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Archaeological Experiment on Reconstruction of the "Compound" Bow of the Sintashta Bronze Age Culture from the Stepnoe Cemetery

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Author(s): Ivan Semyan [1] ✉, Spyros Bakas [2]

[1] Institute of Archaeology and Ethnography NAS RA, 15 Charents St, Yerevan, Armenia.
[2] Independent researcher, address withheld by the editors (GDPR), Florina, Greece.

This article presents data from an international experimental study on the reconstruction of the "compound" bow of Sintashta culture of bronze age South Ural, Russia. The project is

carried out by a collective of researchers from Greece and Russia as part of the grant program of the world association of experimental archaeology EXARC - “Twinning program”. The article reviews the global context of the design features of bows of the Neolithic-Bronze Age. The features and parts of the Sintashta “compound” bow were considered, and the role of long-range weapons in the life of Sintashta society was discussed. Using authentic technologies and materials, the authors of the article managed to make four versions of the bow reconstruction prior to obtaining the correct version.

“This initiative is the first attempt of a scientific reconstruction of the bow associated with the Sintashta culture. This type of bow appears to be potentially very important, since it provides information about the process of appearance and evolution of complex bows of the steppe breeders, and elucidate the special style of combat based on mobility and long distance in this culture.

Introduction

The Sintashta archaeological culture dates to the XXI to XVIII centuries BC. Distinctive features of the culture are high militarism and the existence of large, fortified settlements, of which 23 are known. The world's oldest chariot complex was found associated with Sintashta culture, consisting of the weapons of a chariot warrior (bow, axe, spear) and the chariot itself with the necessary harness elements (Nelin, 1999, p.97). Numerous finds of arrowheads and unusual horn details of "compound" bows were found in 3 Sintashta burial complexes: Kamenny Ambar-5, Stepnoye M, and Solntse II. These finds illustrate the high importance of the bow among the warriors of this society. The authors of the discovery of bow parts created graphic reconstructions of a possible design. However, there was no practical reconstruction that could confirm the significance of this technological solution.

In January 2019, archaeologist Ivan Semyan (PhD c), head of the laboratory of experimental archeology of the South Ural State University Eurasian Studies Center, and his Greek colleague, archaeologist and director of the Association of Historical Studies Koryvantes - Spyros Bakas (MA), won a research “Twinning program” grant from the EXARC and began to develop a completely authentic reconstruction of the Sintashta type bow.

A wide range of consultants, bow-experts, archaeologists, and those who have dealt with issues associated with ancient bows, were involved in the project. The practical experimental experience of reconstructing bows from such an ancient era is unique. This initiative is the first attempt of a scientific reconstruction of the bow associated with the Sintashta culture. This type of bow appears to be potentially very important, since it provides information about the process of appearance and evolution of complex bows of the steppe breeders, and elucidate the special style of combat based on mobility and long distance in this culture.

Relevant finds

In the beginning, the study investigated the wide context of finds of bows of the Neolithic-Bronze Age in Eurasia. Archaeological data indicated the development of the self-bow in Mesolithic times (Shishlina, 1997, p.54). Bronze age cultures of the Steppes, like Yama, Catacomb, Andronovo, Novosvobodnaya, Abashevo, and Sintashta, deployed a slow but distinct technological bow-evolution of self-bows, in a parallel perspective with Western, Central, and Eastern Europe. In this context we can see the first archaeological findings of a new type of bow that emerged in the Steppes: the composite bow, which was shorter and more powerful than the regular self-bow. The most important archaeological findings can be summarized in the following table:

Chronology and Bow Type	Characteristics	Place / Culture and Reference
≈ 3.350 - 3.100 BCE (Selfbow)	"Hauslabjoch Bow" ("Ötzi bow"), likely an unfinished bow, made of yew ,182cm long, "D" Cross section.	Tisenjoch, Otztal Alps, South Tyrol / Italy. (Baugh, Brizzi and Baker, 2006).
≈ 3.150 BCE (Selfbow)	"Seefeld Bows", made of yew	Switzerland (Mills, 2000, p.77)
≈ 3.100 BCE (Selfbow)	"Mozartstrasse Bows", made of yew	Switzerland (Mills, 2000, p.77)
≈ 3.100 BCE (Selfbow)	"Horgen - Scheller Bows", made of yew	Switzerland (Mills, 2000, p.77)
≈ 3.000 BCE (Selfbow)	"Muldbjerk Bow", made of elm, 160cm long	Denmark (Mills, 2000, p.77)
≈ 3.000 BCE (Selfbow)	"La Neuveville Bow", made of yew	Switzerland (Mills, 2000, p.77)
≈ 3.000 BCE (Selfbow)	"Nidau Bow", made of yew	Switzerland (Mills, 2000, p.77)
≈ 3.000- 2.500 BCE (Self bows and potentially Composite bows)	Based on depictions of bows from Anthropomorphic Steles	Kernosovo, Verchorechnoye, Svatoovo / Ukraine (Shishlina, 1997, p.58)
≈ 3.000- 2.500 BCE (potentially Composite bow)	A depiction of a bow from a stone slab. Double concave bow	Novosvobodnaya / Russia (Shishlina, 1997, p.58)
≈ 3.000- 2.500 BCE (potentially Composite bow)	about 1m long, curved tips	Kemi-Oba Culture / Russia (Klochko, 2001, p.91)
≈ 3.000 - 2.000 BCE (Composite bow)	Generic type: Wooden core reinforced with bone plates. The length of the bow was 160-180 cm.	Baikal Lake / Russia (Shishlina, 1997, p.63)

≈ 3.300 - 2.600 BCE (potentially Composite bow)	Two Laminated wood layers, short size	Yamnaya culture / Poland (Klochko, 2001, p.191)
≈ 2.900 BCE (Selfbow)	"Hazendonk Bow", made of yew, fragment, handle area showing a defined grip, wide limbs.	Leiden / Netherlands (Mills, 2000, p.77)
≈ 2.800 BCE (Selfbow)	"Meare Heath Bow", flat bow made of yew, approximately 188 cm long, wrapped with 18 wide bands of rawhide	Meare Heath / UK (Comstock, 2000, pp.93-94)
≈ 2.800 BCE (Selfbow)	The bow from the "Schnidejoch" pass, made of yew and it was 160.5 cm long, the cross section is a narrow D-shape with a nearly flat belly side and slightly rounded corners	Switzerland (Junkmanns, et al., 2019, pp.285-288)
≈ 2.500-2.000 BCE (Laminate bow)	Bow with wooden core, the limbs of which were flexed back. The wooden core was made of several types of wood which were glued together and then wrapped in bark and sinew	Akkermen / Ukraine (Shishlina, 1997, pp.57)
≈ 2.500-2.000 BCE (Composite bow)	The bow has a concave form with the tips of the bow flexed back. The length of the preserved part is around 65 cm but the actual size is around 1 m. A bone plate appears to have supported the core, as a composite bow.	Bichkin-Buluk, Catacomb Culture / Russia (Shishlina, 1997, p.57)
≈ 2.500 - 2.000 BCE (Selfbow)	Generic type: Simple and segmented. Wooden core with notches for the string. The length of the bows are between 90-130 cm.	Catacomb Culture / Ukraine (Shishlina, 1997, p.57)
≈ 2.500-2.000 BCE (Composite bow?)	A thumb ring made of marble and two more thumb rings are indirect evidence for the existence of a composite bow	Catacomb Culture / Russia, Liventsovsk / Russia (Shishlina, 1997, p.57)
≈ 2.800 - 1.900 BCE (Selfbow)	1m long bow and 2.5 cm thick.	Ingul Culture, Crimea / Russia (Klochko, 2001, p.107)
≈ 2.800 - 1.900 BCE (Selfbow)	120cm longbow.	Ingul Culture, Crimea / Russia (Klochko, 2001, p.107)
≈ 2.800 - 1.700 BCE (Selfbow)	135cm longbow.	Catacomb Culture / Ukraine (Klochko, 2001, p.107)
≈ 2.800 - 1.900 BCE) (Selfbow)	144cm bow, curved back, flat inner side	Ingul Culture, Crimea / Russia (Klochko, 2001, p.107)
≈ 2.750 BCE (Selfbow)	"Utoqual bows", made of yew.	Zurich / Switzerland (Mills, 2000, p.77)

≈ 2.700 BCE (Selfbow)	"Sarnate Bow", made of ash, flatbow 144cm long, 5cm wide.	Latvia (Mills, 2000, p.77)
≈ 2.700 BCE (Selfbow)	"Robenhausen Bows", made of yew, several fragments, "D" cross section.	Switzerland (Mills, 2000, p.77)
≈ 2.650 BCE (Selfbow)	"Seefeld Bows", made of yew.	Switzerland (Mills, 2000, p.77)
≈ 2.600 BCE (Selfbow)	"Stadskanaal Bow", made of yew, narrow limb, "D" cross section, no defined grip, 171cm long, max width 2.5cm.	Assen / Netherlands (Mills, 2000, p.77)
≈ 2.600 BCE (Selfbow)	"Aschcott Heath Bow", made of yew, longbow type.	Somerset / UK (Mills, 2000, p.78)
≈ 2.550 BCE (Selfbow)	"Mythenschloss Bow", made of yew.	Zurich / Switzerland (Mills, 2000, p.78)
≈ 2.500 BCE (Selfbow)	"Spijkenisse Bow", made of yew, broken / Incomplete	Leiden / Netherlands (Mills, 2000, p.78)
≈ 2.500 BCE (Selfbow)	"Onstwedde Bow", "D" cross section, 149cm long	Assen / Netherlands (Mills, 2000, p.78)
≈ 2400 BCE (Selfbow)	"Ochsenmoor Bow", made of yew	Germany (Mills, 2000, p.78)
≈ 2400 BCE (Selfbow)	"Barry Brook Bow", made of yew, "D" cross section.	Ireland (Mills, 2000, p.78)
≈ 2400 BCE (Selfbow)	"Charavines Bow", made of yew.	Charavines / France (Mills, 2000, p.78)
≈2.200 BCE (Composite Bows)	Depictions of short angular composite bows in the "Victory Stele of Naram-Sin", and in the "Darband-i-Gawr bas" relief	Akkad Culture / Iraq (Randall, 2016, pp.82-83)
≈ 2.200-1.700 BCE (Selfbows)	"Loetschenpass bows", at least eight yew and elm bows, fragments, length varied roughly between 166 and 177 cm.	Switzerland (Junkmanns, et al., 2019, p.289)
≈ 2.250-2.000 BCE (Laminate or Composite bows)	A series of sixteen partially intact bow artifacts, consisting of two, or in one case three, pieces of overlapping antler, joined construction	Baikal Lake / Russia (Randall, 2016, p.62)
≈ 2.000 - 1.000 BCE (Composite bow)	A bone segment of a composite bow, 9.5 cm in length was found. A deep notch for the string in the "ears" of the bow.	Late Srubna Culture / Russia (Shishlina, 1997, p.63)
≈ (2.000 - 1.000 BCE) (Composite bow)	Flat bone plate with a notch for the string.	Potapovo I cemetery / Russia (Shishlina, 1997, p.63)
≈ 2.000 - 1.000 BCE (Composite bow)	Generic type: it had a notch for the string, horn or bone-made endplates and horn or bone-made middle plates placed on the handle.	Andronovo Culture / Russia (Shishlina, 1997, p.63)

≈ 2.000 BCE (Selfbow)	"Koldingen Bow", made of yew.	Germany (Mills, 2000, p.78)
≈ 1.800 BCE (Selfbow)	"De Zilk Bow", made of yew, broken but almost complete, estimated 160cm long	Leiden / Netherlands (Junkmanns, et al., 2019)
≈ 1.700 BCE (Composite bow)	Depiction on the "Phaistos Disc". Double concave shape. It is categorised as an "Asiatic composite" by Evans.	Minoan Culture, Phaistos / Greece (Evans, 1928, p.50)
≈ 1.730 BCE (Selfbow)	"Cambridge Fens Bow", made of Yew, no defined grip, estimated 152cm long	Oxford /UK (Mills, 2000, p.78)
≈ 1.680 BCE (Selfbow)	"Drumwhinny Bog Bow", 134cm long, "D" cross section.	Ireland (Mills, 2000, p.78)
≈ 1.500 BCE (Selfbow)	"Fiavve Carrera Bow", 134cm long, broken, "D" cross section.	Trento / Italy (Mills, 2000, p.78)

The role of the bow in Sintashta culture and Description of bow details

The vast open landscapes of the Trans-Ural steppe and the endless forest-steppe determined the use of a wide set of long-ranged weapons, mainly represented by the bow and arrow. The high importance of bows is traditionally noted for a number of cultures of the Southern Trans-Urals of the Bronze Age: Sintashta, Petrovka, Alakul, and Sargarinskaya.

The Sintashta culture contains the largest number of finds related to archery warfare. The arrowheads were made mainly of stone, but also bronze, bone, and even wooden types were identified. The high practical significance and semiotic status of long-range weapons is evidenced by the large number of finds of arrowheads in burials, as well as repeated detection of whole quiver sets and alleged bone details of bows (Epimakhov, 2011, p.106; Epimakhov and Semyan, 2016, p.77).

The total number of arrowheads that have been found in the burials of the Sintashta culture is more than 300 specimens. This count looks impressive both against the background of synchronous cultures of Eastern Europe, and subsequent cultures of the South Trans-Urals and Northern Kazakhstan. In 22 of the 56 male burials there were attributes of military affairs - 37.5% of men had associated arrowheads in the burials (see Figure 1).

Weapons in the Sintashta culture were found in almost all known cases in male burials however all men were not warriors. Household axes and other craft tools were a distinctive marker of male burials. Arrowheads were found in many burials, which may have been a hunting weapon and used to protect cattle from wild animals. Most likely, in this case, we are dealing with the burials of shepherds who were armed but were not professional warriors. Nevertheless, bows played an important role even in the lives of ordinary community members.

Despite the fact that the Sintashta society were not agriculturalists and were a completely cattle-breeding society they did not have a shortage of protein based food. The zooarchaeological evidence indicates that fish played a significant role in the nutrition of the society and in some of the burials, bones and canines of wild animals (saiga, elk, wild boar, bear, wolf, fox, etc.) were found.

Some male burials of the Sintashta culture can be confidently assigned to military burials. Unlike other male graves, these burials contained finds of specialized metal weapons, such as various types of spears and battle axes. Some of the burials had parts of a horse bridle and the remains of chariot parts. Interestingly, it was within these militarized burials that the richest sets of arrowheads were found, including exceptional massive stone arrowheads as well as bronze arrowheads (Gening, V.F., Zdanovich and Gening, V.V., 1992, p.321). Finds of “compound” bow details completed the picture of a unique Steppe type of military society.

The Sintashta era created cultural stereotypes of the Steppe population of Northern Eurasia, some of which existed for millennia. There is no doubt that they had a great influence on the type of military affairs at that time, where speed and mobility were important. The horse and the bow were the warrior's main allies. In the Sintshata era, a warrior on chariot would have struck his enemies with a bow (Kupriyanova, et al., 2017; Chechushkov and Epimakhov, 2018; Chechushkov, Epimakhov, and Bersenev, 2018).

At the moment we know that at the beginning of the second quarter of the 2nd millennium B.C. on in the territory of the Southern Urals and Northern Kazakhstan, horseback riding existed, and the bow became an even more important weapon. Armed shepherds became an even more dangerous force. This type of military science was adopted by the nomads of the early Iron Age and the Middle Ages.

Today, it is obvious that the rapid development of specialized weapons, the emergence of a chariot complex, and a unique tradition of strengthening settlements was connected with the Sintashta epoch. Despite the current progress in research, the degree of military influence on the structure of society and the organization of life of the population remains unclear. There is a paucity of information and studies on the production processes that directly affected the practice of using weapons, as well as the problems of the evolution of weapons. The method of experimental modeling can explore and increase foundation data to this knowledge gap.

A complex of horn parts from barrow 4, pit 13 of the Stepnoe burial ground was chosen as the object for reconstruction, since it seems to be the most structurally interesting and integral. The finds were located in one of the largest pits of the multi-grave mound. Numerous remains of sacrificial animals, including a whole skeleton of a dog, lay on the ceiling of the burial chamber. In ancient times, the pit was robbed. In the burial parallel to it were two disturbed bones of a male and a female aged about 9 years old. Despite the looting, a rich funeral inventory was preserved in the pit: 4 ornamented vessels, a horn harness detail with spikes, a wooden object with metal clips, stone tools, 13 arrowheads made of stone, bone, and horn, animal bones, and a piece of silver jewelry. The horn parts of the bow were located in different parts of the pit, which can be both a consequence of the looting, and a feature of the funeral ritual. Examples of ritual damage to weapons in Sintashta funeral practice are well known (Shevnina and Logvin, 2015).

The first item is an object of elaborate shape, it has a rectangular base and a massive S-shaped asymmetrical hook at its reverse side. This hook has a longitudinal grooved channel. The second item is two tips of a bow limb made of elk tines. The third item has a rectangular base with three transversal arranged salient edges, which form two 'cavities' (Bersenev, Epimakhov and Zdanovich, 2011, p.181). To unify the terminology and the convenience of the scientific description of the processes, we decided to use the following designations for bow details: the "S-hook device" as "Item A", the elk antler tips as "Item B", and the "arrow rest" as "Item C" (see Figure 2).

"Item A" was found at the feet of the male skeleton. "Item C" was located at the eastern end wall of the pit. The distance between the finds was 1.3 m. "Item A" had dimensions 70 x 35 x 25-27 mm. The base plate has a ledge, the end of the hook was cut flat, the groove on the back has a rectangular section. "Item C" had dimensions of 40 x 19 x 16 mm, it had a rectangular base in plan, which were integral with three transversely protruding "laths" that formed two "beds" for the arrow. The base had a longitudinal grooved shape. From the same burial there were two bow tip endings ("Item B") from the elk antler. They lay in the western half of the burial, parallel and close to each other, with sharp ends to the wall of the pit.

It is important to note that next to the objects were 10 arrowheads (7 of bone or antler and 3 of stone). The tips were not arranged on the floor of the pit, which was probably due to the looting. The parameters and sizes of the tips differed markedly. The lengths were 118 and 69 mm with similar outer diameters of 19-20 mm. Inside, both products had a blind conical sleeve, which, in the short tip occupied almost the entire internal space at a depth of 55 mm, but in the long specimen it did not exceed half of its length - 69 mm. The minimum wall thickness at the base was not more than 1 mm. Both artefacts had a through hole of a diameter of 6 mm closer to the end. The long specimen had a lateral notch, at the beginning of the sleeve which was probably lost from the short pommel in antiquity.

Theoretical Framework

Based on the archaeological evidence of the contemporary bow technology of the Eurasian basin and noting that the relevant Sintashta burials did not contain any evidence of rectangular or elongated horn/antler remnants (that could be associated with the composite bow technology), the project team postulated that the bow should be a rare case of a hybrid self-bow that used additional pieces to strengthen its mechanics and functions at the higher possible level for the archer.

Furthermore, the calculations of the possible maximum mass of an arrow with a flint tip of ≈ 100 grains, an average length of 27-28” (drawing at 26”), suggest a war-bow of 60+ lbs, of a long type (≈1.8m). Taking into account the rarity of this typology which does not fit in any other of the regular bow-categories which follows the terminology used in the past by Mason and Rodgers (Randall, 2016, pp.38, 40), the bow can be categorized with caution in the general term of “compound bow”.

In 1886, Mason outlined different methods of bow manufacture and was the first to describe a complex manufacture using the term "compound": “Bows made of two or more pieces of wood, baleen, antler, horn or bone fastened together” (cited in Randall, 2016, p.38).

In 1940, Rodgers attempted to combine the best features of the pre-existing systems of bow nomenclature and defined compound bows as “Bows in which the shaft is assembled from several short segments bound or riveted together” (cited in Randall, 2016, p.40). However, this terminology should not be confused with the modern term "compound", as this now refers to a bow that utilizes pulleys and cams such that it is easier to hold at full draw in exchange for a higher initial draw weight. In this concept the directive team were led to the experimental building of some of the versions of the bow - made only of wood, only supported by organic glue and sinew. By adjusting the different archaeological items (“Item A”, “B”, and “C”) in various combinations on the bow shaft, the team were able to investigate the mechanical and structural behavior of the bow, under controlled experiments shooting arrows (see Figure 3).

Preparation and materials

During the period June-September 2019, our working group in Russia, directed by the skilled master Mr Klim Abramov, produced exact replicas of the antler parts of the bow, based on the relevant burial findings. Three sets of “Item A”, “B”, and “C” were reconstructed using elk (Alces alces) antler and traditional techniques and tools. First, the master tested the technology of preliminary softening of the antler submerging it in water and boiling. But after drying, this material became brittle. Therefore, it was decided to work on a hard antler. A bronze axe of the Sintashta type was used for cutting. A replica of a bone saw found in the Sintashta settlement of Ustye was used for the sawing of the antler into parts (see Figure 4).

For the main procedure of the bow-building, our team cooperated with an experienced bowyer from Greece, Mr Ioannis Boukogiannis who had carried out the construction of the bow-shafts and the assemblage and adjustment of the different parts. For the construction of the bow-shafts of the first 3 versions we used native Greek elm wood (*Ulmus glabra*), a species which has a wide distribution (more so than European elm), ranging from the Urals to Southern Greece. It is considered appropriate in the manufacture of Neolithic bows, combining elasticity and compression resistance.

For the construction of the 4th Version of the bow-shaft we used native English ash wood (*Fraxinus excelsior*), one of the most common bow-making wood types in Eurasia. English ash is known for its high flexibility, shock resistance, and resistance to splitting. The acquiring of the proper elm and ash staves was, however, a difficult procedure for the team, as the staves should had been dried for several months prior to use. The selection of damp staves caused the breakage of five bows during the first reconstruction process which occurred between January-May 2020. The bowyer also used self-made leather glue and sinews, both extracted from deer, along with reconstructed woodworking tools of the Bronze Age: a bow-drill, saws, blades, chopper, axe, and knives. A series of modern typical woodworking tools were also used supportively when this could not have been avoided: metal screwdrivers, chisels, saws, rasps, hammers, mallets, planes (see Figures 5-6-7).

The bowyer used metal scrapers for the removal of the bark on the bow stave. The next step was to remove the inner bark which protected the outer growth rings of wood underneath. He then had to decide which side of the stave would form the belly and the back of the bow. Starting from the back, he shaped the preliminary limbs of the bow, thereby reducing its thickness. He crafted the stave so that it would be broad at the handle and slightly tapering at the ends of the limbs. By using a string and a pencil he marked the shape of each limb on the stave and worked for the final shaping.

When the bow was almost ready the items were glued in the bow-shaft with leather glue and wrapped with deer sinew which was dipped in the same glue. It should be noted that "Item A" and "Item B" were wrapped with sinew, and the limb became stiffer and more unbendable. The bow was then rested in a dry place for 10 days in order that the sinew to be properly dried. Then the tillering followed: a method by which one can check the tiller of the bow and the evenness of the distribution of the load when the bow is drawn. The bowyer gradually increased the draw, until the bow became fully drawn and the load of the bow was evenly distributed.

The shape of the cross section of the four reconstructed bows followed the same pattern. The bowyer managed to form a round rectangle cross section for the limbs, and an increased thickness in the center of the bow as a grip. The special characteristics of the "Item A", having a longitudinal grooved channel apparently to achieve a maximal tight adhesive joint where it is attached to the wooden base, required a specially shaped surface in the bow shaft for the perfect attachment of the two materials. In the middle of the length of this elongated surface the recessed hole for a fixing pin (square in plan) was fixed with an insert pin which was fastened also in a socketed hole that was drilled in the bow shaft. In the cases of using "Item B" (Bow Version #1, Version #3 & Version #4), the bowyer formed the relevant end of the bow shaft as a conical projection, that was fixed in the socket of the item. Finally, the bowyer used artificial string for the bracing of the bows.

The arrows that were used for the testing of the bows were reconstructed in February 2020 in Greece, by Spyros Bakas. The final result had to be aligned with the technology of the Sintashta material culture and the contemporary bow technology of the Eurasian basin, so special attention was given to the technical details and the materials that were used.

The arrowheads that were used were replicas of different sizes of the original flint arrowheads that were found in the relevant burials and were made by Ivan Semyan. The arrowheads were tanged, ranging between 45-60mm in length, 15-22mm in width, 3-4mm in thickness and 60-110g in weight. The shafts were following the modern pattern of 11/32 thickness (⌀8.5mm) and were made of regional dried pine wood (*Pinus sylvestris*), a species native to Eurasia, with a distribution from Western Europe to Eastern Siberia and Balkan Mountains (North Greece).

The arrowheads were attached in the shafts with birch tar and were wrapped with sinew dipped in leather glue. Natural goose fletching of 4" was used, attached on the shaft with leather glue and fastened with sinew. Finally, the arrows had self nocks wrapped with sinew for extra rigidity. The shafts were matched to the special weight of each arrowhead, adjusting the relevant spine (ranging between 60-75). The final outcome was eight functional arrows that ranged between 27"-29" in length, to provide clear shots at 26", for a bow draw weight which ranged between 64-72 pounds (at 26") (see Figure 8). This is also aligned with the supposed maximum length (27") of the original arrows of the Sintashta burials (Bersenev, Epimakhov and Zdanovich, 2011, p.180).

Relevant experimental reconstructions and tests on Paleolithic/Neolithic/Bronze Age bows have been conducted in the past (Clark, 1963; Prior, 2000a; 2000b; Hulit, 2002; Howe, 2017). Our team consulted the technical sequence of these works and adapted to the particular features required by the project.

The reconstruction

Version 1

Version #1 bow was constructed in late May 2020 and followed the relevant pattern described by Bersenev, Epimakhov and Zdanovich (2011). The reconstructed bow was made of elm wood that had been dried for 10 months. "Item A" was placed in the outer side of the top end of the bow in the specifically flat shaped surface of the bow-shaft. "Item B" was adjusted in the lower end of the bow ensuring a firm fastening of the bow string. As Bersenev, Epimakhov and Zdanovich have noted previously (2011, p.184), the duality of finds and their location side by side is indirect evidence of this version.

"Item C" was adjusted in the central part of the bow, above the grip, resulting in a peculiar "arrow rest". The final outcome was a bow of 182 cm in length and a 72-pound draw weight

(26”). The bowyer managed to tiller the bow, and then the bow was put into the first preliminary tests by shooting the experimentally reconstructed arrows in a draw length of 26”. From mechanics’ perspective, “Items A” and “B” offered an enhanced stiffness and did not allow the smooth bending of the limbs, while the extra mass of “Item A” caused significant imbalance. Soon the experimental shots confirmed our fears, as “Item A” provided significant vibrations and hand shocks, the bow broke above the base of the upper limb (see Figure 9).

Version 2

“Version 2” bow followed the relevant pattern of Zdanovich (Bersenev, Epimakhov and Zdanovich, 2011, p. 185) (Variant 2 / Type 2) and was constructed in the first half of June 2020. The reconstructed bow was made of elm wood that had been dried for 10 months. Zdanovich maintains “Item A” in the upper limb but on the inner side of the bow. His innovative proposal is that “Item C” could have a different usage, where its laths were performing more like string notches and that it was placed in the end of the lower limb. Furthermore, he suggests that the lath served to fasten one end of the string tightly and the S-shape top-end was used to put the bow in a run position with a detached string (Bersenev, Epimakhov and Zdanovich, 2011, p.185). All of the items were glued in the bow-shaft with leather glue and wrapped with deer sinew which was dipped in the same glue. The final outcome was a bow of 180 cm in length, and a 65-pound draw weight (26”).

The directive team made an amendment to Zdanovich's version and placed “Item A” in the outer side of the bow. Otherwise, the bow would not have performed safely: there was critical danger that under significant pressure the item could be detached from the bow shaft and cause severe injury. The tiller was adjusted, and the bow was put to test. The bow unexpectedly performed comparatively satisfactorily during the experimental shots, as the placement of “Item C” in the bottom end of the bow provided more elasticity and bending efficiency on the lower half of the bow. While drawn, the bow was forming an asymmetrical bending due to the stiffness of the top end of the upper limb (caused by “Item A”). During the shots, the vibrations were considerably less this time, but still the mass of “Item A” caused the bow to lean forward at the “follow-through” procedure (see Figure 10).

Version 3

Version #3 was constructed in June 2020 and was inspired by the relevant work of H. Paulsen (Paulsen H., 1999, p. 99.). The bow was modified accordingly with input from the directive team. This modified version involved placing “Item A” in the outer side of the upper half of the upper limb, so that we would test the possibility that this device would perform as a peculiar “string-hanger” – i.e. when the bow would be hung from the archer's back.

The upper tip of the bow was reinforced with a small deer antler tip. “Item B” was adjusted in the lower end of the bow ensuring a firm fastening of the bow string, while “Item C” was adjusted in the central part of the bow, above the grip, performing as a peculiar “arrow rest”.

At this point, we investigated if a device (“Item A”) could be adjusted on the bow but would interfere with the bow mechanics. The final outcome was a bow of 182cm in length, and a 70-pound draw weight (26”). The experimental shots soon produced obvious difficulties, as “Item A” operated as a "splint" for this small section of the bow and prohibited the proper bending of the limb.

When drawn, the bow was forming an uneven curvature on the upper half and highlighted the fact that this modification worked against the bow-mechanics. During the experimental shots, the vibrations were sufficient enough to destabilize the bow at the “follow-through” procedure and sufficiently interfered with the normal operation of the bow (see Figure 11).

Version 4

After the practical functional failure of Version #1 and by realizing its inherent defects, the team proceeded to develop a new theory, which was an upgraded modification of Version #1.

The bow was constructed and tested in August 2020. Due to the fact that “Item A” provided extra mass on the end of the limb causing significant imbalance and vibrations, the bowyer proposed the diametrically opposite placement of “Item A” and “B” and the construction of asymmetrical limbs: “Item A” was now placed in the end of the lower limb while the lower limb was made slightly shorter in length. The latter was done to achieve the maximum possible stiffness and to avoid the possibilities of vibrations.

“Item B” was placed in the top end of the upper limb, which had the regular length from the previous versions. The final outcome was a bow of 187 cm in length, and a 64-pound draw weight (26”) (see Figure 12).

The results through the experimental shots were comparatively quite satisfactory. When drawn, the asymmetric bow formed a smooth proportional curvature. During the experimental shots, the bow showed remarkable mechanical output, performing under a constant functional repeatability.

“Item A” enhanced the stability of the bow, as it moved the center of mass of the bow to a lower position. The vibrations and hand-shocks, presented in previous versions, were quite limited and the ‘follow-through” movement was more balanced.

“Item C” also performed quite well as an arrow-rest. The choice of the placement of the arrow in the three formed laths of the item, offered three different scaled levels which affected the range of the shot in an absolutely effective way.

When the arrow was placed in the lower lath, it was connected with a shot of a close range (<20 m). Putting the arrow in the upper laths connected with targets that were at a long range and required a lifting incline for the arrow. The experimental shots using all the different levels proved the potentially functional use of the item in this way (see Figure 13).

Evaluation

Usually, to study a phenomenon requires direct observation of the object of study to determine its parameters and properties. We cannot do this in 'real time', but can use experimental archaeological methods and techniques to gain insight into ancient societies and their cultures. Therefore, the main task of the researcher is to create, using archaeological data and other objective indicators, a theoretical image of the object of study.

In this case, it is a set of archaeological experiments which are designed to simulate processes and specific physical objects of the past, generate and test hypotheses, and establish the reliability of the researchers' interpretation which accounts for error in the conclusions.

The research team followed the procedural rules of experimental archaeology as defined by Coles (Coles, 1973, pp.15-18). The materials used in the experiments were locally available to the ancient society of the Sintashta culture: pine, elm and ash wood, deer sinew, leather (deer) glue, elk and deer antler, stone, resin, and tar.

The methods used in the experiment for the reconstruction of the bows did not exceed those presumed to have been within the competence of the ancient society. Replicas of tools for wood and antler carving, bow-drill for hollowing the antler, a string-knitting device, an axe, a saw, special knifes and choppers, were strictly used throughout the whole procedure.

Modern technology and materials were used infrequently and had little interference with the reconstructions and when partially used (woodworking tools) these tools assisted in the further understanding of the materials and the methods of the original item.

The scope of the experiment was assessed before the start of the experimental process:

- the reconstruction of different variations of the bow,
- bow testing in terms of functionality and performance using reconstructed arrows,
- the decoding of the usage of the different pieces of the bow and revealing its original form.

The experimental reconstruction of each version was successive, following the reconstruction knowledge acquired by the previous reconstruction attempts (i.e. versions). The experimental work was undertaken with a desired result in mind, but improvisation was constantly considered and applied if needed.

The experimental reconstructions and tests consisted of a series of observations that led to certain conclusions, but absolute proof cannot be assumed or claimed. Finally, the experimental process was assessed by our research team in terms of its reliability that the adopted procedure was appropriately conceived and honestly applied, and that the results were observed and assessed fairly.

Conclusions

The conducted research offered a multi-dimensional approach on the unknown Sintahsta bow technology. The reconstruction perspective of this research centered around the willingness to develop the existing theoretical framework and to submit additional knowledge and practical information.

The questions that urged the initiative of this research still remain: Could “Items A”, “B” and “C” have been parts of a bow? And if yes, how did they interfere with the bow mechanics in a functional way? Regarding the first question, the traceological analysis of the examples of the three original items could provide valuable information on the better understanding of their function.

By closely examining their working surfaces we can see that “Item A” (Solntze II cemetery) had clear shock-absorbing properties, since a wearing down (and loss) of parts of the item’s material was visible. Taking into consideration the high level of hardness of the used material, it was possible to assume that the functional stress on this structural bow part was enormous. Thus, highlighting the use of a strong bow.

Furthermore, the use-wear traces on the hollow of the winding hook of the top-end displayed a clearly defined direction of abrasion: the first one on the right, the second one on the left. According to Bersenev, Epimakhov and Zdanovich (2011, p.184), this wear pattern appeared to show evidence for different bow modifications: for a right handed and for a left handed archer, indicating that the line of the string projection was not aligned with the bow shaft .

Traces of usage on “Item C” (Stepnoe-M cemetery) were clearly observed on the middle and inner parts of the low edge of this piece. A wear-down of up to 0.5–0.8 mm of the walls were observed, this ostensibly proves a theory of usage of this bow element as an arrow rest during the shooting (Bersenev, Epimakhov and Zdanovich, 2011, p.184). The experimental traceological tests supported the above observations. The team used colour on the string to indicate the direction of the paint line that is being formed when the string is being placed on “Item A”. After dozens of shots the linear features that were created resembled the form of the hollow slope of the original “Item A”. Alongside this, the team researched the traceological evidence on “Item C”, by shooting a series of shots. The results were aligned with the traceological observations of the original items. The surface of the laths presented indications of wear down, resembling the same linear features that appeared in the item of the Stepnoe-M cemetery (see Figures 14-15).

We considered the Items as potential functional equipment pieces of a bow, thus, the next step was to follow the experimental reconstructions and shooting-tests to research the mechanics and performance outputs of the bow under different assembled combinations. As been described above, only Version "4" of the bow provided unequivocal prospects of functionality. During the experimental tests, Version #4 proved a decent performance and a satisfactory repetitive stability.

"Item C" practically performed as a simplified mechanical innovation, as it offered a critical benefit in shooting at targets at scale distances. It therefore acted as a proportionate modern "shooting diopter" which had to be adjusted according to each shooting distance.

On the other hand, "Item A" had a potential dual use. Firstly, it provided an additional small extra weight and mass to the lower limb of the bow, so that the center of mass of the bow would go in a lower height. This is of course was enhanced by the fact that the lower limb was unequal (i.e. shorter) than the upper one and became more stiff resulting in the bow achieving increased stabilization and was balanced in comparison with the previous 3 Versions.

Secondly, "Item A" with its inherent special characteristics was always performing as a device for easy attachment and removing of the loop of the string of the bow. The bow had the firm string fastened in the upper end of the limb and an easily detachable point on the other side, thus helping the warrior to use the bow in a more flexible way during fighting.

The dual uses of the "Item A", were indirectly associated with the theory of the extensive use of war-chariots by the Sintashta warriors. The Chariot warfare requires constant motion, mobile conflicts and a warrior that can easily adopt different styles of fighting during the battle. It is possible that the warrior would need to easily change weapons in the battlefield – thus a strong war-bow that could be easily braced and unbraced would be a very good selection for his armory. Furthermore, the fact that the lower limb is unequal/shorter than the upper one, maybe this is an indication of a preliminary realization of one of the basic principles of the war-chariotry: the need of small-sized bows. The bow limbs must be short enough and able to perform in a narrow space, as otherwise they would interfere with the chariot's box.

Placing the bow in the context of material culture and taking into account the current research, it is likely that we have evidence of a very unique case of a bow, which was part of an evolutionary process that took place in Eurasia during the Bronze Age. The fearsome warriors of the Sintashta culture along with their experimentation in using the chariot for warlike reasons probably also experimented with weapons.

The technology of the standard composite bow, which highlighted the much more simplified construction process of a shorter and maybe more powerful bow, dominated the warfare preferences of the people of Eurasia. The possibility of the existence of the Item "C" bow shows the introduction of significant technological intelligence which reappeared in the archery world after almost 4 millennia and resulted in the establishment of the modern Olympic archery.

The Sintahsta bow could have been a special case of bow type, beyond the framework of the common typology and must be always considered within this context. Hopefully, the archeological research will be able to add more knowledge in the future, so that we can theorize, with support, the true nature of the bow. The present research hopes that it will be a step in the research effort of future scholars who could explore further, through new bow experiments.

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Keywords bow and arrow
(re)construction

Country Russia

Glossary

Self bow: Plain wooden bow consisting of a single piece of wood (Randall, 2016, p.41)

Laminate bow: A bow of identical or nearly identical materials (typically wood) which have been laminated together, creating additional thickness (and at times width) rather than length (Randall, 2016, p.41)

Composite bow: A laminate bow, the working portion of whose limbs consist of more than one type of material such as wood, sinew, and horn, or two or more woods with different material properties such that overall materials strength of the bow is increased (Randall, 2016, p.41)

Compound bow: Bows in which the shaft is assembled from several short segments bound or riveted together (Rodgers, 1940 cited in Randall, 2016, p.40)

Bibliography

Baugh, D., Brizzi, V. and Baker, T., 2006. Ötzi's Bow. *Bulletin of Primitive Technology*, 31, pp.46-49.

Bersenev, A., Epimakhov, A. and Zdanovich, D., 2011. *The Sintashta Bow of the Bronze Age of the South Trans-Urals, Russia.* In: M. Mödlinger, M. Uckelmann and S. Matthews, eds. *Bronze Age warfare: manufacture and use of weaponry*. BAR International Series, 2255. Oxford: Archaeopress. pp.175-186.

Chechushkov, I.V. and Epimakhov, A.V., 2018. Eurasian Steppe Chariots and Social Complexity During the Bronze Age. *Journal of World Prehistory,* 31, pp.435-483.

Chechushkov, I.V., Epimakhov, A.V. and Bersenev, A.G., 2018. Early horse bridle with cheekpieces as a marker of social change: An experimental and statistical study*. Journal of Archaeological Science*, 97, pp.125-136.

Clark, J., 1963. Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe. *Proceedings of the Prehistoric Society*, 29, pp.50-98.

Coles, J., 1973. *Archaeology by Experiment*. London: Hutchinson.

Comstock, P., 2000. Ancient European Bows. In: J. Hamm, ed. *The Traditional Bowyer's Bible, Volume 2*. New York: Lyons Press. pp.81-112.

Epimakhov, A.V., 2011. Some issues of reconstruction of the parameters of Sintashta remote weapons (methodological aspect). *Chelyabinskij gumanitarij* [*Chelyabinsk Humanities*], 16, pp.106-115.

Epimakhov, A.V. and Semyan, I.A., 2016. The arrowheads of the Kamenny Ambar settlement and some remarks about the war in Sintashta society. *Ural Historical Bulletin*, 53, pp.77-84.

Evans, A., 1928. *The palace of Minos. A comparative account of the successive stages of the Early Cretan civilization as illustrated by the discoveries at Knossos. Volume 2, Part 1, Fresh lights on origins and external relations*. New York: Cambridge University Press.

Gening, V.F., Zdanovich, G.B. and Gening, V.V., 1992*. Sintashta. Archaeological monument of the Aryan tribes of the Ural-Kazakhstan steppes*. Chelyabinsk: Yuzhno-Ural'skoe knizhnoe izdatel'stvo.

Howe, D.I., 2017. *A Controlled Archery Experiment to Determine the Presence of the Bow in Prehistoric North America*. MA. University of Wyoming.

Hulit, T.D., 2002. *Late Bronze Age scale armour in the Near East: an experimental investigation of materials, construction, and effectiveness, with a consideration of socio-*

economic implications. PhD. Durham University.

Junkmanns, J., Klügl, J., Schoch, W., Di Pietro, G. and Hafner, A., 2019. Neolithic and Bronze Age Archery Equipment from Alpine Ice-Patches: A Review on Components, Construction Techniques and Functionality. *Journal of Neolithic Archaeology,* 21, pp.283-314.

Klochko, V., 2001. *Weaponry of the Societies of the Northern Pontic Culture Circle: 5.000-700 BC*. Baltic-Pontic Studies, 10. Poznań: Adam Mickiewicz University.

Kupriyanova, E., Epimakhov, A., Berseneva, N. and Bersenev, A., 2017. Bronze Age Charioteers of the Eurasian Steppe: A Part-time Occupation for Select Men? *Praehistorische Zeitschrift*, 92(1), pp.40-65.

Mills, T., 2008 A Copper Age Bow. In: J. Hamm, ed. *The Traditional Bowyer's Bible, Volume 4.* Guilford, CT: Lyons Press. pp.75-90.

Nelin, D.V., 1999. *Armament and military affairs of the population of the South Trans-Urals and Northern Kazakhstan of the Bronze Age*. Dissertation abstract for the PhD degree in Bashkir state university Ufa.

Paulsen H., 1999. Pfeil und Bogen in Haithabu. Berichte uber die Ausgrabungen in Haithabu. Bericht 33. Neumünster : Wachholtz, pp. 93-143.

Prior, S., 2000a. The skill of the Neolithic bowyers: Reassessing the past through experimental archaeology. In: C.J. Webster, ed. *Somerset Archaeology: Papers to mark 150 years of the Somerset Archaeology and Natural History Society*. Taunton: Somerset County Council. pp.19-24.

Prior, S., 2000b. Recreating the Neolithic Meare Heath Bow: Reassessing the past through experimental archaeology. *Journal of the Society of Archer-Antiquaries*, 43, pp.44-48.

Randall, K.C., 2016. *Origins and Comparative Performance of the Composite Bow*. PhD. University of South Africa.

Shevnina, I. and Logvin, A., 2015. *Bronze Age burial ground Halvay III in North Kazakhstan*. Materials and researches of archeology of Kazakhstan, 7. Astana: Branch of Institute of Archaeology named after A.Kh. Margulan.

Shishlina, N., 1997. The bow and arrow of the Eurasian Steppe Bronze Age nomads. *Journal of European Archaeology Archive*, 5(2), pp.53-66.

Corresponding Author

Ivan Semyan
Institute of Archaeology and Ethnography NAS RA
15 Charents St
Yerevan
Armenia
E-mail Contact

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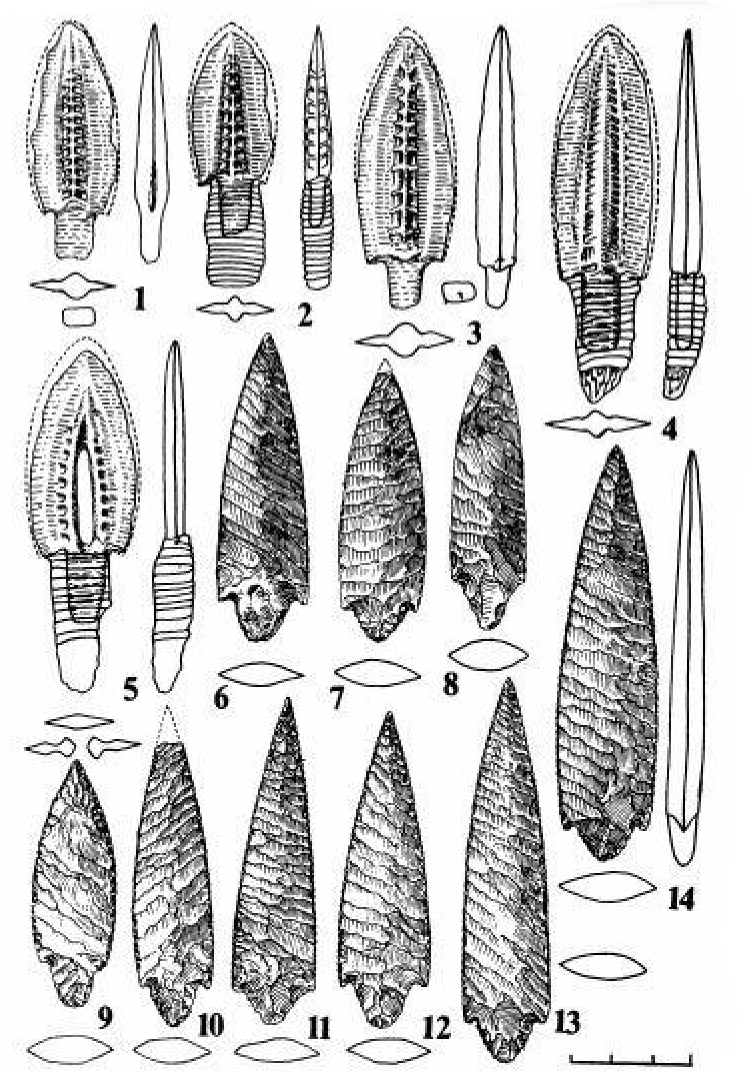

FIG 1. A SET OF DIFFERENT ARROWHEADS OF THE SINTASHTA CULTURE. (AFTER GENING ET ALL, 1992, 321)

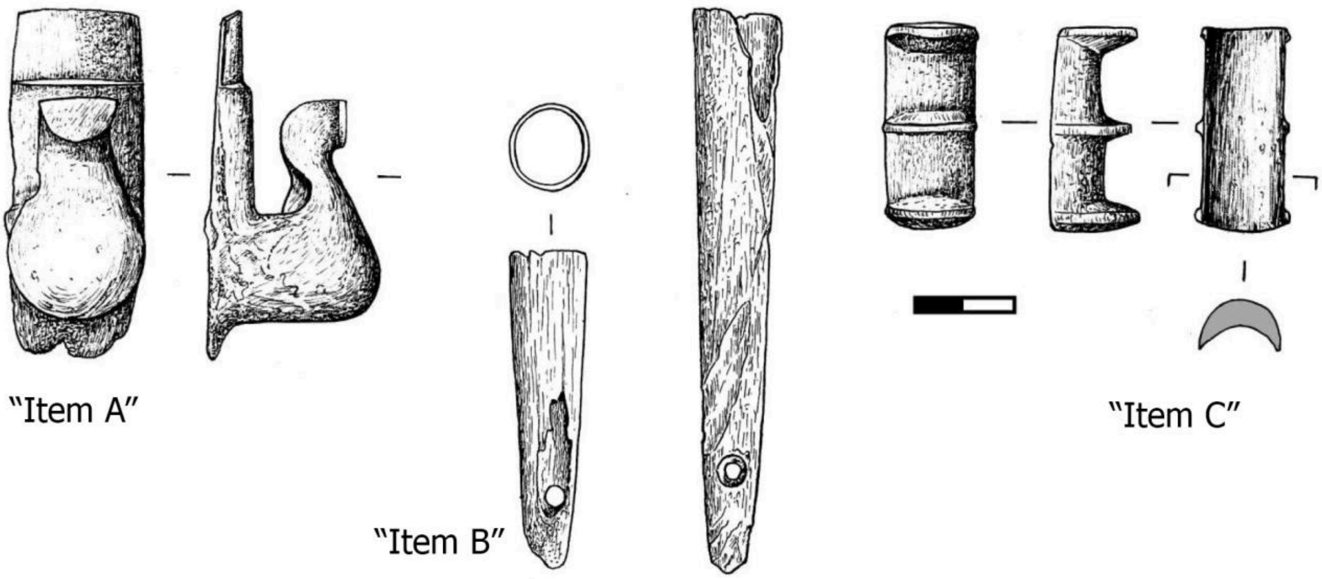

FIG 2. PARTS OF THE SITASHTA BOW (AFTER BERSENEV ET ALL. 2011, 180,182).

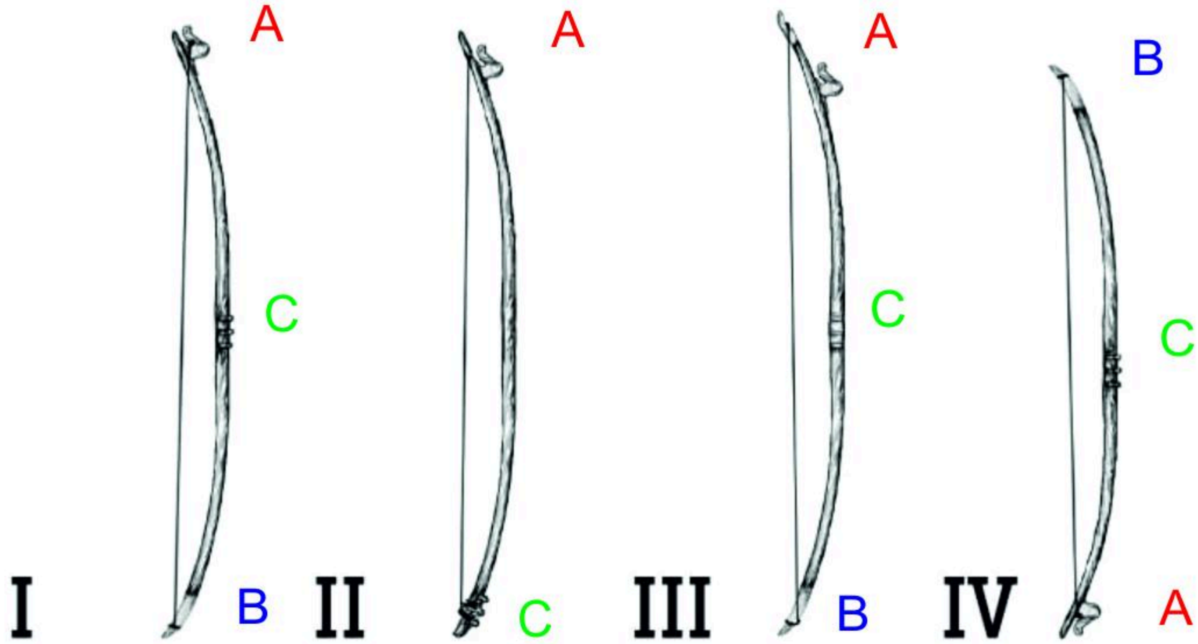

FIG 3. THE SCHEMATIC DEPICTIONS OF THE FOUR RECONSTRUCTED VERSIONS OF THE SINTASHTA BOW (VERSIONS OF THE BOW. DRAWINGS BY ANTON SUVOROV)

FIG 4. RECONSTRUCTED REPLICAS OF THE "ITEM A".

FIG 5. MOMMENTS OF THE RECONSTRUCTIONAL PROCESS. WORKING ON THE ELK HORN WITH A CURVED BLADE ("ITEM B").

FIG 6. MOMMENTS OF THE RECONSTRUCTIONAL PROCESS. MEASURING AND PRELIMINARY PLACEMENT OF THE "ITEM A" ON THE SHAFT.

FIG 7. MOMMENTS OF THE RECONSTRUCTIONAL PROCESS. ADJUSTING THE "ITEM C" ON THE SHAFT.

FIG 8. RECONSTRUCTED ARROWS DURING THE EXPERIMENTAL SHOTS.

FIG 9. PRELIMINARY TESTING OF THE VERSION 1 BOW, BY JOANNIS BOUKOGIANNIS. PHOTO BY SPYROS BAKAS

FIG 10. EXPERIMENTAL TESTING OF THE VERSION 2 BOW, BY SPYROS BAKAS. PHOTO BY ELENA ANTONIADOU

FIG 11. EXPERIMENTAL TESTING OF THE VERSION 3 BOW, BY SPYROS BAKAS. PHOTO BY ELENA ANTONIADOU

FIG 12. EXPERIMENTAL TESTING OF THE VERSION 4 BOW, BY SPYROS BAKAS. PHOTO BY ELENA ANTONIADOU

FIG 13. EXPERIMENTAL TESTING OF THE VERSION 4 BOW, BY SPYROS BAKAS. THE ARROW SHAFT IS GUIDED BY THE LATHS OF THE "ITEM C". PHOTO BY ELENA ANTONIADOU

FIG 14. TRACEOLOGICAL EXPERIMENT PART A. THE TEAM USED COLOUR ON THE STRING TO INDICATE THE DIRECTION OF THE PAINT LINE THAT IS BEING FORMED WHEN THE STRING IS BEING PLACED ON “ITEM A”.

FIG 15. TRACEOLOGICAL EXPERIMENT PART B. THE LINEAR FEATURES THAT ARE BEING CREATED RESEMBLE THE FORM OF THE HOLLOW SLOPE OF THE ORIGINAL “ITEM A”.