The Deane brother's Mary Rose Bow X1-3 – The 'Mean' wood longbow?

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Residing in The National Museum of Wales in Cardiff for many years was a bow recovered from the wreck of the Tudor warship, the *Mary Rose*. Recently it was returned to the Royal Armories in Leeds. The bow, labeled as being made of yew, is very interesting as it has a number of anomalous features that immediately attracted the attention of the authors when they first viewed it a number of years ago.

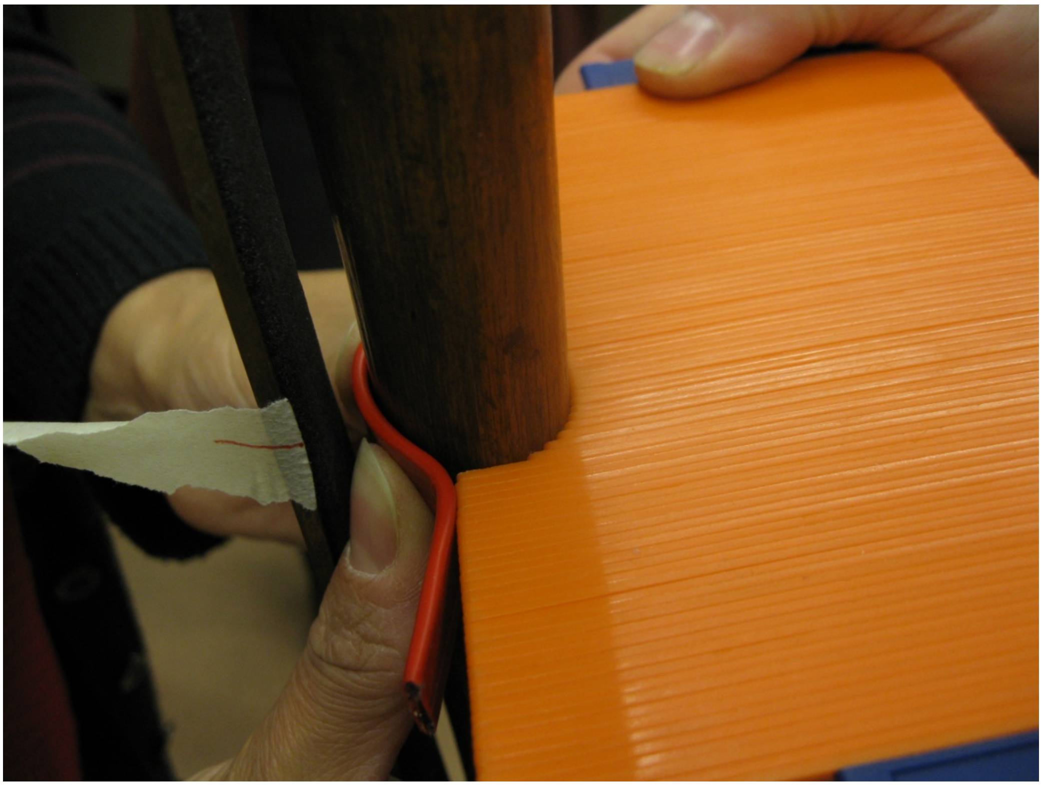
Much of what we know about the medieval military longbow, or war bow, is based upon the 137 longbows recovered in the early 1980s from the Mary *Rose*, once the flagship of Henry VIII's navy. All of the longbows recovered from the excavation on this occasion were made of yew which was (and still is) the commonly accepted premium bow wood especially for heavy bows including hunting bows and war bows. Writing close to the time to when the *Mary Rose* was in active service, Roger Ascham emphatically states 'As for Brazil, elm, wych, and ash, experience doth prove them to be but mean for bows; and so to conclude, yew, of all other things, is that whereof perfect shooting would have a bow made.'[1]

The 'Anthony Roll' is a contemporary (1546) inventory of the ship and records 250 'bows of eugh (yew)' being on board. It does not mention bows of any other type.[2] However, equipping Tudor warships exclusively with yew bows was not a universal practice. In a navy inventory of 1514 the *Trinity Sovereign* carried two chests of yew and 'witch hazel' bows. The *John the Baptist* carried a staggering 151 bows of yew and 84 of witch [wych] hazel. A galley called *The Rose* had 55 yew bows and 40 of elm, probably wych elm.[3] Indeed, the *Mary Rose's* active service was over a long period and it is unlikely that its soldiers were never issued wych elm bows.

It must not be forgotten that the 1980s excavation of the *Mary Rose* was not the first time objects had been recovered and in 1840 the pioneering salvage divers the Deane brothers recovered a number of artifacts from the wreck. Accounts are contradictory but 8 bows were believed to have been discovered and subsequently auctioned, of which only 3 remain. The surviving bows now belong to the Royal Armories. One of the Deane brother's bows was on long term loan to the National Museum of Wales in Cardiff from the early 1970's.

Being on display a decade before the *Mary Rose* was properly excavated and analysed, the bow has not received as much attention as the recent finds. Whilst the authors were granted permission to scrutinise and measure the bow, it was unfortunately not possible to remove the bow from its display cradle. In order to measure the section at points where the contour gauges could not be applied a lead strip was bent around the bow adjacent to the cradle and gave a good approximation of the back of the bow which was resting on the support.

From left to right, the back and side profile of bow X1-3 (Image by kind permission of the Royal Armouries)



Application of the contour gauge. The bow's belly is facing right.

A short description of the unusual features of Bow X1-3

Dimensions

The first striking characteristic about the bow is its length, of only 1710mm (approximately 67in.). This length is appreciably shorter than the average length of a typical complete *Mary Rose* bow by at least 25cm. The bow is also very broad in the centre being 42mm wide yet just under 30mm deep. This is wider than any of the other bows recorded in the Mary Rose Trust's authoritative study of the artifacts from the vessel.[4] A width much larger than this dimension is difficult to shoot, as it is uncomfortable to hold whilst shooting. At this width a full-compass bow, a bow with working centre, is near the limit an arrow can bend around the bow stave (archer's paradox) without deflecting off to the side. The bow does not have a stiffened handle area or a bias to one side.

Bow Measurements				
Centre	Width	42.03	Depth	29.79
Lower Limb				
100mm	Width	40.73	Depth	27.03
200mm	Width	38.24	Depth	25.87
300mm	Width	37.91	Depth	23.00
400mm	Width	26.70	Depth	22.74
500mm	Width	21.71	Depth	19.12
600mm	Width	19.23	Depth	18.65
700mm	Width	17.57	Depth	17.54
800mm	Width	18.60	Depth	17.57
900mm	Width		Depth	
1000mm	Width		Depth	
1100mm	Width		Depth	
At staining	Width		Depth	
At tip	Width	16.54	Depth	16.83
Upper Limb				
100mm	Width	41.41	Depth	28.75
200mm	Width	42.12	Depth	26.35
300mm	Width	40.81	Depth	25.73
400mm	Width	36.29	Depth	26.24
500mm	Width	29.48	Depth	21.89
600mm	Width	24.16	Depth	21.22
700mm	Width	20.5	Depth	18.09
800mm	Width	18.27	Depth	17.47 – TWIST IN LIMB OCCURS 170mm FROM TIP
900mm	Width		Depth	
1000mm	Width		Depth	
1100mm	Width		Depth	
At staining	Width		Depth	
At tip	Width	16.47	Depth	12.00
De/Reflex at Centre	10mm			

onal Museum of Wales and the Royal Armouries

Timber

The bows of the *Mary Rose* are made from timber that is of exceptional quality, the like of which is nowadays generally unobtainable but probably not unusual for the period. Building bows from staves that are largely straight, dense and free from large knots enables a bowyer to quickly produce efficient and reliable weapons. A number of bows exhibit small patches of wild grain but these were easily accommodated for by leaving a little extra wood to spread the strain. However, bow X1-3 exhibits knots on the back that penetrate through the bow to the belly. The back is particularly knotty and has been worked down with a seemingly gay abandon which would indicate that the bowyer was working quickly. To remove wood at pace takes a mastery of bowyery and a thorough understanding of the limits of a material.

Tool marks

Heavy tooling marks on the bows belly are clearly evident. Although they appear on other bows of the *Mary Rose*, they are a lot finer nature and the finish is generally very good with fine fluting showing in some cases on the belly, perhaps from a bowyers float. The finish is especially good on the bow's back which is polished and smooth. The deep tool marks on bow X1-3 appear to have been made by a sharp edged tool, perhaps a draw knife. They are at approximately 30 degrees to the horizontal in such a way as to probably indicate a right-handed bowyer. Drawing the knife in this way, with the dominant hand held lower, ensures the blade in making less of a contact with the wood and avoids 'chatter' as the blade judders across the surface.

Little time has been wasted to produce an aesthetically pleasing finish with evidence of the bows manufacture left honestly apparent. No trace of the pith line is apparent on the belly which may indicate that the bow was made from a log that was elliptical in section with the most convex surface serving as the bows back. Given the radius on bow X1-3 back, cleaving the stave from a circular log would have probably left traces of the pith channel in the handle area.

Chamfered and bevelled tips

It is possible that since Victorian times the bow has had approximately 5 to 7cm sawn off the two ends resulting in a blunt tip of some 16mm diameter. This is the sort of length that can be estimated by projecting the limb taper to where the cone for the horn is likely to start at around 13mm in width. However if the present tips are original they could tell us a lot about its manufacture and use. The other limb has very deliberate bevelling that does not look like part of the coning process. When working down the limb tip, a bowyer does not remove such a small amount of wood around the circumference. The cone is typically 40mm from the tip to base so longer strokes are far more efficient.

A flat facet has been carved onto one end of the bow.

Lay out and tapers

The way the bow is laid out is not typical of the *Mary Rose* bows and both limbs taper aggressively in width from approximately mid limb to the tip.

Bowyers mark

Bow X1-3 does not have any bowyer's marks to either to indicate the maker or the arrow pass but this cannot be taken as evidence of the bow being unfinished as over 10% of the 137 on *Mary Rose* do not have any discernible markings.[5]

Discussion

Clearly, bow X1-3 is extraordinary and raises many questions as to why it possesses so many features atypical of the other bows of the *Mary Rose*. Having made many war bows of different historically available wood types, the authors immediately noted a connection between the design of bow X1-3 and modern replicas that have been made. The bow exhibits traits associated with successful wych elm replicas, a less elastic wood than yew. It became a priority to get the bow examined by a wood expert. The wood type of bow X1-3 would have a fundamental impact upon its design to produce a bow that best utilised its inherent properties. If this were a wych elm bow it would be a unique survival from the sixteenth century and could provide important insights into the nature of non-yew bows.

Wood type

To help identify the construction material of the bow, Vicky Purewal, the National Museum of Wales' Botanical Conservation Officer, inspected bow X1-3 in December 2012. She was struck by the pores shown in the annual growth rings visible on the bow tips chamfered edge.

(Above)The chamfered end of the probable lower limb of the bow showing the pores of the wood.

She reported that this feature made it unlikely to be ‘softwood’, which yew is, and suggested elm as a likely candidate. The fact it had insect damage, probably occurring since it was raised, supported this. The concentrations of yew’s natural toxins make it highly resistant to insect attack though wood worm can bore through the sap layer but not usually into the belly. The bow also exhibits wide annual rings of well under 25 per inch that are clearly visible to the eye, despite the bow being lacquered with a translucent finish that is thicker in some areas than others. This coarseness of grain would be quite unusual for a yew bow of continental origin that may have a 100 plus rings per inch. Another feature not associated with yew is the visible medullary rays (featured at right angles to the annul rings) on the edges of the bow that are apparent with wych elm. Nor could her examination identify a distinct sap or heartwood as would be expected in a yew bow unless the sap layer had been deliberately removed. Although sap removal has been recorded on ancient European bows, none of the *Mary Rose* bows have had the sap layer removed. Bow X1-3's back is formed from an un-worked growth ring so sap removal is very unlikely.

(From left to right) A close up view of X1-3 and a modern wych elm replica

As the bow belongs to the Royal Armouries no further wood type testing, to give a definitive answer, could take place at this stage but it is hoped that will be possible in the future.

Is the bow X1-3 an unfinished stave or has it been altered since 1840?

The bow does not follow the string (permanent deformation or natural deflex in the stave) which may indicate that a bow has not been used, nor is there any evidence of wear from an arrow. Many bows of the *Mary Rose* show no wear around the arrow pass and, presumably, were finished bows that had not been used. Even if the bow was well used and had suffered string follow it is quite possible the long immersion and the inevitable softening of the timber could remove evidence of this. The authors have seen this happen in bows that have been accidentally left outside or in damp outbuildings.

The bow has truncated tips that terminate in a blunt end of some 16mm in diameter. All of the other complete bows of the *Mary Rose* have conical tips that were once provided with horn nocks, but these have disappeared during their immersion in the Solent. Only one extant horn sidenock survives but this was not attached to a bow and has a string notch filed 20mm from its base.

There is a level of standardisation exhibited in the horning cones of the bows and most exhibit limbs with the termini ,originally covered by the horn nock, some 40mm long with and with the cone base of about 13mm diameter. Horning is necessary in yew bows to protect the soft sapwood from abrasion by the string. It is also possible that bow X1-3 had some other method of attaching the string. No self-nocks are visible on the bow. Some bows found in Africa, such as those of the Hadza, use bindings to create a ledge for the string to sit on or a self-tightening knot usually on the lower limb. The use of a double self-tightening knot would mean that a bow would be permanently braced and thus weaken it quickly. However, self-tightening knots work best on a distinct taper far greater than the limbs of bow X1-3 and no trace of binding is present. At 16mm in diameter, the bow tips are quite large and would have a negative effect on the cast. These features might indicate that the bow has not been finished due to the difficulties of it taking a string for tillering.

A useful insight into Victorian ideas of the war bow is shown in the Pitt-Rivers collection at Oxford. A replica *Mary Rose* longbow (1893.65.1) of Spanish yew made to the precise dimensions of one of the Deane Brothers finds by Woolwich armourer, Mr. R. Warry was purchased by the Museum in 1893.[6] It is fitted with a hemp string directly attached to the cone (in reality tapered for horning) which is self-tightening in the manner previously described for Hadza heavy bows. It is likely that many antiquarians did not realise that the bows of the *Mary Rose* were horned.

The blunt tips may be the result of 19th century alterations made in an abortive attempt to horn it or for another reason that can only be guessed at. What can be said with certainty is that it was not unusual for historic objects to be treated in a somewhat cavalier fashion. In 1901 Sir Ralph Payne Gallway shot a bolt from a medieval Genoese crossbow 460 yards across the Menai Straits[7] and submerged a whole cross bow in water for an hour to note the effects of dampness on its performance.[8] To add further context, one of the Deane brothers' bows hung in the National Army Museum has a hole drilled through the centre for suspension! Even reducing bow X1.5 to fit a display cabinet that was too small is a possibility or an aborted attempt to pike/ re-horn the bow with a view to shooting is not out of the question. It is likely that the several unaccounted for Deane brother's bows were made into walking sticks; such was the casual Victorian attitude to historical artifacts.[9]

To conclude, there are two likely hypotheses as to why the bow has no string nocks. The first is that bow X1-3 is unfinished and was never strung in readiness for the tillering tree where fine adjustments are made. If the bow is unfinished the dimensions could not been larger than its present state but may have needed to be reduced in depth and/or width during tillering. If it was awaiting horns to be fitted, the nock to nock distance would be around 167cms (approximately 66 in) due to the length lost for the horning cones. It is possible self nocks were intended so less length would have lost from the nock to nock dimension to a maximum of 169cms (approximately 67in). Some modern elm war bow replicas have been self nocked but far more durable and reliable results have been obtained by fitting horns.

(Left) A detail of the tip of (probably) the upper limb. Notice the saw marks and the bevelled edge

The second possibility is that is has been shortened at some point after its recovery from the Solent. Saxton Pope, writing of one of the Deane brother's bows gives its dimensions as:

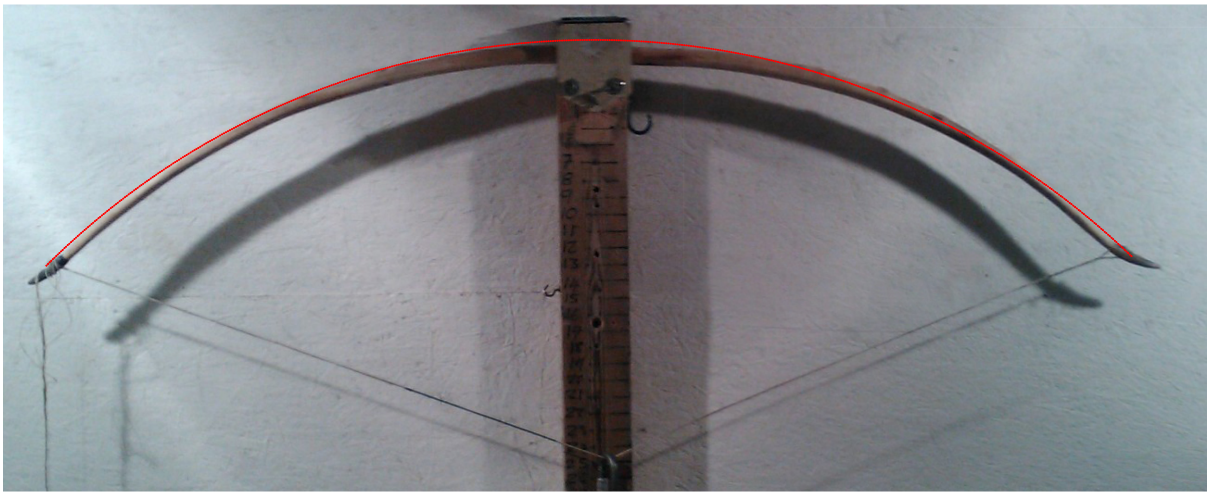
'Of all the bows of the days when archery was in flower, only two [sic] remain. These are unfinished staves found in the ship *Mary Rose*, sunk off the coast of Albion in 1545. This vessel having been raised from the bottom of the ocean in 1841, the staves were recovered and are now in the Tower of London.

They are six feet, four and three-quarters inches long, one and one-half inches across the handle, one and one- quarter inches thick, and proportionately large throughout.'[10]

The bows he refers to cannot be X1-3 due to the centre section being too narrow even if the length was the same, (which could have been trimmed at some point since his writing in 1923). Interestingly, he states that only two bows survive and both are 76in. Clearly he knows of no Deane brothers bow far shorter than these and it is strange that no mention has ever been made by any author since 1840 about a bow so notably different to the accepted dimensions and form of the obviously yew bows.

The bow is appreciable thinner and narrower on one limb (the upper one as it is display on the cradle but also likely to be actually the lower limb) which could add weight to modification after its recovery from the wreck. The lower limb of a full compass bow is under more stress than the upper limb, due to the arrow resting on top of the knuckle, and made slightly stouter to compensate.

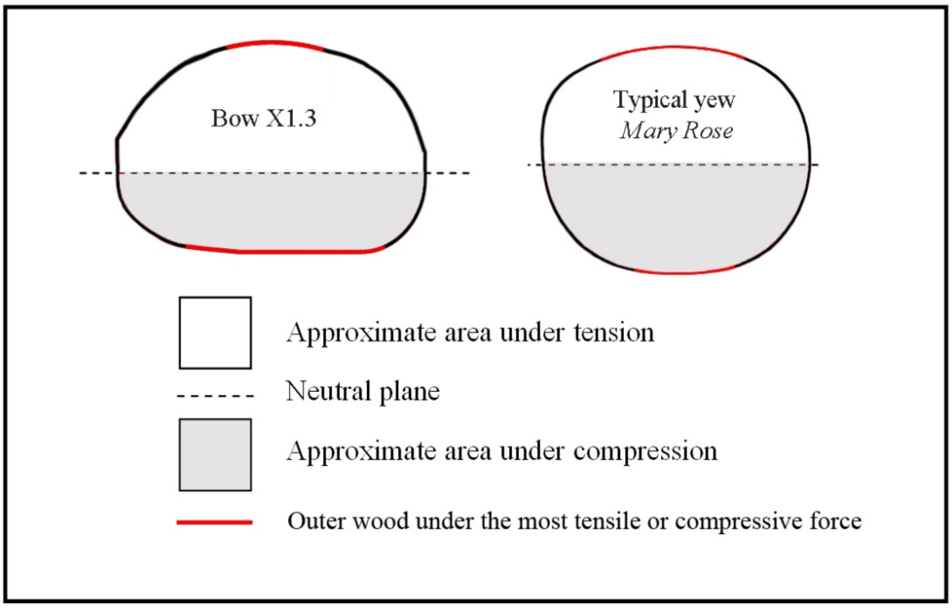
This is subtle and not usually very apparent to the eye as it is largely the thickness that is slightly increased. Increase in a bows thickness has far more of an influence on a bow's draw weight than its width. A bow made twice as wide will double the draw weight but making the same bow double the thickness will increase it by around eight times. However, bow X1-13 has a dramatic reduction in the width and depth of one limb. Such adjustments are usually made when a bow is on the tillering tree when the effect of differing densities within the wood as well as natural reflex/deflex will present itself. With a self bow it is very common to find one limb far stiffer than the other and bow X1.3's much reduced thickness and width dimensions on one limb strongly suggests that the bowyer has taken these measures to balance the bow. Some modern recreational longbow bowyers will initially floor tiller, a process whereby one limb is flexed against the floor. However, this is only a rough guide as the bowyer cannot clearly see the both limbs moving and is far harder with a heavier (therefore stiffer) war bow.



(Above) MRX1-3/S2 on the tillering tree drawn to 23 inches so fine adjustments still need to be made. This allows the bowyer to ensure the limbs are working evenly to ensure that the strain is evenly distributed across the whole bow. When working to the dimensions of the original the bows drew into a segment of an arc (show in red). Roger Ascham refers to this as 'full compass' in *Toxophilus*. Because of the nature of wood (a heterogeneous material) small alterations of a millimeter or so were needed in the thickness/width dimensions along the length of the limbs to ensure a good tiller.

Section

The bow is made from a small diameter stave (around 70mm) and the back is virtually semi-circular in section. The profile of a self bow's back is heavily influenced by the outer shape of a stave it was constructed from as the outer annual rings often form the bows back. Very crowned backs place more stress on the back than bows made from larger diameter staves. This is because most of the stretching is done by the highest point of the wood and the amount of timber available to take the strain is proportionately smaller as the circumference of the stave decreases. Wych elm is very resistant wood to tensile forces and can cope with the small amount of wood doing the stretching but has far less strength in compression than yew. Yew, in comparison to wych elm, is a isotropic material as its tensile and compressive strength are more balanced. Using a small diameter stave with a flat belly maximises the properties of white woods and minimises its short comings. The flat belly spreads compressive stress over more of the width of the limb as more wood is available to withstand the loading. When the back is rounded the stress varies across the width since the distance from the most extreme fibres to the neutral plane or axis increases in the centre. Simply put, the neutral plane is a conceptual line where stretching stops and crushing starts. In reality it is a curve as a small amount of bi-axial loading takes place. The location of the neutral plane is an important factor as it can reduce the amount of wood under compression.[11] By contrast, the yew bows of the *Mary Rose* are constructed from far larger logs at least 20cm in diameter.[12]



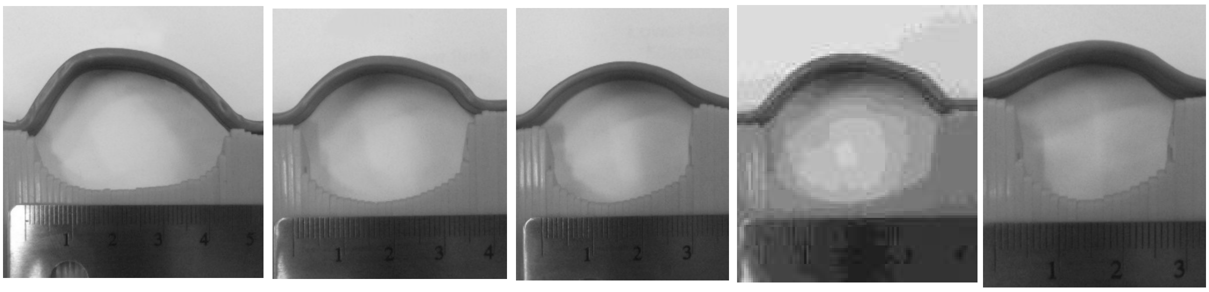
Wych Elm stave: Note the small diameter, giving a very rounded back

(Left) The centre section of X1-3 showing the crowned back that extends to half the section of the bow and the knots raised on the surface. Notice how the edges of the back are not rounded over as they are under little stress. (Right) A modern X1-3 replica in Wych elm made of a comparable diameter stave with similar knots.

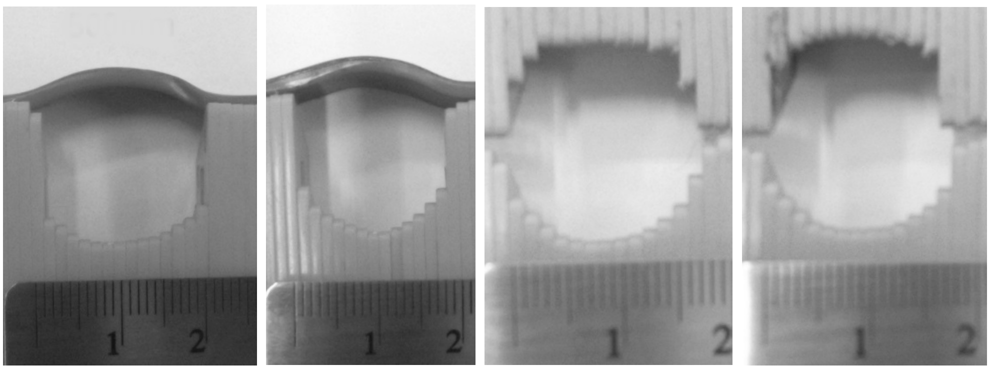
The square (or flatter curved) section is a good choice for tension strong/ moderate compression strength woods, such as elm. Elm war bows readily suffer compression failures on the belly if too stressed or less than perfectly tillered. The heaviest *Mary Rose* bows, and therefore under the high stress, are more rectangular in section or 'slab' sided. Practical experiments have shown that replicating a bow typical of the *Mary Rose* (a plano-convex section and a width/depth ration of 1.1:1) in elm usually gives mediocre results. Pip Bickerstaffe has probably made more longbows than any other commercial bowyer in the UK and was the first to make heavy weight longbows widely available in recent times. On using the plano-convex section for elm bows he states:

'Try making a (narrow) 'D' section bow of Elm and as it fails miserably to meet your expectations and becomes just so much more firewood you will appreciate that it is the concept and not the design which lead to the English Artillery bows.'[13]

Profile: Lower Limb

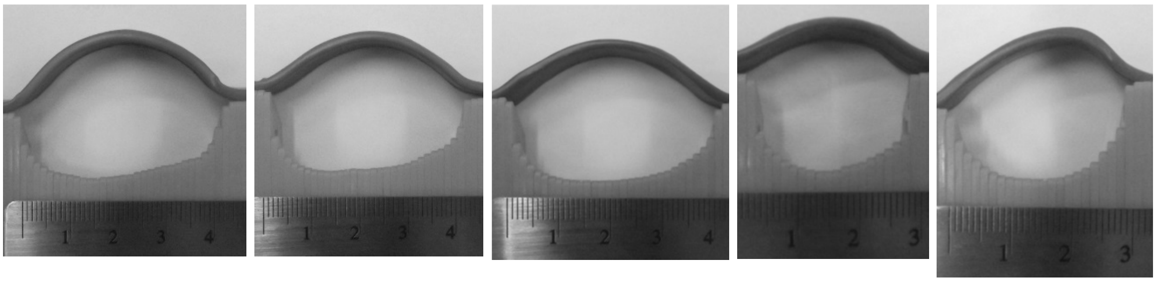


Centre of Bow | 100mm | 200mm | 300mm | 400mm

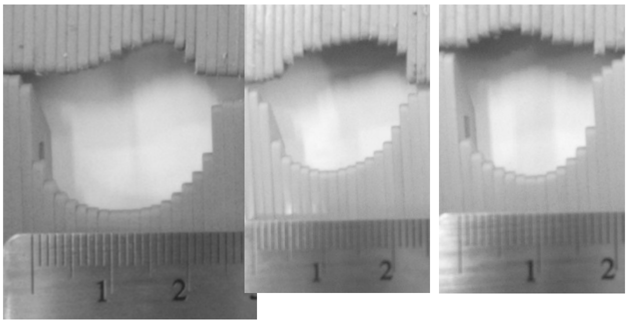


500mm | **600mm** | **700mm** | **800mm**

Profile: Upper Limb



100mm 200mm 300mm 400mm 500mm



600 mm 700 mm 800 mm

The season the stave was harvested

Observation under a microscope could identify when the stave was cut and merits future examination. However, is unclear whether the bark was peeled immediately after cutting, or left on whilst it seasoned. If staves are cut in the spring or summer it is often possible to peel the bark from the stave to leave an unblemished surface that will form the bow's back. During the autumn and winter, the bark and cambium bond to the rest of the stave and need to be removed with an edged tool. This is more labour intensive and has the potential hazard of the bowyer accidental cutting into the bows back which can reduce the longevity of a bow or, in the worst case, make it explode when drawn. However, cutting a stave from a tree during the spring or summer, whilst the sap is up, also has some drawbacks. It is hazardous to the health of the mother tree as the sap can continue to 'bleed' thus loosing moisture and nutrients. This would risk supply as further staves could not be harvested from a tree that shoots off further staves from the base of the bole as wych elm readily does. Such a harvested stave will have a very high moisture content that needs to dry out. When this takes place it can often cause drying checks, or longitudinal

splits, in the outer surface as it dries quicker than the core and thus places internal strains on the wood. Modern bowyers will often coat the exposed surface of a stave with PVA or similar to form a barrier to control the drying rate but it is conceivable that bees wax or tallow may have been used in this way during the Tudor period.
It appears that the bark has been removed with an edged tool, possibly a draw-knife, due to the way pins, or small knots, had been sliced through making a late harvest likely. A late harvest, when the sap is down, ensures that the outer annual ring of the bows back is composed of the tougher late growth that is not as porous as spring growth when the cambium is more active. Elm bark or bast is a very strong material and was used to make cordage for woven chair seats. To harvest this material the bast is stripped whilst green but is not ideal for bow wood.


Left: wych elm stave with some of the bark or 'bast' removed. Due to the paucity of clean wych elm staves, some steaming was needed to make them usable. Right: roughed-out stave with the cambium attached.

Construction of the approximations

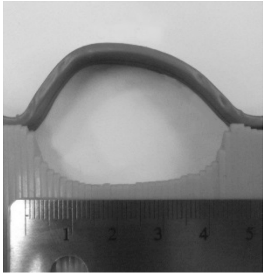
Master bowyer, Jeremy Spencer, roughing out an elm stave for one of the first approximations of bow X1-3

Selection of material: Yew or wych elm?

The decision had to be taken as to the material to be used in the construction of the approximations. Having closely inspected the museum bow profile and dimensions, it seemed to fit within the accepted contemporary approach to the building of a heavy draw weight white wood bow; wide and flat in section. Richard Wadge, when discussing the existence of 'broad bows', agrees that 'Wyche bows may well have been much flatter in section because of the nature of the wood' [14]
Observing the suitability of bow X1-3's design for a white wood bow and Vicky Purewal's botanical analysis, confirmed the authors suspicion that this could indeed be the only extant example of a white wood bow from the *Mary Rose*.

When the bow was taken from its case the authors were immediately struck by its extremely short length. The average length of all recovered *Mary Rose* bows, measurement tip to tip is nearly 2 Metres (77.5 inches) yet this example was significantly shorter. Testing was needed to determine whether was possible to make a military weight elm bow by faithfully following bow X1-3's dimensions. As discussed, the tips of the bow gave some insight into how to take the project forward: it was decided at first to make approximations based on the current dimensions of MR X1-3, with the assumption that it was not shortened after it had been completed, although needing the addition of horn nocks and tillering. Alongside these bows, a longer version would also be constructed with the limbs projected to similar base of nock and cone dimensions of bows found on the *Mary Rose* of 12-13mm, with the premise that at some point the bows' length had been reduced after full completion. As one surviving *Mary Rose* bow horn nock example exists it was used as a basis for the reconstructions.

As stated, when observing the dimensions of the original artefact, it is noticeable that one limb is significantly smaller than the other. A bowyer would assume that the original stave must have been demonstrably unbalanced, and was reduced to rectify the balance of the limbs. After unsuccessful attempts to strictly follow the very uneven upper/lower limb dimensions, a different approach was adopted. It was decided that for further experiments the dimensionally larger limb would be 'mirrored' so as to produce a datum from which to work. If one limb was very stiff it could be reduced at some point. The first approximation, MR X1-3/S1 was shaped from a reasonable quality stave, having a naturally deflexed centre and undulations near one of its tips. The stave was roughed out and brought down to the exact dimensions and duly coned, horned with side-nocks carved in.



A flat belly, rounded back and a small radiuses edge reflect the profile of original   Centre section of MR X1-3

Cow horn nock drilled out and shaped to approximate the solitary one found on the *Mary Rose*

During the tillering process the bowyer would expect to undertake some form of wood removal in certain areas of the limbs to encourage the bow to form either a 'full-compass' or more elliptical tiller. Interestingly, MR X1-3/S1 'came around' without the need for any adjustments after the originals dimensions had been followed. It produced a pleasing bow of over hundred pounds at 762mm of draw length (30 in). Had the stave not been deflexed in the handle, the final weight would have been slightly higher. Although not exact in all aspects of bow X1-3, the back being flatter, this experiment demonstrated that X1-3's design could provide a meaningful military weight bow from wych elm. Intriguingly, there were also failures, as the length and relative depth of the shorter bows clearly pushed the natural limits of the material, with several tension induced failures on the tiller at around 650mm. As stated, this was especially so when one limb was made narrower as per the original. It was becoming certain that this thinning must have taken place during tillering to balance the density and bend strength of bow X1-3 as one limb must have been far stronger. It also became apparent that only the best quality elm stave could handle the stresses of tillering to 762mm (30 inches); this would only have been apparent during tillering.

MR X1-3/L1 on the tiller dimensionally correct, but requiring a little more scraping to come 'full compass' due to the unique properties of each stave. It does, however, demonstrate that the longer reconstructions adding the projected limb length is a viable design.

MRX1-3/S2 still holding some of its original natural reflex in the stave. This would indicate that the belly is relatively unstressed.

MRX1-3/S3 followed the same protocol with both limbs shaped to the larger dimensions of the upper limb of MRX1-3. This approximation felt appreciably stiffer than the other bows, such that when braced for the first time the tillering string cut straight through the horn nock. It was clearly a powerful bow that was a struggle to brace, even with the use of a stringer. Material was then removed from the belly, reducing its depth in the centre by one millimetre from that of bow X1-3 dimensions, though still keeping close to the original profile.

Damaged cow horn nock from initial bracing of MR X1-3/S3

Interestingly when the physical properties are compared; MRX1-3/S1 physical mass is more than MRX1-3/S3, but has a lower draw weight.

MR X1-3 Approximation Bow	Physical Weight
MR X1-3/S1	905 grams
MR X1-3/S2	868 grams
MR X1-3/S3	785 grams
MR X1-3/L1	939 grams

Table showing relative physical mass of approximations

MR X1-9/S3 66ins nock-to-nock 141lbs@30 braced and unbraced. Right: Section of stave from which bow was made

Finally all four approximations were chosen to be finished with a proofing agent made a contemporary mix of animal fat/bees wax/ rosin. [15]
This was deemed more appropriate than the use of more modern and protective varnishes, as the very hydroscopic nature of white woods affects the performance of bows and could skew results.

Testing

Approximations of bow X1-3 that survived the tillering process were completed and testing with appropriate arrows. During the course of 2014 the bows were shot during flight shoots held by *Warbow Wales*. The conditions varied from shoot to shoot; therefore providing a rounded view of the capabilities of the bows. Testing has shown that shots for maximum distance (that is, aimed at around 45 degrees in elevation) into a headwind with precipitation is easily capable of reducing distances by more than 25% compared to ideal conditions. All the testing was conducted by experienced heavy longbow archers who could master the bows, namely Alistair Aston, Joseph Gibbs and Jeremy Spencer.

The two former archers had recently held the FITA World Records in the Unlimited Longbow class. The latter is probably the current leading exponent of warbow archery in the world and certainly the strongest which was very necessary for approximation bow MR X1-3/S3.[16]

Testing arrows

To test *Mary Rose* bow X1-3 two extant arrows were selected, *Mary Rose* arrow AZ472/19 and the earlier Westminster Abbey arrow, as they represented the most common draw lengths, shaft diameters and materials of the arrows of the *Mary Rose*.

Although a broad spread of arrow lengths was recorded for her arrows, most lie in the range 715-854mm in a bimodal (double peaked) distribution of 740mm and 790mm.

If the median nock depth (6mm) and the median tip (cone for the arrowhead) length (22mm) is subtracted from the two modal values it gives estimated draw lengths of 712mm (28.03in) and 762mm (30 in) respectively.

Arrow number AZ472/19 had an effective draw length, which is from nock valley to the shoulder of arrowhead, of 758mm (29.84 inches). It is made of aspen or poplar which was by far the most common arrow wood found. The profile of the shaft is tapered from the head end to the nock, known as bob-tailed. This is the most common design with 43.1% of the recorded Mary Rose arrows profiled in this way. For comparison, the next common profile (28.5%) was parallel. AZ472/19 has fletches of 174mm (6.85 inches) as evidenced by the witness marks left on the bees wax/animal fat binding compound. This also closely corresponds to the median fletching length of 181mm (7 1/8 inches).[17] The original height and shape of the fletchings of the arrow is uncertain as none have survived but practical experimentation has shown 5/8 in at the highest point provides adequate steerage yet allows decent range. Near contemporary carvings on Prince Arthur’s Chantry Chapel in Worcester Cathedral, shows a triangular fletch with a forward raked end. Ascham also states ‘the triangle fashion which is much used now-a-days both be good’.[18]   All of the replica arrow fletchings were made from greylag goose feathers although the original arrows may also have been fletched with swan also. It is likely that *Mary Rose* arrow number AZ472/19 was armed with an arrowhead commonly known as a ‘Tudor bodkin’ or M2 according to Jessop’s taxonomy of arrowheads.[19] This type of arrowhead is also depicted in the carvings. The heads used were made by the master arrowsmith, Hector Cole. Thanks must be given to the Mary Rose Trust for the data kindly provided on arrow AZ472/19.

Tudor livery arrows portrayed on Prince Arthur's Chantry Chapel dating from 1502 (Photograph is reproduced by permission of the Dean and Chapter of Worcester Cathedral)

Testing was also carried out using replicas of the arrow found in the turret of Henry V's Chantry in Westminster Abbey. It was found over a century ago during renovation work. Its precise date is unknown but it cannot be later than 1437 as that was the completion date of its location in the Abbey. The draw length is just less than 29 inches (approximately 730mm) and the shaft is 11mm in diameter at the shoulder so, although earlier than the sinking of the *Mary Rose*, it is very close to the design and materials of her arrows. It is also an arrow that is regularly shot at *Warbow Wales* shoots so provides useful comparative information. The best distance results recorded for the test arrows (which also included a 28in *Mary Rose* type arrow) can be seen in the tables below.

MR X1-3 Approximation Bow	Draw Weight @30ins	Arrow Type	Distance Achieved (yards)
MR X1-3/S1	108lbs	Westminster *	235
MR X1-3/S2	101lbs	Westminster	227
MR X1-3/S3	141lbs	Westminster	255
MR X1-3/L1	134lbs	Westminster	232

* Westminster arrow is approximately 29ins shoulder to nock and weighs 50 grams. A distance of 255 yards has been recorded with MR X1-3/S1 in favourable atmospheric conditions.

MR X1-3 Approximation Bow	Draw Weight @30ins	Arrow Type	Distance Achieved (yards)
MR X1-3/S1	108lbs	28" draw length MR Livery**	209
MR X1-3/S3	141lbs	28ins draw length MR Livery	228

**Weighing 61grams

MR X1-3 Approximation Bow	Draw Weight @30ins	Arrow Type	Distance Achieved (yards)
MR X1-3/S1	108lbs	AZ472/19 ***	225
MR X1-3/S2	101ibs	AZ472/19	203
MR X1-3/S3	141lbs	AZ472/19	241
MR X1-3/L1	134lbs	AZ472/19	206

*** *Mary Rose* arrow AZ472/19, a 30 inch draw length arrow weighing 62.5 grams armed with a M2 ‘Tudor bodkin’ arrowhead.

As a comparison the table below shows the best distances shot at *Warbow Wales* shoots with *Mary Rose* self-yew approximation bows and natural strings.

***Mary Rose* design yew warbow (shot with a natural string)**	**Westminster Abbey arrow 29 inch draw length Distance achieved (yards)**	***Mary Rose* arrow 31.5 inch draw length Distance achieved (yards)**
Italian yew 118 lbs @ 32”	183 yards	199
Welsh yew 129 lbs @ 32”	224 yards	252
Italian yew 150lb @ 32"	234 yards	242
English yew 170 lbs @ 32"	255 yards	Not shot

Westminster arrow replica with tallow and beeswax compound over silk whipping on shaftment

The shooting of an arrow from a bow should be seen as part of a whole delivery system; many factors influence the performance on any given shot. Notwithstanding the effect of atmospheric conditions, consideration should also be made of the quality of the wood used to make the bow, its design and manufacture, as well as the type of string that is employed. The capabilities of the archer are also vital to getting the most out of a bow. An archer with poor technique or a dead loose can lose yardage when shooting for maximum distance.

Joe Gibbs and Alistair Aston drawing up bows MR X1-3/S3 and MR X1-3/L1, respectively

An arrow captured leaving Approximation MR X1-3/S1

Strings

Most testing of *Mary Rose* replica bows are carried out with modern synthetic strings and although undoubtedly durable and of a high performance, they cannot give as reliable results as using hemp strings. Initial testing on the MRX1-3 approximations was carried out using single looped Flemish twist strings from hemp fibres; the results were encouraging, not only did they withstand the strain of 100lb plus draw weight bows; they also provided a reasonable performance in comparison to modern synthetic strings. As testing of the bows progressed, full-length hemp fibre strings of double-looped design were used for tested with MR X1-3S/3 and MR X1-3/S1. These hemp strings were easily capable of fitting any of the arrow nocks found on the *Mary Rose*, which had a median width of 3mm and depth of 6mm. [20] The sound created when ‘plucking’ on a braced bow with these strings was of a much higher pitch; similar to that of modern ‘Fastflite’ strings. Further testing must be carried out to explore the qualities of this material, but it would seem that it is both durable and efficient.

Above: Side nock and double loop string reinforced with linen thread reinforced with animal glue

Below: Full-length Hemp fibre string with linen serving (2.5mm diameter at serving)

Drawing beyond 30 inches

The distances recorded for the approximations should demonstrate that, in the right hands, the bows are capable of projecting missiles, close to, or beyond Henry VIII's mandatory minimum practice distance of 220 yards[21], and even in some cases beyond 240 yards (known as 'bowshot)' especially in the case of the Westminster Abbey arrow.

Informative though the bows distance capabilities are, it does not indicate the overall performance, particularly with regard to the longevity of these bows. If obtaining a usable bow from a serviceable stave during manufacture was problematic with the short approximation bows; survival in the field would be no less so. MR X1-3/S2 broke after just a few shots and most of the approximations show signs of chrysalling to a greater or lesser degree.
This would also seem to be apparent in Tudor times with the complaint by the Navy Council addressed to Thomas Howard, Lord Admiral aboard the *Mary Rose* in 1513:

As touching the receiving of bows and arrows. I shall see them as little wasted as shall be possible. And where your lordship wrote that is greatly marvelled where so great a number of bows and arrows be brought to so small a number, I have enquired the course thereof: and as far as I can see, the greatest number were wych bows of whom few could abide the bending'[22]

Though it should be noted that much damage (both catastrophic and chrysal ling) to the MRX1-3 approximation bows was induced when drawing beyond 30 inches, thus indicating that although the short and (projected) longer length approximations are indeed capable of shooting arrows longer than 762mm (30 inches), it will certainly shorten the working life of the bow. Drawing to this length or less would not only be safer relative to the qualities of the wood, be within the compass of most Tudor archers draw length, and project effective missiles a required distance. Most importantly, a 762mm draw length is reflective of the majority of the arrows recovered from the wreck of the *Mary Rose.*

(Left) An approximation of Bow X1-3 (using a nock to nock length of 1676mm) broke on tiller at 720mm (28 inches) due to tension failure. Examination of the belly revealed no sign of any compression failure, usually evidenced by chrysals. (Right) Light chrysals emanating from pins on MR X1-3/S3 after shooting. Pins or small knots are usually a weak point in compression.

MR X1-3/S2 being drawn to 800mm (31.5 inches). Note the bottom limb failing in tension in the inset and extreme bend induced by the long draw.

Conclusions

Experience in the construction and testing of the approximations would strongly suggest that MR X1-3 has, at some point, had its length reduced. There is a possibility of it being in this truncated state prior to immersion, perhaps as an unfinished bow stave or as a repurposed object perhaps made obsolete by superior bows of yew. However, it would seem highly likely that this occurred after retrieval by the Deane brothers, and prior to its loan to the National Museum of Wales in 1970.

The design of the bow matches the qualities of a white wood such as wych elm; with its rounded back, wide limbs and shallow 'D' to flat belly profile. Categorical confirmation that the bow is indeed elm and ancient will have to await further analysis, but visual inspection by experts at the National Museum of Wales indicates that bow X1-3 is not constructed of yew. It must also be appreciated that white wood bows were very common in military service prior to the sinking of the *Mary Rose* in 1545. Although from an earlier time, an indenture relating to Edward the IV's mission to France of 1475 shows that about one in six of the bows in storage for a major military expedition to France were not made of yew.[23] It seems unlikely that yew staves capable of making a war bow would be any easier to find 70 years later.

It would be wrong to assume that as the *Mary Rose* was reputedly Henry VIII's favourite ship of the fleet it would naturally have had the best yew bows available and bow X1-3 may represent an expedient approach to the supply of livery bows. The *Mary Rose* first saw battle in 1512 and it is possible that bow X1-3 was onboard from any point after this and overlooked. Given the choice it is apparent that archers would choose to shoot a yew bow over an elm one. The Deane brothers did not accurately record the location of where they found their artifacts on and around the wreck so its location cannot give any indication to this.

The research into MR X1-3 has raised two important discussion points: firstly, should MR X1-3 prove to be wych elm and its recorded provenance correct, it would be the only white medieval or Tudor white wood livery bow in existence. Secondly, the profile, dimensions and proportions are significantly different to that of any other extant *Mary Rose* bow. It is a very enigmatic artefact and certainly warrants further testing under the microscope to definitively classify its wood type and age.

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