A bowyer's experiments with Ascham's 'mean' wood bows

Jeremy Spencer

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. Roger Ascham *Toxophilus* 1545

The heavy longbow of yew represented the zenith of Anglo-Welsh military archery in the medieval and Tudor periods. It is the weapon of Robin Hood and eulogised by Sir Arthur Conan Doyle in the 'Song of the Bow', a poem from *The White Company*. Its properties and achievements have gained semi-legendary status but little has been written about its less glamorous cousin, the white or mean wood warbow; the workhorse of mediaeval and Tudor archery. Easily fashioned by a master bowyer, from one of many indigenous hard woods, a functional weapon can be made in around two hours[1]. These days, finding a native yew stave, suitable to make a heavy bow, is always an event to be savoured by a bowyer because of the scarcity of suitable material. However, a wander around any ancient British woodland would identify enough bow wood to fill any castle armoury with bows. Coppiced hazel grows in a profusion of staves, and a cluster of ash will race for the upper canopy. Both will produce clean and pipe-stove straight boughs in the process. Sadly, wych elm no longer heavily populates the same woods to furnish the bowyer with yet another abundant and valuable resource. Ash, now under threat from a fungus (*Hymenoscyphus fraxineus*) disease could pass the same way. If appropriately managed it is what we would now call a sustainable resource. By comparison, a Spanish yew stave may have annual rings that are barely discernable to the bare eye, thus needing hundreds of years to reach stave yielding proportions. Juxtapose this with hazel that can take as little as 10 years to develop from nut to and we can appreciate how it would outnumber its glamorous cousin, the yew bow, to such a degree.

Design solutions and adaptations

It is well documented that during the later era of the warbow's military use, much of the supply of yew staves was importedin a trade that was heavily regulated. Most was reserved by the crown for military use and only available for civilian use under certain circumstances. Author Richard Wadge has collated Medieval and Tudor documentation showing the staggering amount of raw material needed to equip an army.   Modern replicas, based on extant Tudor bows, have furnished us with a decent understanding of the considerable potency of the weapon and, to a large degree, justifying the legend.   However, a well made yew warbow can only be a potent weapon in the right hands and to become a competent military archer takes many years of practice. Only by putting in regular hours of shooting heavy weight bows, perhaps at the butts, will the body's strength and hand-eye coordination develop to the requisite level to master the martial discipline. It must be recognised that the martial prowess of many archers must have been honed not with a yew bow but with a weapon of lesser wood. This is not to suggest that mean wood bows were not useful weapons in the field. It is likely that these bows constituted a significant number of the battle winning weapons at the battle of Crécy. In the 13th year of Edward III's reign an order is issued for all northern counties to provide five hundred white bows for his coming war in France.[2] Perhaps it was more necessary to maintain bows of yew in readiness against the Scots than the French? In the historical records, the term white and painted bows are used but the meaning is not completely understood. It seems probable that mean wood bows, being largely a consistent pale colour, would be termed 'white' to differentiate them from yew. The latter has a distinctly two toned appearance with the creamy sap wood on the back contrasting with the heartwood belly which ranges from a honey buff to rich auburn. ‘Painted bows’ are also commonly mentioned and the term could refer to yew for this reason. What can be said with certainty is that ‘painted bows’ were more considerably more expensive which supports the likelihood they refer to bows of yew. Perhaps ‘painted bows’ also referred to laburnum which is similarly elastic and also with a distinct sap and heartwood. An order from 1359 values white bows at 18d and painted considerably more at 36d.[3] Even in the twilight of military archery measures were taken to conserve the dwindling supply of warbow quality yew, usually imported. An edict of Elizabeth I proclaimed that...

The use of yew- no persons under seventeen, unless possessed of movables worth forty marks, or the son of parents having an estate of ten pounds per annum, might shoot with a yew-bow, under a penalty of 6s 8d and *that every man might be able to furnish himself with an inferior sort of bow every bowyer dwelling in the cities of London and Westminster or the cities of London and Westminster or the borough of Southwark was always to keep in stock fifty good bows of elm witch hazel or ash well and substantially made and wrought upon pain that every of the said bowyers who for the space of twenty days should not have the number of bows of those materials readymade and fit to be sold and used should for every bow wanting of that number forfeit 10s one half to the Queen and the other half to any armourer fletcher or maker of bow strings that would sue for it*[4]

Clearly it was possible to make useful bows that were broadly commensurate with yew. According to the military theorist, William Neade, writing at a time, in the early seventeenth century, yet further into the period of the war bows decline, the range of a longbow was still reckoned to be from sixteen to twenty score yards; 320-400 yards is no small distance!

Given that mean woods do not enjoy many of the advantages of yew, how could bows be made to military weight and be capable of delivering a manstopping missile at least a furlong (220 yards)? The answer lies in finding a design that capitalises on the inherent strengths of 'mean woods' whilst minimising their shortcomings. Practical experiments have shown that replicating a bow typical of those found on the *Mary Ros*e (a plano-convex section with a width/depth ration of 1.1:1) will usually produce pedestrian results. Indeed, it is like an arrow smith attempting to make a needle bodkin in bronze; the material is just not compatible with the design. It may even have been that heavy draw weight mean wood bows (with lesser cast), compared to yew, and were employed as a training tool to develop the archer's strength. It was a common strategy for soldiers and athletes to use heavier weapons in peacetime in an effort to prepare for the sapping privations of war. Roman soldiers used heavy wooden swords and wicker shields to this end and it may have been a tactic adopted by the yeoman archer but there is no evidence for this other than good practice. Even today, an oft quoted maxim of boxers is 'train hard – fight easy!'

Clearly the pertinent question about the mean wood warbow is *how* they were made to achieve suitable military draw weights, not *why*?

Fig.1. Above is a youthful four inch diameter ash stave that would yield two warbow staves in only 10 years. Bowyers should search for staves with a high proportion of dense late growth in the annual rings to yield sterner material.

The qualities of mean woods comparative to yew as a bow wood

Although as strong in tension, mean woods have comparatively less compression strength than yew. The author has successfully used ash to back a 160lb laminated ‘warbow’ made to a *Mary Rose* section. Trying to make an ash self bow in a similar design would prove to be an ordeal worthy of Sisyphus. This is because mean woods are less elastic than yew and quickly show the permanent deformation, known as following the string, when put under the same strain as yew. A bow with string follow will store less energy than a straight limbed bow for a given draw weight due to proportionally more of the energy being stored later in the draw. Plucking the string of a heavily string-followed bow will result in a dull sound as the cord is under low tension. This is due to the bow possessing little early draw weight thus making it sluggish of cast.

A more complex challenge than string follow lies ahead for the mean wood bowyer. This is how to avoid over-straining a bow past the point it permanently deforms and the wood actually collapses. Ascham calls compression fractures ‘frets’ and these manifest themselves as thin (and not so thin) cracks that run transversely across the belly. They are usually progressive and ultimately lead to the bows destruction. An inaccurate depth taper is usually the culprit but pins and knots can also start the process. Longbow’s limbs must gradually thin as they approach the nock in order to spread the strain on the bow. The handle section must be the thickest part as it is under the most strain with less stress progressively along the limb towards the tips. This is due to the leverage of the string at the nocks and with the hand acting as a fulcrum. Yew is far more forgiving to the bowyer and will tolerate wrongdoing to a greater degree. It is normal for well-made mean wood bows to have very fine frets over the whole of the bow belly. This is actually an indication that the crushing stress is being equally distributed and the bow is not overbuilt. When elasticity and bending strength/mass calculations are combined, yew and wych have values of 1.16% and 0.97% respectively[5]. If all else is equal, a wych bow will fail before yew in compression. This is why making a mean wood bow is such an effective and strict teacher that will not suffer fools gladly.

Fig.2. A potentially catastrophic ‘fret’ emanating from a pin on the belly of a 110lb rowan warbow.

Even the smallest flaw in the wood or poor depth taper in a ‘mean wood’ bow can end prematurely end a bow’s life. Avoiding deep compression induced ‘frets’[6] are the biggest challenge to overcome when making heavy ‘mean wood’ longbows. Notice the prick marks on either side of the crack; this is to help relieve the pressure on a weak point. Ascham cautions about piecing in new wood or letting-in slivers of quill and glue. Experience has shown that a seemingly disproportionate amount of stress seems to be placed on the belly of a mean wood bow while tillering the last two inches of a modern 32 inch draw. This is is due to a non-linear strain on the bow as the draw progresses. Due to string angles the limbs have to move progressively further, pro rata, to facilitate increasingly longer arrows. Modern mean wood bowyers may care to remember that most arrows on the *Mary Rose* had a usable draw length of 30 inches and this represents a safer option with less chance of causing deep frets.

Due to the hardness of mean woods, self-nocked designs have successfully been employed, although horning enables the limb tips to be kept thinner to improve cast.

Hysteresis and moisture absorbency

Typically, mean woods are far more hydroscopic than yew which, in the damp climate of Britain, is a drawback. Internal moisture increases the level of hysteresis in a wood by imparting more performance-robbing internal friction. Any energy stored in a drawn bow that is not transferred to the arrow reduces cast and if too much is lost will make its performance sluggish. A *very* well-made and designed longbow from the finest materials would struggle to be more than 70% efficient. Many modern bowyers will use a 2-part epoxy finish on mean wood bows in order to keep the elements out of its sponge like wood cells. Historically correct proofing methods, using various combinations of beeswax, animal fats and tree resins do not even approach the same effectiveness[7]. At American flight championships white wood bows are often the top performers in the parched Utah air. In Britain a warbow flight archer wishing to get the best distances out of his mean wood bows will leave them on a radiator the night before the shoot to ensure moisture levels are low, much in the same manner of the Turks drying their composite flight bows in a bread oven. It seems understandable that Thomas Lord Howard, when writing in to the council in 1513 about a consignment of navy warbows, states,

...,the greatest number were witch (wych or perhaps hazel?) bows, of whom few could abide the bending[8].

The damp maritime air must have played havoc with the absorbent bow wood and dramatically reduced the cast. Damp wood is also more apt to follow the string. It is possible that the consignment of bows was poorly made or constructed from inferior wood but even decent wych elm will suffer in high humidity. High moisture content will also add a degree of mass to a bow without a gain in draw weight. However, the rub is that although mean woods absorb water readily, they also lose it rapidly and staves reduced to near bow dimensions can be seasoned in as little as four weeks under the right conditions.

Fig.3. An ‘explosion’ of wych elm staves that would need little labour to get ready for the bowyer’s tillering tree.

Material selection

Experienced bowyers know that there can be almost as much difference from tree to tree as from species to species; for mean woods this is especially true. The author has made ash warbows that have fretted deeply at low strain levels whilst other ash staves have yielded resilient and efficient bows. The compression weak bows can usually be recycled as durable backings for laminates. The medieval bowyer would have understood likely locations to find decent quality staves to avoid fruitless labour. Experience has shown that good density is a key quality in ash and wych elm staves, often coming from shaded limestone areas. A tree needs to be healthy but not spoilt by too much sun and nutrients. Most mean wood bows are primarily made of sap wood with only the inner annual rings being of heart wood. Occasionally, wych elm staves will have strong, dark heartwood close enough to the outer rings to be retained on a bow's belly but this is unusual. The ratio of late to early growth is also very important. In the spring, ash and elm trees lay down a spongy section of growth, through which the rising sap will flow, that possesses little compression strength in comparison to the denser late summer growth. This forms a structure of strong late growth layers 'stuck' together with weak spring growth 'glue'. An ideal stave will have a high proportion of resilient late growth that will withstand compression. Too much spring growth will easily result in collapse and cause the bow to follow the string severely.

Fig.4. Wych elm density being measured

It is useful for a bowyer to perform a density test using a bone dry sample as all unseasoned wood will appear dense due to the moisture content. Simply cut a strip of bywood to a regular section that is equidistantly divided into ten. Where the strip settles in the water is the specific gravity. The specific gravity of water is 1 so this wych sample is a reasonably dense 0.75. However, excellent warbows can still be made from light woods such as hazel and even the balsa like elder, with commensurately larger dimensions, due to their elasticity.

Small stave Bows

Bow from small staves usually have naturally highly crowned backs as they are formed from the outer layer of the stave once the bark and cambium are removed. This partly defines the bows final section. Small diameter staves can be sourced from young or coppiced wood which ensures a more readily available supply. On the bow's back the annual rings are ideally left un-violated to ensure maximum longevity of the bow and if harvested in the growing season the bark can simply be peeled by hand, leaving the future bow's back complete.

However, it is safer to leave the bark on as peeled green staves can take on drying cracks or shakes along the grain whilst seasoning. Bows with highly crowned backs are under more stress than bows from larger diameter staves which are usually flatter on the back. 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. White woods are so tension strong they can cope with the small amount of wood doing the stretching but, as stated, have far less strength in compression than yew. Using a small diameter helps balance white woods properties by distributing the strain away from the belly of the bow. In section, the thickest part of the bow is in the centre and this is where the maximum compressive force is exerted. If the belly is kept flat there is more wood to withstand the compression. Successful mean wood bows of military weight have been produced from staves fewer than three inches in circumference, many with the pith line still visible. In some elder bows, with large pith lines, the belly shows a guttered effect along much of the belly to no ill effect. Dogwood, ash and wych elm, being especially strong in tension, work very well with small staves. Such diameter staves can be rapidly roughed out, with a side-axe to near bow dimensions, as there is little bywood to be removed.

Fig.5. An ideal section for a heavy bow made from a tight ringed shade-grown wych elm stave of 2 ½ in. diameter.

Note that it is unnecessary to round over the edges of the back as the sides are under less pressure. The belly can be left perfectly flat if more compressive strength is needed. Giraldus Cambrensis, a Cambro-Norman clergyman travelled through Wales in 1188 and wrote of the archers of Venta (modern Gwent):

the bows used by this people are not made of horn, auburn, or yew but of wild elm unpolished rude and uncouth* [9]

* *Eburneo*: from *alburnus*, whitish (from *albus* ,white) ie. auburn ;a type of wood, usually interpreted as laburnum. Giraldus is apparently describing the early medieval mean wood bow.

Section

Amongst other criteria, the British long-bow Society defines a recreational longbow as being of a plano-convex section whose depth must equal or exceed 5/8 of the width. This deep 'D' section is a Victorian design that functions well at low draw weights and with elastic woods. This is not the section of the bows of the *Mary Rose* which typically have an ogival section with a slightly wider width to depth dimension. The heaviest *Mary Rose* bows are more rectangular in section and known as 'slab sided'.

Experience has shown than an exceptional stave must be used to make an effective mean wood weapon if the *Mary Rose* bow 'galleon' section is replicated but more consistent results are achieved with the 'slab' section. Roger Ascham, again in *Toxophilus* (and characteristically cryptic) gives some guidance to the buyer of a bow about the various merits of bow sections. His advice is that in all things related to archery, a circular shape is ideal, therefore, a bow should be 'gathered round'. It is possible that this could refer to either a full-compass tiller, to the bows section, or both. However, as he dismisses all bow woods other than yew as 'mean' it is improbable he is referring to bow of any other wood. Sadly, we can learn little about the mean wood bow of Tudor (and by comparison medieval) Wales or England from Ascham other than its inferiority.

Interestingly, examples of heavy nineteenth century warbows from the Andaman Islands (not the more familiar ones with paddle-like limbs), exhibited in the superb Pitt Rivers Collection, look very similar to many modern 'mean' wood warbows. Looking into the cabinets, the author could almost believe he was observing his own work they look so familiar.   Clearly they are made from less elastic wood than yew with a design to match.

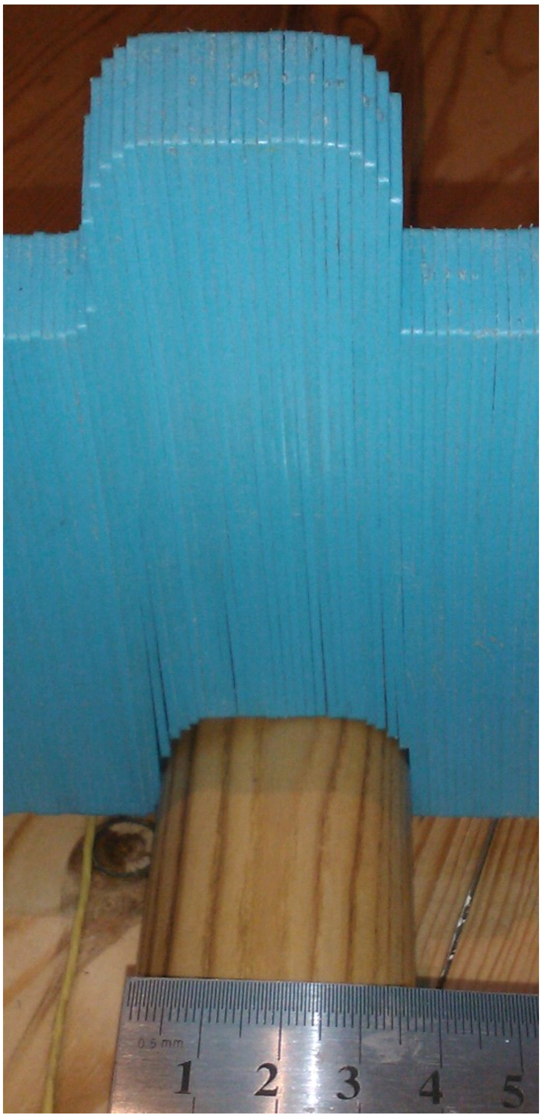

Fig. 6. A flat bellied 115lb ash warbow by talented Czech bowyer, Jaroslav Petrina. The bow is from a large diameter stave so the sides have been heavily rounded to form a pill section, that is with a flat belly and back with hemi-spherical edges. The wood is a dense 0.8 SG.

Heat belly tempering

Experiments by modern warbowyers have shown that heat tempering the belly of a bow can harden the wood and make it more resistant to compression. This is much in the same way a simple wooden spear tip may be fire hardened to produce a more effective weapon. An artefact found in Clacton, constructed some 250,000 years ago, may be part of such a weapon. It is a sharpened and charred yew that resembles the last 120cm of a bow.[10] In *Target Archery* Dr. Elmer, writing in the early 20th century, mentions refreshing a bow with string-follow by using dry heat. The dry heat enables the wood to reach around 300-400 degrees Celsius, at which point it plasticises. This also enables a crooked or deflexed stave to be brought into line whilst simultaneously hardening the belly. Wood 'corrected' in this way makes an otherwise useless stave usable and can simplify tillering as both limbs can be balanced by evening natural reflex and deflex.

Fig.7. An elm stave that was later corrected using dry heat. Whether it was worth the medieval bowyer's time to straighten such a character stave is unlikely given the former

abundance of elm. However, the difference between fire wood and a useable stave may be a five minute 'toasting'.

Dry heat is capable of producing higher temperatures than steaming and boiling and is thought to alter the chemical composition of the lignin and cellulose in the wood. Whether this happens by 'caramelising' or by shrinking the pores of the wood (or both) is not fully understood but the result is undeniable. This process leaves visible charring of the surface and removes a lot of unwanted moisture from the bow. Fire hardening is easily achievable by placing a bow, belly down, around four inches above embers that are arranged in a line. It is a technique that would transfer to batch production in a medieval context.

Fig.8. A wych elm stave is simultaneously set straight as its belly is heat-tempered over embers.

Heat-treated bows can gain up to 10lbs in draw weight with a reduction in physical mass. Modern warbowyers often do not wait for a bow's moisture content to re-stabilise to ambient levels as white woods can much feel springier when very dry. Despite the bone dry wood making the bows back more fragile the tension strength of ash and elm is still usually able to cope. Recent experiments to further toughen the bow's belly, in a process called 'mælming', have taken place in Scandinavia. It involves impregnating the belly with wood resins during heat tempering for many hours. It is likely that we will never have a definitive answer as to whether 'mælming' was a practice carried out by medieval and Tudor bowyers but the time needed makes it unlikely. However, there is slight evidence for heat treatment via an enigmatic reference by Ascham, again in *Toxophilus*:

*Of the making of the bow, I will not greatly meddle, lest I should seem to enter into another man's occupation, which I can no skill of. Yet I would desire all bowyers to season their staves well, to work them and sink them well, to **give them heats** convenient, and tillerings plenty.* [11]

However, it seems likely this is advice to store a bow inside so the moisture content of the wood does not get too high.
With the speed of production required of bowyers to fulfil their orders, little time must have been available for making 'character' staves useable, even if the master bowyer had apprentices. Modern master bowyers generally accept that a rate of around two bows per day is attainable. Given that heat belly tempering takes time to do and often requires the treated bow's tiller to be re-balanced afterwards, it make the routine practice of heat tempering unlikely.[12]

Experimentation

Very little primary source data is available to the modern warbowyer to inform mean wood reconstructions other than extrapolation and experimentation. The paucity in the archaeological record of any bows, with the notable exception of those from the *Mary Rose*, is largely due to broken weapons (and all wooden bows will break at some point) being of little value as anything but kindling. Therefore, experimental archaeology and historical records must be used in somewhat of a vacuum.

In 1560 legislation was passed in an effort to ensure that affordable bows were available for practise to ensure competent archers ready for military service. Section 5 enacts: *that every person may have bows of mean price* and that for every bow of yew, four are to be made of other woods to *meet to shoot in, of elm, witch-hazel, ash, or other wood proper for the same* on penalty of 3s.4d.[13] It is very clear that many other woods must have been commonly accepted as suitable for warbow production than those specifically mentioned. Indeed, more than is practical to write down.

Recently, many species of deciduous indigenous woods have been be used and with appropriate design, to produce effective artillery weapons. For the past three years data has been compiled (by the author and A. Aston) at *Warbow Wales* shoots, recording the distances that have been achieved using a number of bow woods available to the medieval Anglo-Welsh bowyer. All bows were strung with either hemp or flax strings and, importantly, finished with historically accurate waterproofing agents. This may seem like an aesthetic decision but modern varnishes are more effective at protecting the wood from moisture which has a profound effect upon mean woods performance. Two designs of military arrow were used for the testing based on the Westminster Abbey arrow, and an arrow of modal average from those of the *Mary Rose*.

It is remarkable that the Tudor statutory distance for butts shooting of 220 yards or a furlong, was accomplished with a number of bows around hundred pounds in draw weight. It is likely that this represents the lower end of the warbow draw weight spectrum on the *Mary Rose*.

Species

There has been a resurrection of the lost art of mean wood bowyery in the past decade. The Internet has provided a hothouse for the exchange of knowledge and ideas and what was previously thought of as impossible has been proven as readily achievable. The following notes are based upon the author's experiments with the mean wood warbow:

Hazel (*Corylus)*

Hazel grows in abundance and if coppiced will grow into multiple bow staves in a short period of time. Successful bows have been made in very high draw weights that are comparable to those found on the *Mary Rose*, notably by Master bowyer Joe Gibbs. Due to the lighter density of hazel, a bow's dimensions need to be proportionally larger. Draw weights of over one hundred and fifty pounds have been achieved with a centre section of 45mm wide and 37mm deep. Making a bow wider than this in not always a viable option as the arrow reaches the limit it can bend around ('archer's paradox') without deflecting off to the side. It is easy to imagine a medieval drover rapidly crafting an effective hazel weapon with little more than a knife; such is the cleanness of most staves and its wide distribution. Due to the bark being thin it can even be left on the final bow although this gives no practical benefits other than a small labour saving and some possible waterproofing as bark is virtually impermeable.

Fruit woods

It is said that any wood that bears fruit or nuts is suitable for make a bow of and experience has borne this out. Indigenous fruit trees such as crab apple *(Malus sylvestris)*, wild cherry *(Prunus avium)* will make very fast bows indeed and fantastic distances have been recorded. This is due to the woods inherently low hysteresis. Unusually for mean woods, fruit woods often benefit from being made in a 'D' section. This is due to comparatively high compression strength and weaker properties in tension, the inversion of a wych elm bow. Blackthorn *(Prunus spinosa)*, the tree of the sloe, yields a pale, dense (around .87 SG) and aromatic wood that is excellent for many types of bow with warbows being no exception.

Holly *(Ilex aquifolium)*

A fascinating medieval reference, preserved in the Public Records Office, categorically defines holly as a military bow wood at the Welsh marcher castle of Chirk (*Calendar of Patent Rolls* 1396 – 1399). It lists the armoury as containing missile weapons of *divers bows of yew, holly, part of 2 catapults, arrows and cross-bows of no value*[14]. When working with holly it has a tangibly supple and resilient quality and bows of this wood have proved very durable.

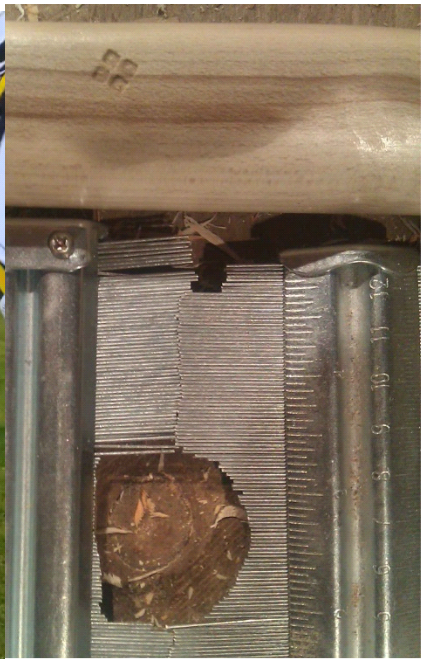

Fig.9. A 110 pound draw weight holly warbow that is tillered to come 'full compass', or bend in the segment of an arc.

Fig. 10. Section of holly wood bow.

The stave was wind twisted around forty five degrees but 'rescued' with liberal steaming and 'unwinding'. Unusually, the wood copes well with a traditional rounded belly section. Frustratingly, holly frequently grows in a spiral that reveals itself only when the log is split. For this reason, sawing is not advisable.

Hornbeam *(Carpinus betulus)*

Noted for its tough timber, hornbeam deserves it name. In the past the wood was prized for its hardness and used for wooden screw threads, butchers cutting blocks, and cogs. The wood gets even harder with heat tempering and heavy draw weights can be achieved with low mass. This make hornbeam bows very responsive indeed.

Dogwood *(Cornus sanguinea)*

Fig.11. A young archer drawing back a *Westminster Abbey* arrow replica with a dogwood bow that draws just under one hundred pounds at 32in. Even though this bow is relatively light it can shoot a replica war arrow a furlong.

Dog wood makes a very robust and springy bow from slim staves. Even when

cutting the green stave it feels like working horn, such is its toughness. Large logs are rare and one or two bows per stave are the norm.
It is interesting to note that Giraldus Cambrensis writes, in Latin, that the Welsh of Venta (modern day Gwent) did not fashion their bows of *Cornus*. It is possible, referring to dogwood and not horn, which had not been used as a bow material (except in crossbows) in Britain since the Roman's departed? Certainly he would have been aware that bows of horn (and sinew) were used in the Levant and by the Romans due to his classical education and often used for arrow shafts by Greeks and Romans.

Ash *(Fraxinus excelsior)*
Ash is specifically mentioned by Ascham as a 'mean' wood' and whilst its tension strength is astounding, it can be weak in compression. Ash also suffers from high hysteresis which gets even worse when the highly hydroscopic wood's moisture level creeps up. This is very apparent when ash staves are seasoned in an unheated outhouse and, in the winter, can harbour mildew whilst staves of other wood next to it do not. Indeed, the author has taken readings of 9% and 16% moisture content in staves respectively of yew and ash (of near bow dimensions) respectively, that have been stored together for two years. This has led to ash gaining a reputation as being sluggish of cast but when dry and well made from superior wood, this is not the case. Ash varies widely in quality and careful selection is essential. North facing hills are often shaded and a stand of ash trees will compete for the diminished light by growing straight without heavy boughs. The slower growth will also make the wood denser and thus more resistant to compressive forces.

Wych elm (*Ulmus glabra*), is widely distributed throughout Europe and not to be confused with witch hazel which is a North American shrub.

Fig.12. A wych elm warbow that draws one hundred and thirty four pounds at full draw and would provide an excellent yew bow substitute whilst shooting at the butts or in battle. It measures only seventy inches from nock to nock yet has no compression frets. It is also, in the right hands and with ideal weather, capable of reaching bowshot with a replica *Westminster Abbey* arrow.

For consistent results from a readily available source it is easy to see why wych elm was the favoured alternative to yew. English elm (*Ulmus procera*) is more susceptible to Dutch elm disease than wych elm and now, sadly, a rare sight and no experiments have been made. However, it is generally accepted that wych is the better bow wood. Tough and stringy, there can be fewer woods stronger in tension. Whilst it is not the equal of yew in compression, wych elm timber does offer a good stiffness to mass ratio with decent levels of compression resistance.

Very hard grown wych elm from Norway has made extremely heavy self bows that equal or exceed the draw weights calculated for those found on the wreck of the *Mary Rose* (based on both mathematical modelling and practical experimentation). British wych elm is not quite as sturdy but still very serviceable and capable of making reliable heavy warbows. However, the medieval bowyer is likely to have been very skilled at selecting staves and certainly had a far greater choice. However, even during the Middle Ages it seems that the supply of mean wood staves needed supplementing with imported wood.

Rowan (*Sorbus)*

Fig.13. Rowan is a fast bow wood but will fret badly if the belly section is too rounded. This example draws one hundred pounds at thirty inches and can reach a furlong with a replica *Mary Rose* war arrow, which is comparable with an average yew bow of similar weight.

Rowan warbows are usually of all sapwood construction but if the tree has been growing in very damp ground it may contain enough heartwood to form the bow's belly which adds valuable compression strength. Notice the naturally reflex tip of the lower limb naturally formed from the base of the tree. This is the limb that is under more stress so benefits from the extra 'kick'.

Elder *(Sambucus nigra)*

Elder *(Sambucus nigra)*

Elder can make a very serviceable warbow although finding a stave straight enough is a challenge. Although not directly transferable to Anglo-Welsh bows, there is a late 13th Century Italian reference to three suitable bow woods in a book about sylviculture and uses of both wild and domesticated trees by Pietro de Crescenzi called *Agricoltura*. Other than yew he offers hazel and elder as woods fit for bow making[15]

Given that it's wood is very light and the pith channel very pronounced it seems an unlikely candidate for warbow wood, yet very heavy examples have been made that have lasted for many arrows.   Dimensionally, elder bows are some of the largest warbows with massive centre sections yet still can be tapered to regular sized half inch tips

Laburnum (*Laburnum anagyroides)*

Fig.14. A characterful laburnum warbow of just over one hundred pounds at full draw. The unbraced image shows how elastic the wood is as it shows no signs of permanent deformation or string follow.

'Hiding' until spring the laburnum will erupt into a stunning shower of yellow flowers. Historically referred to as 'aubourn', it has similar performance to lower quality yew and is one of the most handsome of bow woods. The chocolaty heartwood is perfectly set off by the creamy sapwood to provide a two tone effect similar to yew. The sapwood can be left on although some bowyers will remove it completely. Like yew the laburnum is also poisonous. It is difficult to find suitable billets let alone a warbow stave and the bowyer may have to work around a good deal of 'character' to produce a bow. If white wood bows are the plain Jane's of the warbow world, laburnum is certainly the dandy. It is easy to see why laburnum bows commanded a premium price despite being functionally inferior to yew, just as peacock fletchings have more drag than goose but are aesthetically prettier. During the Middle Ages, bows of laburnum are mentioned as payment for rent which may suggest their usage in a sporting or recreational role which is not surprising, although they are also referenced in a military context in 1285.[16]

This list of mean woods capable of being made into a warbow is by no means comprehensive. It is of little doubt that it will be added to. Woods such as field maple and sycamore, available to Tudor bowyers, are likely to make effectual missile weapons. Testing has shown that even seemingly unlikely candidates, such as elder, can work well. This demonstrates that it could be all too easy to overlook a valuable resource growing under our noses. The amount of suitable indigenous bow woods 'proper for the same' as yew (when a sensitive design is employed) is astounding. In 1991 'Ötzi' the copper age ice mummy was found with items crafted from seventeen species of plant and trees. Each object insightfully matched its function to the properties of the material.[17] This connection to natural materials is one that still, in the main, existed in Tudor times but has since been largely been lost.

However, a growing group of individuals are working to recover some of the forgotten knowledge and rediscovering the incredible properties of natural materials. Recently, hemp bow strings have been made that equal the performance of their synthetic successors. One of the heaviest warbows made in modern times, drawing well over two hundred pounds at full draw, was been fashioned from Norwegian wych elm. Both of these would have been though impossible only a decade ago. The exponential increase of our understanding of yew warbows and military arrows since the rediscovery of the *Mary Rose* is now percolating down to the mean wood longbow but much experimentation is still needed. The yew-centric view of the warbow has, perhaps, been biased by the hundred and thirty seven bows recovered from the *Mary Rose.* That warbows of other woods existed is unquestionable but limited extant examples have been found so a definitive picture is impossible. However, it can be said with certainty that modern interpretations, even with the disadvantages of a diminished supply of wood and less expertise in both shooting and making than our forbears, are still capable of shooting a military arrow for bowshot. White wood bows of humble materials have proved their worth as effective weapons with a slightly modified longbow design.

[1] A discussion (informally chaired by R. Head) at the 2014 Guild Mote of the Craft Guild of Traditional Bowyers and Fletchers.

[2] *Annual Register*, vol. 27, Crowder, 1800,p. 65

[3] *Calendar of Close Rolls* 33 Edward III,p. 601
NB. It is unlikely that the term 'painted' is a literal reference to some form of applied protective coating. Waxing or lacquering a bow could not account for a doubling of its price.

[4] Scott, Sibbald David *The British Army: Its Origin, Progress, and Equipment*, vol. 2, Galpin & Company 1868, p.103.

[5] Hardy, Robert *Longbow*, Haynes Publishing ,2000, p. 224.

[6] Frets ; often referred to as a *chrysal*. As defined by Thomas Roberts *The English Bowman* 1801 , a chrysal was 'a kind of pinch, in form like a canker worm'; possibly derived from chrysalis hence a fret resembling an insect in that state.

7 Hoadley, R *Understanding Wood: A Craftsman's Guide to Wood Technology* Taunton Press, 2000,p.208. Test were carried out with pine samples sealed with different finishes and immersed in water with periodic moisture measurement.

[8] Strickland & Hardy *The Great Warbow*, Sutton Publishing, 2005,p. 5.

[9] (Ed.)Wright. T, *The historical works of Giraldus Cambrensis* H G Bohn ,1863, p.371.

[10] Webb, A *The Archaeology of Archery, '*The Glade'/Dean Archaeological Group, 1990, p.13.

[11]Ascham, Roger *The English Works of Roger Ascham: Preceptor to Queen Elizabeth*, White & Cochrane ,1815, p.130.

[12] Guild Mote 2014

[13] Harland, J *Manchester Court Leet Records*, (Published for the) Chetham Society ,1843,p.208

[14] *Calendar of Inquisitions Miscellaneous, Chancery*, vol. 6, H.M. Stationery Office, 1963,p.111.
Thanks to Richard Wadge for making me aware of this document.

[15] Cenni, A *Wooden Bows in Medieval Italy*, Journal of the Society of Archer-Antiquaries, 1999, p.52
[16] Wadge, R, *Archery in Medieval England: Who Were the Bowmen of Crecy?,* Historic Press, 2012, p.199

[17] Hurcombe,L *Archaeological Artefacts as Material Culture*, Routledge ,2014,p.144.