffness and bend of each individual strip to match each other. This was a form of pre-tillering the bow before the glue up. The approximate thickness of horn was 4.5 mm.

Once the strips for both limbs matched in shape, and the stiffness of each strip was checked so that the strips for both limbs would match in strength, they were scored along with the wooden core with a small saw blade and the process of sizing with very thin fish glue could begin. Since the horn is much denser than wood, the sizing glue solution needed to be made very thin like water. The horn was warmed gently before each coat of sizing, with the sizing glue made very hot. This allowed the glue to penetrate better. After approximately 60 coats of sizing, the scored grooves in the horn strips and core were completely filled with thin glue leaving smooth flat surfaces. This process of sizing the parts was very important due to the fact that the horn to core joint will be under extreme strain when the bow is bent. The bond has to be very strong. The scoring increases the gluing surface and the sizing of parts penetrates into the material making somewhat of a small laminate of glue itself once the pieces are joined together.

Gluing the strips to the core was done in a similar way as the original experiment. This time, small blocks of wood placed 1.5 inches apart were made and c-clamps would be used instead of the rope clamping method. A thick pad made of five small diameter pieces of rope laid on masking tape was glued to the blocks. When used while clamping, it would simulate the rope method by pressing into the horn distributing even pressure. The wooden core and horn strips were well heated and a thick solution of hot fish glue was applied to both parts which were immediately joined together. The construction ribbon was used again as the initial material to hold the horn strips in place. The rope pad and blocks were then laid on top of the joined horn strips and clamped with C-clamps. Once done, the limb was allowed to slightly cure for two days before repeating the process on the second limb. When the second limb was finished, the bow was set aside to cure for a month.

The next step was to process and separate the animal sinew. White tail deer back strap sinew was chosen for this bow due to its lengths. It was lightly pounded with a mallet against an anvil and rolled through the hands separating each fibre strand and placing the strands into bundles. These bundles were of different lengths and would later be applied to the bow with fish glue in a strategic system layering the bundles of different lengths. After the core had cured for a month it was then ready to be dressed down to final dimensions and tapered in thickness in preparation for sinew.

The cores limbs tapered in thickness starting at 15 mm thick at the transition of handle to limb down to 7 mm thick at the end of the working section of the limb. The transition from working limb to the V-splice of the *siyahs* increased in thickness forming the 20 mm thick tips. Both sides of the V-splices of the tips were carved out using a gouge and forming a small ridge line. Doing this reduced the mass of the bow by removing excess weight in wood material. The total limb thickness at this point was measured by measuring both the horn and wood together. Limb thickness would be increased by the layering of sinew.

Before the bow could be sinewed, a temporary laminate of canvas soaked in tendon glue was glued to the horn belly. This was not a necessary step but was done to protect the horn from possible splitting or cracking during the drying phase. Once the canvas dried, the wooden back and sides including part of the horns along the sides of the bow up to 3-4 cm up the tips were lightly scored using a small toothed saw blade. Ten coats of thin fish glue sizing were applied and allowed to dry.

The sinew layers were divided into bundles. The first layer consisted of 13 g of sinew on each working limb that started approximately 3 cm into the handle reaching to the base of the *siyahs*. Another short bundle of 6 g was added to overlap the longer bundles on the handle section. Once the sinew was applied, the bow was set aside to cool allowing the glue to gel and holding the sinew fibres in place. A string was tied to the tips and the bow was pulled into approximately 13 cm of reflex to put the sinew layer under compression. The second layer would be applied 3 days later. Before the second layer was applied, the first layer was resurfaced by rasping high spots and sanding making a new clean smooth surface for gluing. Three to four coats of sizing were applied to the new surface to increase the bonding for the second layer.

The second layer consisted of four bundles. On each limb, a 13.5 g bundle started from the centre of handle and extended up to ¾ of the working limb. The second bundle of 9 g overlapped the first by 4 cm and extended up to about half the length of the *siyahs*. After the sinew was applied, the same process of cooling and allowing the glue to gel was done and the bow pulled into more reflex and allowed to dry. After four days of drying the bow was prepared by rasping, sanding and sizing the second layer for the third layer to be applied. The third layer consisted of three bundles. Very long bundles for the working limbs weighing 16.5 g each were applied starting 3 cm into the handle and extending all the way to the base of *siyahs*. The third bundle weighing 7.5 g was placed over the handle to overlap the longer bundles. The same process of cooling and pulling the bow into more reflex was done. Three weeks after the last layer, the sinew was filed and sanded to bring down any high spots and to make sure the layering continued the even tapering of working limbs. The bow was then sized and was ready to season.

After 6 months of seasoning, the bow was ready to be opened and tillered. The string holding the bow in reflex was removed along with the canvas covering the horn belly. Before going any further with the tillering process, the fade out sections above and below the handle and the area of the *siyah* splices, were wrapped in a thin layer of sinew to reinforce the joints. This can be seen on old bows. Once the sinew was applied, it was filed and sanded smooth and set aside to dry for 3 weeks. After the 3 weeks of drying, the bow was then slightly warmed over a hot plate and *Tepeliks* (Turkish word –additional datas in appendix section) which are blocks of wood shaped to the curve of the bows approximate brace height were applied (Klopsteg 1947; Karpowicz 2008). The limbs were slowly bent over the *Tepeliks* and tied into place. Once in place, the bow was ready to be braced for the first time. It was placed on a bow press (see picture example) and slowly brought down to brace height so a tillering string could be placed on the bow. Usually at this stage of finishing, the bow will show some misalignment or twist in the limbs due to warping that can occur during the seasoning phase. This was not the case with this bow. Everything was in perfect alignment. Once the bow was strung, the *Tepeliks* were removed and the bow was further examined to check the balance of limbs. The bow was in perfect tiller at brace height. Now the bow needed to be drawn to check for further balancing of limbs. The bow was placed on a tillering wall and the bow slowly drawn only a few inches at a time. Warming the bow up slowly over a period of 5-10 minutes by drawing it further and further, the bow was brought to a 35 inch draw. The limbs were bending evenly in a perfect tiller without having to remove any horn from the belly of the bow, or use any heat to correct imbalance.

The last stage of construction was to finish the bow by covering the sinew back, and handle section with very thin goat rawhide. The sinew wrappings above and below the handle, and at the *siyah* splice would be wrapped with hemp cordage. The rawhide was sanded and the thickness brought down to 0.3 mm. The sinew backing on the bow was lightly sanded and a coat of thin sizing glue applied. The rawhide, already cut to the correct lengths and widths of limbs and handle, were soaked in warm water for an hour. The rawhide was then placed on a flat surface and the excess water wiped off with a clean cloth. Fish glue was then applied to the rough sanded underside of the rawhide and placed onto the bow. Some manipulating and holding in specific spots to remove air bubbles was needed. After both limbs and handle were covered, the bow was set aside to dry for 2 weeks. The bows tiller and balance needed to be checked again once the rawhide was fully dry. The bow remained in perfect balance.The hemp cordage was then wrapped and glued in place covering all the sinew wrappings near the handle and base of the *siyahs*. The horn was scraped smooth with a sharp knife and lightly sanded and polished.

The cross-section of the *siyahs* is close to a particular intact bow from Xining Museum. Paintings from the Yuan Dynasty period where bows show more curvature in the *siyahs*/ of the bow as in the case with the Omnogov, Tsagaan Khad, or any intact bows from the Yuan era, informs us that there were other forms as well. One intact bow residing in the Xining Museum, was found in a cemetery consisting of a well-preserved corpse of a Mongolian warrior estimated to date back to the Yuan Dynasty (Journal of Society of Archer AntiquariesVol.3). A slightly damaged bow consisting of *siyahs* which are at their base, circular in cross-section becoming narrower toward the very tips (Hall 2006, 70). The circular cross-section continues for most of the *siyah*. There is a gentle curve in the transition from limbs to *siyahs*. Observing the picture of the bow parts and according to circular cross-section at the base of *siyahs*, one could conclude that the rigid tips are joined by overlapping rather than using the V-splice method as in the case of the reproduced bow.

Most of the modern bowyers today prefer a single horn strip on each limb of the bow. Relying on the available material, it is most often water buffalo horn. Artefacts and old manuscripts through the long period of the bow development indicate climate and available materials determined the forming of horn belly on composite bows. Faris and Elmer (1945) in discussing the issue of multiple horn strips used to form a single plate on the belly of the flexible limb of the bow note, that five or six narrow strips were necessary on each limb of the bow. However, they do not have an explanation for the manner in which multiple strips were laid down. Andrew Hall (2006) in his article on bone-reinforced bows examined multiple horn strips on the belly of the intact bows from Tarim Basin, the period of the Eastern Han Dynasty and those from Khitan. Some of the observations are based on discussions and photos of bows exposed to X-rays which were published by Stephen Selby on the Asian Traditional Archery Research Network website. The bows in question have very wide flexible working limbs consisting of a larger number of narrow horn strips set parallel side-by side instead of a common single strip. Bearing in mind the dissected bow published by Henry Balfour (1889), one gets the image that the wide limbs of most Persian bows consist of a larger number of narrow horn strips set parallel side-by side. Later Ottoman Turkish bows do not show this feature and it is very rare in Mughal bows. Plakhotnichenko (n.d) informs us that the belly of the Buryat bows consists of a larger number of cow horn pieces instead of single horn strips on each limb. Sung Ying-Hsing (1997, p. 262)mentioned that "the horn used here (Kwantung province) is made by joining the toothed ends of two pieces of oxhorn together" and that northern barbarians (thinking probably of some sub-groups of Mongols) had to use four pieces of sheep horn on each limb to form a single horn strip in absence of available long steer horns. All of these solutions could been possible among Mongols. For instance, as we have seen aforementioned, the Shiluustei sum bow consists of a couple of butt joined pieces of horn to form a single horn strip for each working limb.

The process of constructing this bow with the use of multiple horn strips was very challenging and time consuming to say the least. With the use of modern hand and measuring tools, one can only imagine the sort of ingenuity and skill the bowyers from the past possessed along with their patience and conception of the time it took to manufacture this type of bow. I do believe there is still more to be learned by experimentation for this type of construction. There are still questions that could be answered by delving further into reconstructing the type of tools they may have had at the time and reconstructing another model with those tools. How long did it take the old bowyers to make these weapons? Were they made in high volume as to indicate a production line? Or, were they made individually?

In conclusion, this experiment answered many questions as to the functionality of the use of multiple horn strips but, generated many more questions as to how this specific technique of construction was beneficial.

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Appendix

*Tencik*or *tendyek* is a tool ressembling wrecking bar with ropes for applying pressure between the horn strip and wooden corewhile binding the parts together during gluing. It appears in different forms and under different terms such as *sonimok* in Korean bow making nomenclature, although its purpose is the same.

*Tepeliks*are a pair of curved wooden pieces with a slight longitudinal concave groove along the convex side where the bow limbs are placed during first stringing and opening the bow.

*Siyah*derives from Arabic terminology and basically means "curved arm" of the bow (Nicolle 1982, p. 123). It was primarily used for the rigid tip of the composite bow. Spliced in limbs by V- splice and being triangular in cross-section they provide tensile strength thus lateral bone or antler fittings were not necessary.

*Kasan*is a ridged section of bow limb of Ottoman Turkish bows and other bows from the same lineage unlike *sal* which is bending part of the limb according to Turkish nomenclature. In Arabic nomenclature bending part of the limb was known under name *dustar*. Nowadays, *siyah* means the whole ridged section together with the tip called *baş*.

*Stacking i*s rapid increase in draw weight of the bow thus hard to achieve the proper draw length in last stages.

*String bridge*is chunk of horn, wood or padded leather attached to the base of the siyahs. It is feature of Crimean Tatar, Qing, late Ming and Chosŏn dynasty as well modern Korean bows with aggressive recurved siyahs. It helps holding the bow string further from the limbs and allowing the siyah to rest at an angle forward of the string.

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Image sources:

Fig 2. Four Generals of Zhongxing by Southern Song Dynasty artist Liu Songnian (1174–1224) source: https://en.wikipedia.org/wiki/File:Four_Generals_of_Song.jpg

Fig 3. Besieging the city of Ūq Edinburgh University Library, MS. Or. 20 f.124v – source: http://www.warfare.netau.net/Persia/14/Jami_al-Tawarikh-Mongols_Besiegi... accessed: January 26th, 2017

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Gallery Image

FIG 1. GENERAL GUO'S MEETING WITH UYGHUR CHIEF IN 765 BY LI GONGLIN

FIG 2. FOUR GENERALS OF ZHONGXING BY SOUTHERN SONG DYNASTY ARTIST LIU SONGNIAN (1174–1224)
SOURCE: HTTPS://EN.WIKIPEDIA.ORG/WIKI...

FIG 3. BESIEGING THE CITY OF ŪQ EDINBURGH UNIVERSITY LIBRARY, MS. OR. 20 F.124V – SOURCE: HTTP://WWW.WARFARE.NETAU.NET/... ACCESSED: JANUARY 26TH, 2017

FIG 4. ST PROCOPIUS HOLDING BOW IN BOWCASE, GRAČANICA MONASTERY, FIRST DECADES OF 14TH CENTURY, ENDOWMENT OF SERBIAN KING STEFAN UROŠ II MILUTIN (1282-1321), AFTER ZORAN PAVLOVIĆ (2013)

FIG 5. BOW FROM ŽAGARLANT, COURTESY OF PETER DEKKER

FIG 6. ČONOT UUL BOW FROM KHOVD AIMAG, COURTESY OF PETER DEKKER

FIG 7. CAGAAN KHAD BOW EXCAVATED IN ÖVÖRHANGAY AIMAG, MONGOLIA, COURTESY OF PETER DEKKER

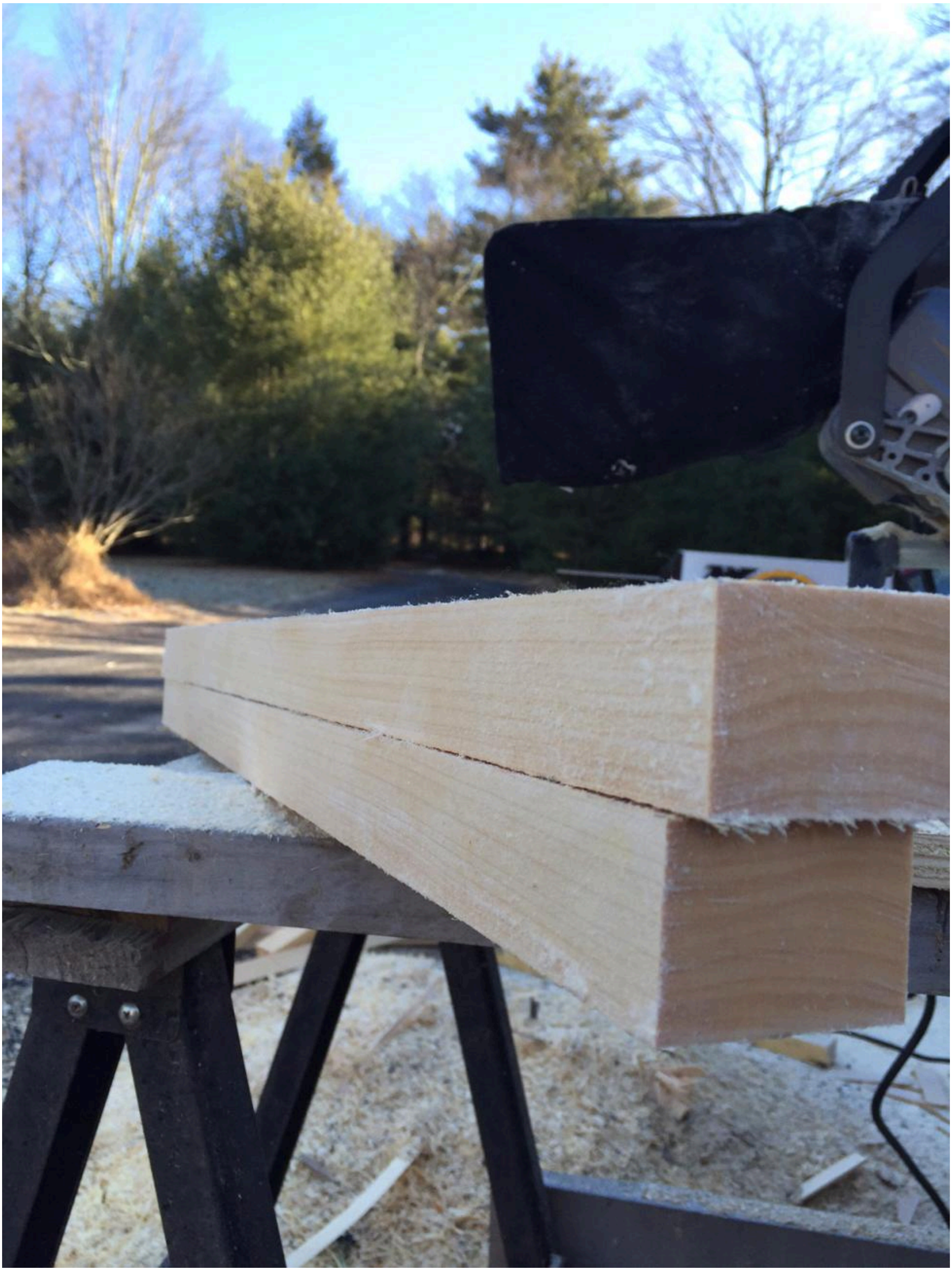

FIG 8. THE RAW MATERIALS

FIG 9. CROSS SECTION HORN STRIP TEST

FIG 10. CORE SHAPING

FIG 11. SHAPING THE CORE BEFORE SINEW

FIG 12. PREPARED SINEW

FIG 13. PREPARING THE HORN SAND CORE

FIG 14. AFTER SINEW TIPS PULLED TOGETHER

FIG 15. FINAL SINEW FINISHING

FIG 16. FISH BLADDER GLUE

FIG 17. BRACED BOW

FIG 18. BOW AT FULL DRAW

FIG 19. FINISHED BOW

FIG 20. ULRICH VELTHUYSEN

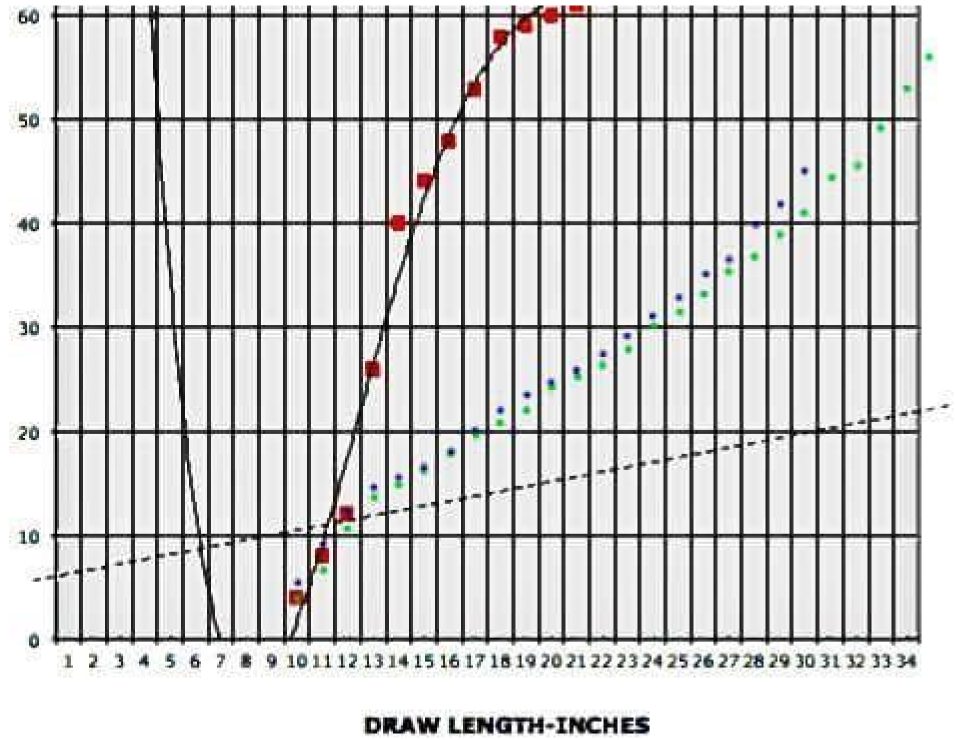

FIG 21. FORCE DRAW CURVE CHART

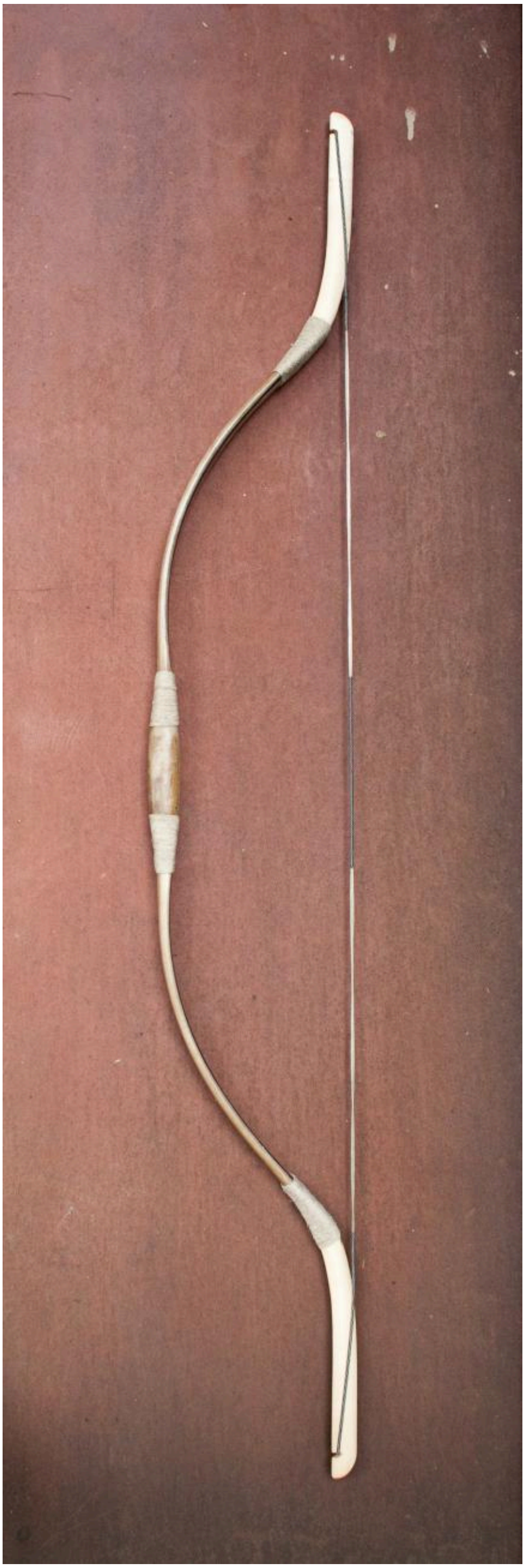
FIG 22. COPY OF MONGOL BOW FINISHED