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IDENTIFYING AND STUDYING BOW & ARROW SYSTEMS IN THE IÑUPIAT ETHNOGRAPHIC COLLECTIONS FROM THE 19th CENTURY

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INTRODUCTION

Neo-Inuit cultures of the 1st and 2nd millennium AD used and propagated the technology of the « free-backing bow » on the entire Alaskan coastline until guns were introduced ca. 1870's :

▻ A reinforcement of sinew cables tied on the back of the bow and the use of *siyah** on curved limbs (fig.1) were key technological innovations in the archers' ability to use powerful bows while making the best use of the limited materials available in the arctic environment.

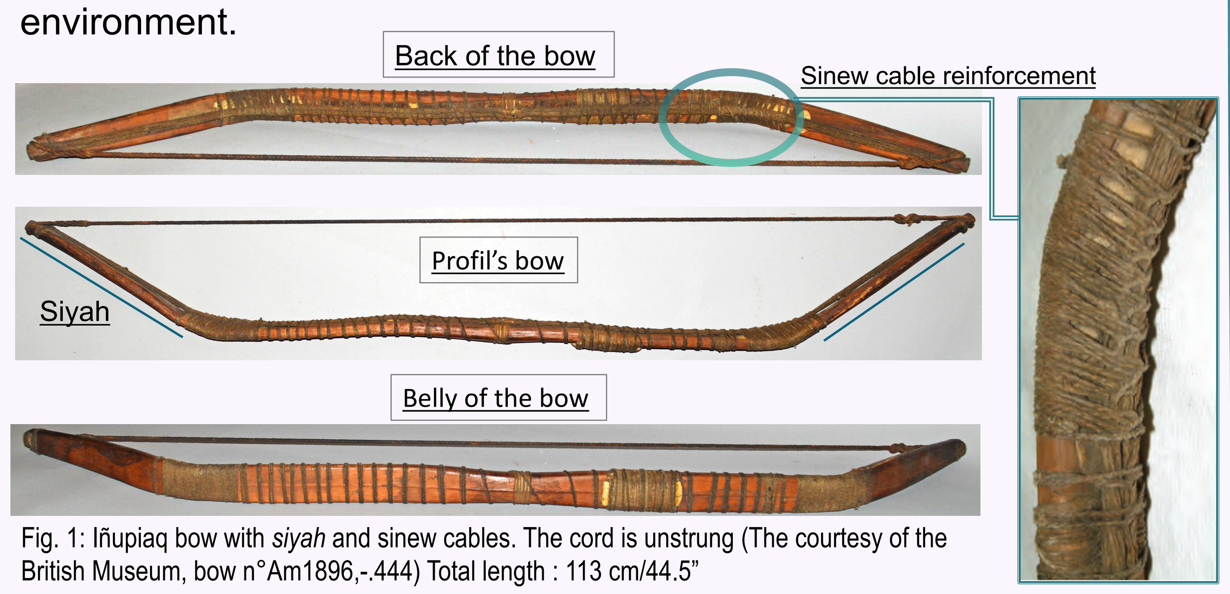


Fig. 1: Iñupiaq bow with *siyah* and sinew cables. The cord is unstrung (The courtesy of the British Museum, bow n°Am1896,-.444) Total length : 113 cm/44.5"

▻ In 19th century Iñupiaq ethnographic collections, bows and arrows show strong variability in terms of morphologies and assembly techniques[1] (fig.2).

▻ Variabilities in the technology have been analyzed according to regional and chronological typologies[1,2], most often by looking independently at the bow and/or arrow.

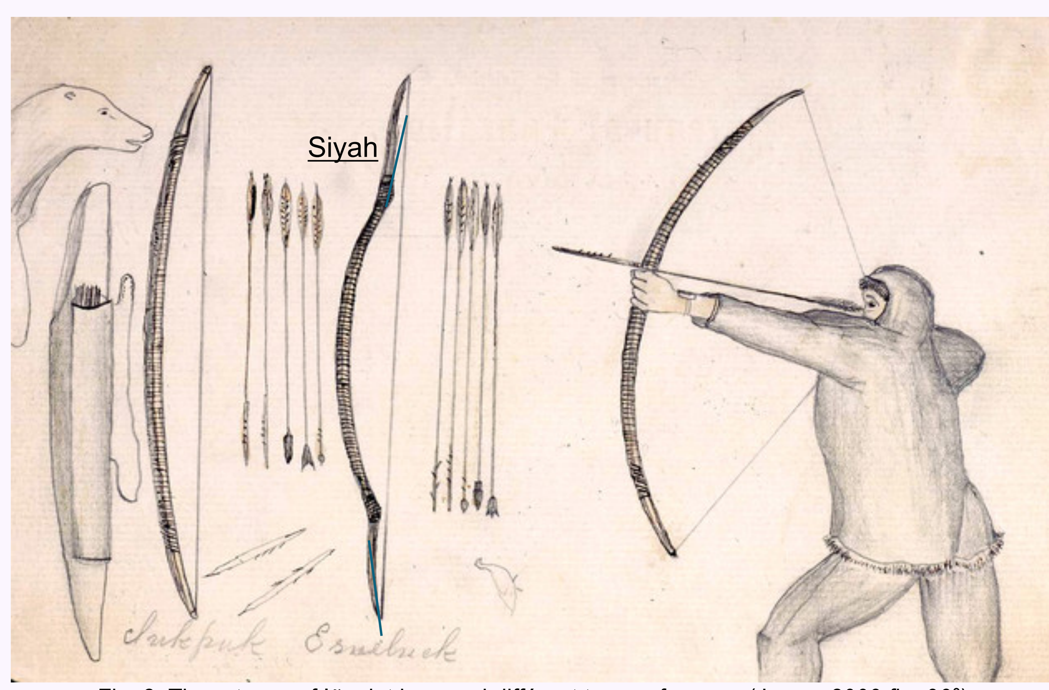


Fig. 2: Three types of Iñupiat bow and différent types of arrows (Jones, 2003 fig. 36[3])

▻ The bow and the arrow (B&A) depend on each other and work jointly to fit the archer's needs and abilities, by forming one **technical and mechanical system**.

RESEARCH GOALS

▻ Demonstrate the utility of developing an analytical protocol that combines typology, technology, mechanics and ballistic for the study of the bow and the arrow conjointly to understand both items as part of possible systems fitted to the archers and their activities (hunting or wage war).

▻ Identify and discuss the technical and mechanical choices involved when archers creates system(s) that meets their needs.

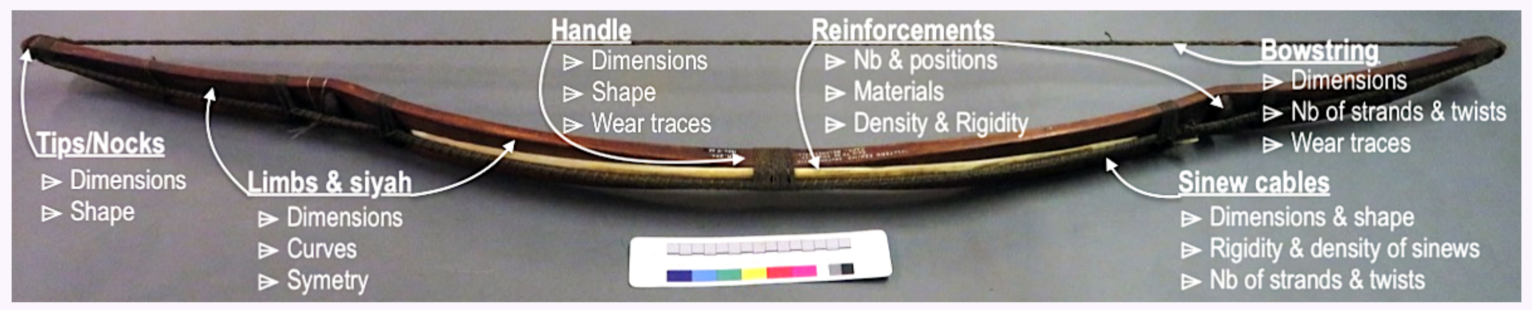
MATERIAL & METHODS

▻ A sample of 4 bows and 18 arrows from the W. Beechy, E. Belchers and J. Barrow (1808-1898) collections presently held at the Pitt Rivers Museum in Oxford[4] and the British Museum in London, GB.

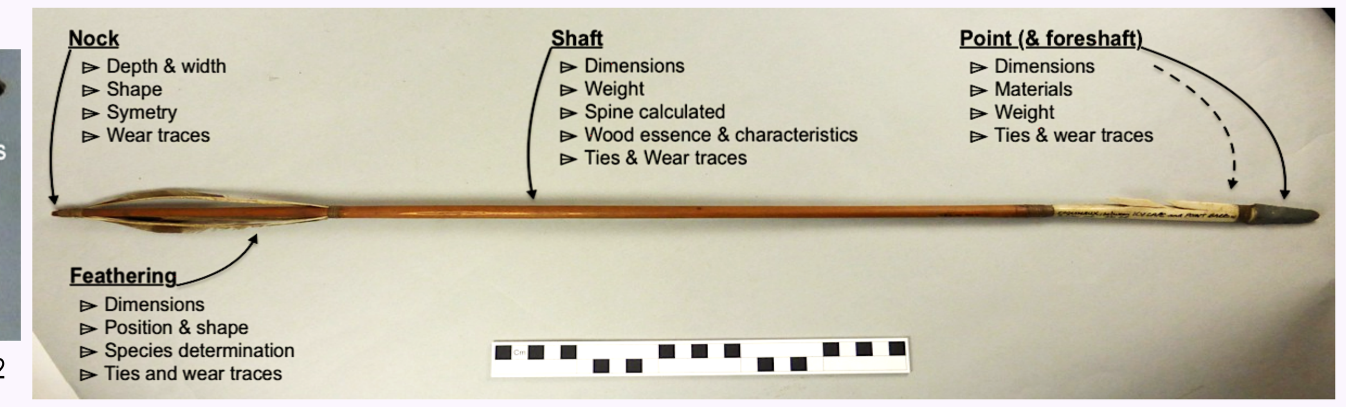
▻ We created a three-fold analytical protocol based on bow and arrow settings used in contemporary traditional archery

(1) Morphological and dimensional recordings :

Fig.3 et 4 show the multiple characteristics and their measurements systematically recorded on key elements of the bow and the arrow.



(the courtesy of the Pitt Rivers Museum, University of Oxford) ; bow n°1884.15.23, arrow n°1884.10.902.2



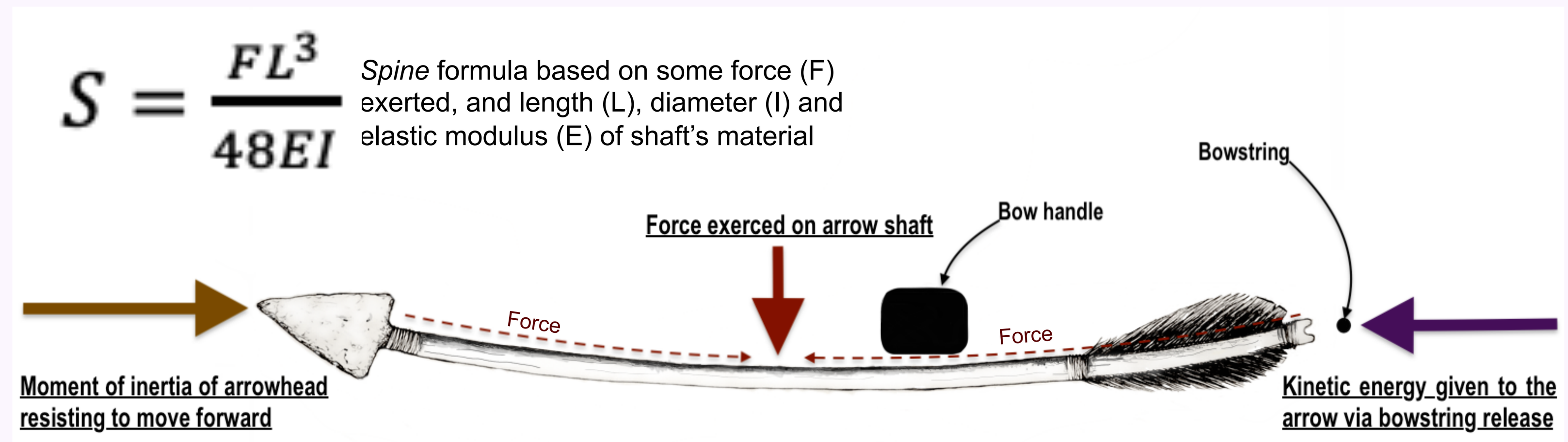


Fig. 5: Diagram of the archer's paradox during arrow release. Spine calculation reproduce its effect (drawing by C. Lemaitre, not to scale).

(2) Calculations of mechanical properties

▻ In archery, the arrow *spine* (fig.5) is a fundamental mechanical element that measure arrow's flex during the exercise of a force applied in its middle. It represents the rigidity of the shaft and its capability to bent during the release of the cord. The more rigid an arrow, the more it need to be shot with a powerful bow, and *vice versa*. Matching the arrow *spine* to the bow's proper draw weight (in lbs #) of the bow helps prevent fractures of either, improve accuracy, and limits the effect of the archer's paradox*.

(3) 3-D modelling of ethnographic bows and simulations

▻ The analyzed ethnographic bows are 3-D modeled using the systematic recordings of shape and dimensions.

▻ We used *VirtualBow,* a software designed by Stefan Pfeifer, to simulate the draw of a 3-D modeled bow (fig.6) shooting a fictitious arrow.

▻ *VirtualBow* allows visualizing 1) the power of the bow at a given draw length, 2) the exit speed of the arrow, 3) the force exerted on the limbs' sinews and cord during drawing and shoot, among other things.

☞ These simulations only measure the "interior ballistic"*

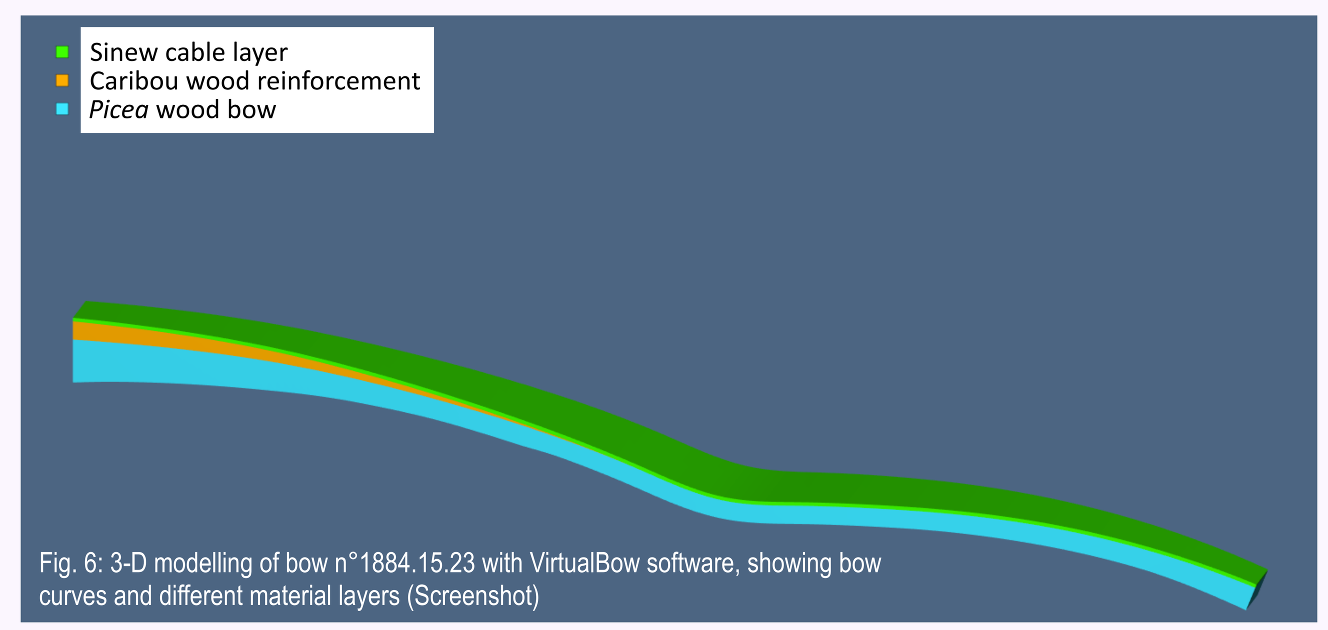


Fig. 6: 3-D modelling of bow n°1884.15.23 with VirtualBow software, showing bow curves and different material layers (Screenshot)

PRELIMINARY RESULTS

(1) Arrows showed a variability in dimensions, but we noticed a correspondence between length and diameter of the shaft. It is a sign that archers selected arrows *spine* matching their bow and draw length.

(2) The simulated mechanical performances of the four modeled ethnographic bows are high and show strong draw weights (ca. 60# to 110#) pointing to their use by adults with relatively good shooting skills.

(3) Only four of the 18 analyzed arrows share appropriate length and *spine* to be shot with the analyzed bows. Another five smaller arrows have spine suited for being drawn by small but strong bows. The remaining arrows have yet to be related to specific bows.
More specifically, on the analyzed bows, the angle of curvature of the *siyah* is such that, quickly, a stacking* effect is felt. As a result, the bows have an optimal range of use limited to 19-25" draw length before staking. This effect is illustrated by the draw length/force curve (fig.7). This draw length range is that of the four arrows and the related bow weight is suited for their spine. This means that theoretically they could have come from the same quiver and form coherent B&A systems.

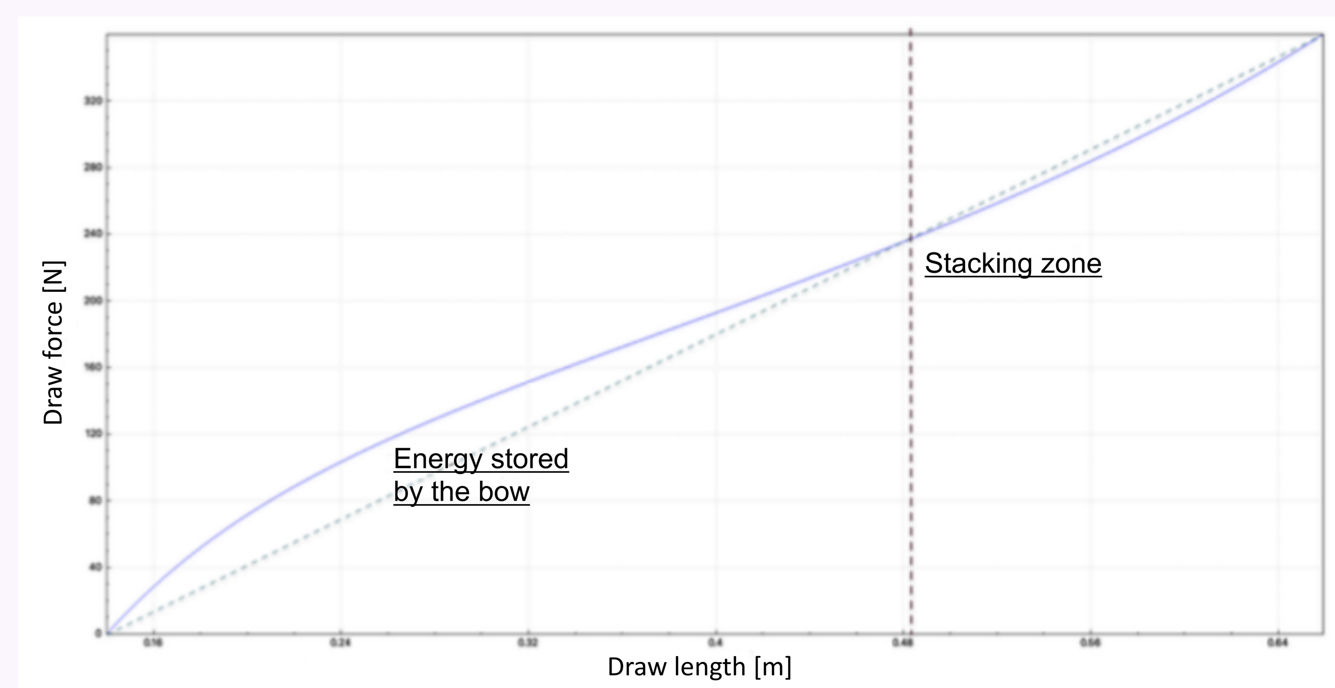


Fig. 7: Visualization of the draw length/force curve with stacking effect in VirtualBow

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DISCUSSION

▻ 3D modelling and simulation are useful for assessing the performance of fragile bows and arrows from Museum collections.

▻ However, our preliminary results have yet to take into account the varying elasticity and strength of the sinew cables in relation to whether (and how) it was twisted (or not). Indeed, Iñupiaq archers adjusted the cables to conditions of use (humidity, temperature, individual strength…) by twisting or untwisting the cables which most likely had an effect on the power of the bow. Similar questions arise for the bowstring. Thus, these mathematical simulations should not prevent us from considering how Iñupiaq archers chose the settings of their bows and arrows. Our preliminary analysis show these settings to be highly precise, which is based on Inupiaq empirical knowledge and experience[5].

☞ Future experimentations and practical shootings will test these questions.

Fig. 8: Archers at a competition in Noatak (Ak) (Philip and Retta Reed papers, Archives and Special Collections, Consortium Library, University of Alaska Anchorage)

Iñupiaq B&As are complex and variable. Unlike common assumptions on Iñupiaq archery, there is little opportunism in their making and use. They respond to specific and crucial needs for subsistence and social activities (fig.8) and are in true adequacy with the environment and its resources. The B&A complexity is a testimony of acute knowledge of archery and empirical understanding of material properties learned from an early age[6]. There is no ideal system, there are systems that suit each archer at every stage of its life.

☞ Further research will provide a database for the study of B&A systems in archaeological collections and will include experimentations and testing of different B&A settings.

DEFINITIONS* & REFERENCES

Siyah : rigid and curved end forming a "knee" on the limbs. This technology is originated from Asia in Scythian, Chinese and Korean bows.

Archer's paradox : During release, arrow flex and "snakes" around the handle instead of following a straight line inside its trajectory.

Interior ballistic : « [mechanical] phenomena until arrow exit [the bow][5]»

Stacking : increase in draw weight happening when drawing bow past its optimal draw length. It becomes unpleasantly harder to draw the bowstring.

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[6]See also : WALLS M., "Kayak games and hunting enskilement : an archaeological consideration of sports and the situated learning of technical skills ", in: World Archaeology, Vol. 44, No. 2, THE ARCHAEOLOGY OF SPORT AND PASTIMES (JUNE 2012), pp. 175-188