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Experimental approaches to ancient Near Eastern archery

R. Miller, E. McEwen and C. Bergman

Introduction

Warfare, in the sense of intergroup conflict resulting in casualties, can be assumed to have occurred occasionally in the Near East whenever population density was high enough to enable social and unsocial contact across group boundaries (Vencel 1984), but clear archaeological evidence of how warfare was conducted is harder to identify before the 3rd millennium BC. Despite the number of studies of ancient Near Eastern warfare based on art historical and textual sources (Bonnet 1977; Yadin 1963; Malbran-Labat 1982; Drower 1973; Reade 1972), archaeological studies of warfare have been fewer and have tended to focus on features such as fortifications (cf. Wright 1985: 172–215). These had to be attacked or defended using some form of weapon, but studies of individual weapons or groups of weapons, have been limited in scope, apart from a few studies of performance based on ethnographic observation or experimental replication (eg. Stout 1977; McEwen and McLeod in press).

Until the factors relating to the comparative efficiency and performance of weapons have been taken into account, the discussion of warfare in the Near East will necessarily be incomplete. Some of the factors can be studied by observing how a particular class of artifact works for people who are familiar with its manufacture and use, and the continuing sporting interest in archery makes the study of bows and arrows well suited to this approach. Since military applications of these weapons depend on the reliability, accuracy and power of the cast, it was decided to evaluate the comparative performance of the different weapons used to shoot projectile points by replicating the weapons and clocking the velocity of projectiles appropriate to each type of weapon. The results of this experiment show a clear linear trend in improved performance (Fig. 1). While these experiments are still at a preliminary stage, it is possible to draw some useful results from the replication of the weapons and some of the projectiles they delivered. While we can see how a range of bronze, ebony, ivory, iron, flint and fire arrows performed, more work on how projectile design affected flight and impact is needed.

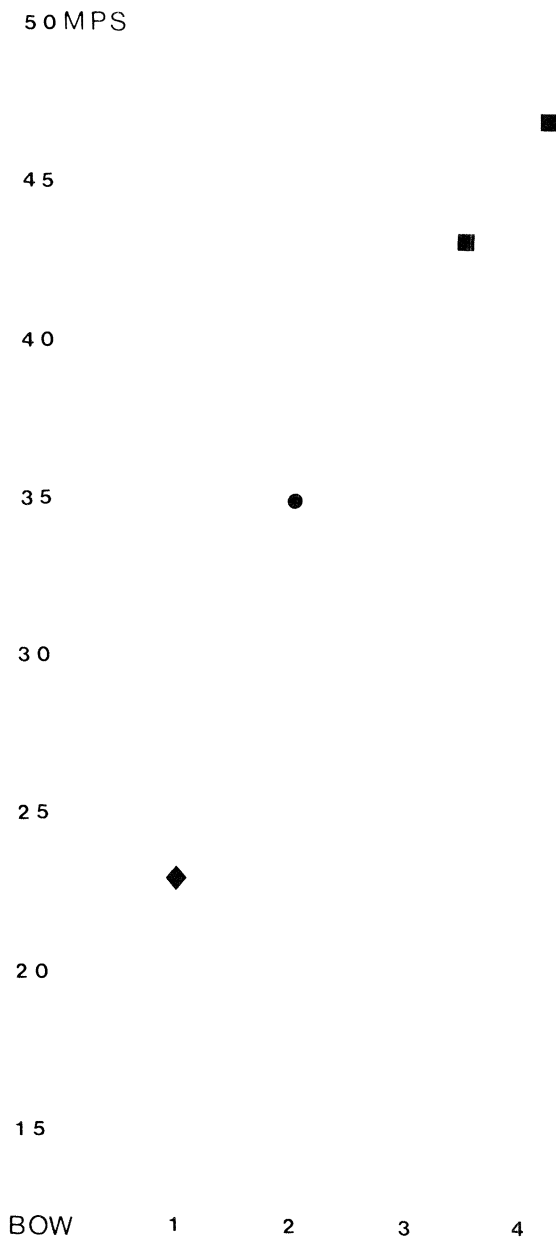


Figure 1 Graph showing the velocity (m/sec) of projectiles shot by (1) a spear thrower, (2) a modern African simple wooden bow, and (3)–(4) replicas of ancient Egyptian angular composite bows. All of the bows shot the same ebony-tipped reed arrow. Velocity was computed using equipment at the Royal Ordnance Small Arms Division, Enfield.

Bows

Bows can be divided into three main groups, all three of which were in use in the ancient Near East: simple wooden bows, also known as self bows, which are made of a single stave of wood; sinew-backed bows reinforced with sinew glued to the back to prevent breakage and to increase the bow's cast; and composite bows which, in the classic forms developed and used in ancient western Asia, combine layers of horn, wood and sinew to

create a weapon with a balance of strength under tensile and compressive forces to facilitate an efficient transfer of the potential energy stored in the fully drawn bow. While the sinew-backed bow was probably used in the ancient Near East (Rouault 1977: 63, 141) most of the evidence for military archery relates to wooden or composite bows.

Different designs of bow represent a careful choice of materials adapted to the forces of tension increasing along the back as the bow is drawn, and to the forces of compression on the belly of the bow nearest the archer. All bows must be designed to withstand both tensile and compressive strain and stress and to recover rapidly from stretching and compression without significant distortion on release, while transferring as much as possible of the potential energy stored in the strung and drawn bow to the arrow shot by the bow.

Wooden bows

The wooden bow is the simplest and oldest solution to the problem of transferring the potential energy of the drawn bow to the arrowshaft, using the energy-storing capacity of materials to propel a projectile faster than could be achieved with the human arm alone, or an extension of it like a spear thrower (see Fig. 1). While the earliest direct evidence for wooden bows and arrowshafts dates to the late Upper Palaeolithic of Europe (Rust 1943; Rausing 1967: 33–34), projectile point design and impact damage suggest that arrows could have been shot by archers during the Upper Palaeolithic and Natufian periods in the Levant (Bergman 1981; Valla, in press), although the use of spear throwers in the Upper Palaeolithic is also possible (Bergman and Newcomer 1983).

The history of warfare, practical experience and replication experiments show that a wooden bow, if made from carefully selected materials, is an extremely effective weapon (Ascham 1545; Heath 1980). In Mesopotamia wooden bows would have been one of the primary weapons until the mid third millennium BC when the composite bow came into use (Yadin 1963, 1972). Even in the late third millennium BC wood was being used in the construction of bows in northwest Syria, when Ebla paid a tribute of 500 bows to the city of Ur (Michalowski 1978: 36), although these bows could have been either wooden self bows or composite bows with wooden cores (J. N. Postgate, pers. comm.). Throughout the third and early second millennia BC wooden bows were still in use in warfare in the Levant, as well as in Egypt (Drower 1973: 497; Yadin 1963: 63–4).

However, there are weaknesses in the mechanical properties of simple wooden bows. In a simple bow, with arms long enough to give a good shot, the energy needed to carry forward the long relatively heavy limbs uses up more of the potential energy stored in the bow at full draw than would be the case in a more energy-efficient composite bow with shorter limbs (Paterson 1984: 109). Using high-speed photography Klopsteg found that after the arrow has left a wooden longbow both the bow and the string oscillate following a relatively inefficient transfer of potential energy to the arrow (Klopsteg 1947: 156). This vibration causes the bow to kick as the flex in the drawn bow is released and runs up the limbs from the handle towards the bow tips, where it is suddenly brought to a halt by the taut bowstring, bouncing shock waves back down each limb to the handle (McEwen 1979: 92). The archer not only loses some of the potential energy from the drawn bow (which is wasted in the bowstave and string oscillation instead of propelling the arrow),

but has to apply extra effort to control the kick of the bow. Given the tendency of wood fibres to buckle under stress when they become loose (Page et al. 1971) it is possible that the small zones of crushed wood on the belly of the bow (chrysalis) which cause a wooden bow to follow the string after prolonged use (Ascham 1545: 114; Elmer 1952: 154) are due to the stresses and strains imposed on the bowstave by the oscillation and kick.

The mechanical weaknesses in the wooden bow may be responsible for the scarcity of clear representations of it in the art of western Asia, apart from the bows carried by the losing side in a neo-Assyrian engagement (Yadin 1963: 450), although this may also reflect the prominence given in palace art to the royal archers who carried composites (Collon 1983), as well as to the idealized upgrading of the tackle of ordinary archers (cf. Reade 1981).

One reason for the success of other forms of bow in ancient Near Eastern archery is that, although composite bows can be kept strung for long periods of time without losing power (Klopsteg 1947: 90), wooden bows can lose strength while braced. However, if the tips are bent towards the belly of the bow the tension on the bowstave is reduced (cf. Yadin 1963: 450). Another way of conserving power in a simple wooden bow is to have a low brace height. If the marines advancing on the double, ready for action, shown on a Fifth Dynasty Egyptian tomb are carrying bow cases as Hayes suggests (1953: 68–9, fig. 45), they are probably equipped with low-braced wooden bows such as those used recently in Somalia, where the distance between string and stave can be as little as an inch or less (Grayson 1961: fig. 1a). Low brace height, combined with bowtips curved towards the belly, put the wooden bowstave under a minimum of tension when braced. Bows could also be strung as a battle began; an archer stringing a long bow, as his companions fire arrows at a besieged city, is depicted on an early second millennium BC tomb painting from Beni Hasan (Newberry 1893: plate 14; Yadin 1963: 63). The possibility that this latter technique was also followed in western Asia is raised by Sinuhe's account of an armed encounter in the Levant during the early second millennium BC (Simpson 1973: 64–5), where his bow was strung and used for practice shots to get the correct range on the eve of battle. This suggested to Yadin that a wooden bow which could only be strung at the last minute was in use (Yadin 1963: 64).

One of the main problems reducing the effectiveness of wooden bows in warfare is their tendency to let down, so that a different angle of release and draw length is required to achieve the same result at different times. This would inhibit effective shooting against massed concentrations of troops and could prevent accurate marksmanship against advancing foot soldiers, who would soon be at close quarters where weapons other than the bow would be needed for hand to hand combat. Since arrows kill by bleeding rather than by impact, shots which did not hit vital areas would necessitate close-quarters follow-through with other weapons, as the story of Sinuhe demonstrates (when Sinuhe, who has successfully shot his opponent in the neck, has to finish him off with his battle-axe) (Simpson 1973: 65). The emphasis given to this one-to-one encounter in the story of Sinuhe might suggest that such accuracy was the exception rather than the rule with wooden bows in ancient battles.

A simple wooden bow, especially a short bow, is difficult to shoot well since even small variations in draw length will lead to great variation in arrow flight and velocity (Klopsteg 1947: 144). While a wooden longbow shoots better and more evenly than a short wooden

bow, it still suffers from serious disadvantages:

A wooden bow has to be made of great length — six feet or more — to withstand the strains imposed by a long draw. This factor meant that the archer could only be at his best when on foot, with an inevitable lack of tactical manoeuvrability. If the foot archer failed to stop a charging enemy with the first one or two shots he became obsolete as an effective missile agent (McEwen 1978: 188).

The vulnerability of the individual archer meant that the foot archer using a wooden bow needed the training and discipline to take part in an engagement as part of a compact company which could release a shower of arrows against an advancing enemy (Heath 1980). Although there is at present little clear evidence of military organisation in northern Mesopotamia, the mustering of troops in disciplined units seems to be depicted in southern Mesopotamian and Egyptian art of the third millennium BC (Moortgat 1969: pl. 119; Hayes 1953: fig. 45). To make archery an effective element in combat, units of spearmen and close-quarters infantry must be provided to protect the archers and to follow through after the enemy ranks have been thinned and demoralised by arrow showers. Although similar depictions of compact fighting units, including companies of archers using the wooden bows current at the time in the Levant, are as yet lacking, the design of Early Bronze fortifications with towers and platforms at fairly regular intervals (Helms 1977; Amiran 1978: 11–13, pl. 174) would have been well adapted to defense by units of archers familiar with the declination and range of covering fire needed to prevent approach by attacking parties.

In engagements in the open field, however, the lack of manoeuvrability of foot archers with long bows was a handicap to armies confronted with mobile carts and chariots. It is no accident that the appearance of a more accurate, reliable and manoeuvrable bow, the composite bow, can be clearly documented soon after the introduction of equid-drawn carts in Mesopotamian warfare towards the middle of the third millennium BC (Littauer and Crouwel 1979) and following the appearance of horse-drawn chariots in Egypt and the Levant a millennium later (Drower 1973: 493–6; Yadin 1963). The independent invention of composite bows following the introduction of equid transport has been noted in a number of other instances in the history of archery (McEwen 1978; Hamilton 1982).

Composite bows

Clear representations of composite bows appear in Mesopotamia in the middle of the third millennium BC in Early Dynastic III and Akkadian art (Yadin 1963, 1972; Collon 1983). These bows can be recognized as composite by the recurved ends standing above the bowstring when the bow is braced (Figs. 2–3) and by the full semi-circular curve the centre of the bow takes when fully drawn, as well as by the full draw across the front of the archer. Angular composite bows of a type found in Egyptian tombs (McLeod 1970; Balfour 1897) are also widely represented in the art of the late second and early first millennium BC. (Yadin 1963). When fully drawn the angular composite bow takes a semi-circular curve throughout its length (cf. Madhlloom 1970: 58–9; pls. 3–4), a feature



Figure 2 (left) Akkadian composite bow with recurved ends.

Figure 3 (right) Early Dynastic composite bow with recurved ends used in siege to shoot a fire arrow.

misunderstood by Yadin who assumed that the strung and drawn angular bows depicted in art were two different weapons (Yadin 1963: 81).

The importance of the military applications of the composite bow is emphasized by a number of the earliest representations depicting its use in siege warfare (Parrot 1971; Yadin 1972) and in close quarter combat (Collon 1983: pl. 19b). Composite bows figure prominently in narrative and triumphal representations of warfare in the art of the late second and early first millennium BC, and these have been extensively discussed (Yadin 1963; Reade 1972; Ussishkin 1982).

The mechanical properties of composite bows which made them so useful in warfare have received less attention. With the experimental replicas of 18th Dynasty bows from the Cairo Museum (McEwen and McLeod in press), combined with analysis of other composite bowmaking traditions, it becomes possible to put ancient composite bows into perspective.

The design of a composite bow takes full advantage of the mechanical properties of the materials used in its construction. Sinew has great tensile strength (Alexander and Bennet-Clark 1977) while horn has compressive strength. These materials are bonded on opposite faces of a wooden core which is too thin to contribute significantly to the power of the bow but provides a surface to glue the horn and sinew to, and is essential to keep the sinew and horn accurately aligned for maximum energy storage and release (McEwen 1979: 91). The wooden core can be made of any non-resinous wood which takes glue well; poplar, maple and ash were used by Persian, Turkish and ancient Egyptian bowyers (McEwen and McLeod in press; McLeod 1970). As each layer of material is added, the bow is set aside to cure thoroughly before proceeding to the next

stage so that the whole process can take a year or more to complete (Klopsteg 1947; Latham and Paterson 1970: 8; McEwen and McLeod in press). This patience is required because of the nature of an essential component of the composite bow, the glue used to bond the layers together. Glue made from dried fish swim bladders was widely used throughout Asia in construction of composite bows, and, while it takes some time to set well, it is more flexible than sinew or hide glue, as well as avoiding the tendency of hide glues to granulate with age.

The time needed for the layers of the bow to cure and set during manufacture meant that composite bows were often made in batches of several hundred at each stage of production (McEwen 1978; cf. CAD Q 148a), a scale of production which would be typical of urban palace workshops. A completed composite bow was a tour de force of precision engineering and bonding which fits readily into what is known of both the methods and materials of the urban craft milieu of Mesopotamia and surrounding areas in the third millennium BC. Good timber was scarce in much of Mesopotamia, especially in the alluvial region, and piecework construction combining wood with other materials in tools and furniture, presumably with the aid of adhesives, is characteristic of Mesopotamian and northern Syrian carpentry in the mid third millennium BC. Composite objects of wood and other materials produced at this time include game boards, musical instruments and inlaid woodwork from Ur (Woolley 1934), inlaid woodwork from Ebla (Matthiae 1980: 88–93) and wagon wheels (Littauer and Crouwel 1979: 18–19). In traditional Persian woodworking, fish swim bladder glue was used for fine work (Wulff 1966: 86, 238), and the special mention of fish swim bladders in a Sumerian text referring to the harvesting of fish from brackish canals to be traded or consumed later, presumably after drying (Civil 1961: 163, 172, 174) raises the possibility that the swim bladder was not only recognized anatomically but used as a source of the glue needed for making fine inlaid furniture and composite bows.

The need for horn elements in composite bow manufacture may also account for the presence of worked horn cores at a number of mid-late third millennium BC sites. While water buffalo (*Bubalis*) or gazelle horn would have been the material of choice for the horn laths a few sixteenths of an inch thick needed in the composite bow belly, any horn could be used, including sheep or goat horn if this were straightened following the process used for knife handles in Persia (Wulff 1966), and pieced together evenly (McEwen 1978: 191) with techniques of cutting out composite flat inlay pieces of shell used for Early Dynastic art work. If a bowmakers' workshop were identified on a third millennium BC site it might be from the flat scraps of horn among burnt waste debris which would not lend themselves to an immediate determination of species. Gazelle horn cores have been noted in significant numbers on a number of mid-late third millennium BC sites in and around Mesopotamia (Hilzheimer 1941: 22–4; Compagnoni 1978: 119; Clutton-Brock and Burleigh 1978: 95; Mudar 1982: 28).

It should be emphasized, however, that production of composite bows in Mesopotamia and surrounding areas in the third millennium BC does not necessarily argue for or against a particular point of origin for this manufacturing technique. Independent invention of composite bows has occurred where the shortage of good timber for longbows (not necessarily found everywhere there are trees), or where the availability of equid transport has led to the development of a powerful bow with speed and

manoeuvrability (Hamilton 1982; McEwen 1978). However, it should also be noted that evidence of composite lath construction in Central Asia in the first millennium BC (Rausing 1967) and the presence in Siberia c. 2500 BC of sinew-reinforced bows of antler with elements too thick to be successfully bonded to a composite laminated bow (Rausing 1967; Hamilton 1982) have little bearing on the origin of the Mesopotamian composite bow.

Composite bows in warfare

Given the presence of composite bows in Mesopotamia from the mid third millennium BC, and in the Levant and Egypt from the mid second millennium BC, why were they so well adapted to warfare? Perhaps one of the main characteristics of the composite bow, which suited it for warfare, is that it could be kept strung for long periods of time without losing power or following the string like a simple wooden bow.

As bracing or unbracing the bow was a tricky operation which ran the risk of twisting the bow limbs (McEwen and McLeod in press), it was sometimes left to the bowmakers to string a bow (Klopsteg 1947: 90). Bows could be kept braced for the duration of the campaign and would thus always be ready to use even in case of a surprise attack. The triangular bow cases found on the chariots represented in second-first millennium BC art were not only to protect the bow from weather and hard knocks (Yadin 1963: 81) but are themselves a sign that a composite bow, which can be kept strung, is carried in them.

A passage in one of the Mari letters, which has puzzled commentators, can be partly explained by this ability of composite bows to remain strung for long periods (Klopsteg 1947: 90):

They should wrap the new bows with tanned leather and turn the end toward the centre. . . these bows will go on campaign with me (ARM 18 9:4; Rouault 1977: 29, 142; CAD Q 148a).

This passage may be describing the reflexing given to composite bows to preserve their strength when they are put in storage after being unstrung. The limbs are warmed to soften the horn, pulled back into a reflex and then tied in place. This is one more advantage the composite bow has over simple wooden bows, as the bow can recover its full strength in this way.

Rouault has some difficulty with this passage and suggests it is a reference to aligning of the seams of loose-fitting leather covers (1977: 29, 142). However, he admits other interpretations are possible and notes that the phrase could mean bending one end toward the lower extremity. This is exactly what someone standing on the ground does when he rests the lower tip of the bow against one foot, steps through the string, and bends the upper bowtip down toward the lower end while slipping the string over the nock (Plate 1). If the translations of this passage by Rouault and the CAD are correct, this text probably describes the stringing of bows in preparation for a campaign, but it is possible to read the same passage as referring to wrapping something around the ends (J. N. Postgate, pers. comm.). There may be a parallel for this treatment of the ends in other composite bow traditions where the bow and bowstring of the newly braced bow is



Plate 1 Angular composite bow being strung.



Plate 2 Truing limbs of angular composite bow.



Plate 3 Angular composite bow when braced.



Plate 4 Angular composite bow at full draw.

wrapped with string, a length of cloth, or strap of leather to hold the bow limbs in correct form. When the composite has just been braced, it can be wrapped for a couple of hours until the bow stabilizes, as the limbs of the freshly braced bow are 'fluid' and usually require some form of adjustment to set them. As tanned leather would not shrink, it would be suited to this task.

The importance of the adjustment of the bow limbs can be seen represented on an orthostat from Ashurbanipal's palace at Nineveh, which shows two people working on stringing bows a millennium later than the Mari reference (Barnett 1976: plate 5). One person is shown bending the bow against his knees, taking care to flex it evenly and to avoid twisting in the limbs of the bow, as misaligned limbs would throw the string off, resulting in a broken bow.

The same orthostat from Ashurbanipal's palace at Nineveh shows another important detail relevant to the construction of the angular bow which has been discovered by McEwen in replicating its design. When the bow is first braced, its limbs have the tendency to take a recurve rather than a straight line. If this is not adjusted the bow may twist, shed the bowstring and break. The recurve needs to be removed by applying pressure (Plate 2) to give the bow limbs the straight lines either side of the central angle, which then remain stable (McEwen and McLeod in press). The attention given to making this adjustment in the fluid limbs of angular bows is depicted on the orthostat to one side of the bowyers or archers stringing the bow: the bow on the left being held with the limbs uppermost shows that one of the limbs is recurved and in need of adjustment, in contrast to the evenly angular limbs of the bow on the far left of the slab.

Once the limbs of an angular composite bow had been adjusted it would have been an extremely effective weapon which combined accuracy and reliability with power up to twice that of a simple wooden bow of the same draw weight. This latter characteristic enabled archers to choose between two tactics, depending on the needs of the moment: either to deliver a lightweight projectile over a distance twice what a wooden self bow could shoot (McEwen 1978: 189), or to deliver a projectile of greater weight or force at short range when the capacity to pierce armour or to thoroughly disable an opponent was needed. The composite bow depicted on Early Dynastic III and Akkadian archery scenes has recurved ends which add to the force of the shot and make the bow easier to hold at full draw than a wooden bow of the same draw weight (McEwen 1979: 92; Klopsteg 1947: 146), allowing a careful aim to be taken on a stationary or moving target. Using a composite bow of later design, Inigo Simon succeeded in hitting a swinging matchbox with four shots in succession at twenty yards (Paterson 1984: 96) and this accuracy would have also been useful to an archer faced with an opponent mounted in a mid-third millennium BC war wagon, or shooting from a 2nd–1st millennium BC chariot.

Composite bows are generally more efficient at transferring the potential energy stored in the draw to the arrow (Klopsteg 1947), so that no energy is dissipated in the kick and oscillation which characterise other bows. In shooting the reconstructed angular composites it was found that the central grip remains rigid throughout the draw, contributing to smooth action and greater accuracy (McEwen and McLeod in press).

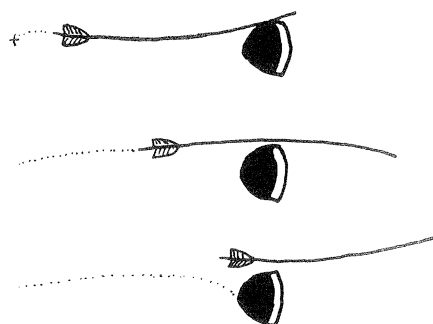
Arrowshafts

Reeds are one of the best materials for arrowshafts (Ascham 1545: 116; Mason 1893; Moseley 1792: 115–19) and the same word was used for ‘reed’ and ‘arrow’ at Nuzi and Ugarit (CAD Q 89; Sukenik 1947: 13). According to a later Persian manual on warfare:

No arrow travels further and is lighter and works better than one of reed but it needs to be well matured and dried and driven through a mould and straightened (translated by E. McEwen 1974: 84).

Dried reeds have a combination of lightness, rigidity and elasticity ideal for arrowshafts (cf. Elmer 1952: 264). Reeds are also already well adapted to their aerodynamic role as arrowshafts by their need while growing to maintain an evenly round profile to reduce wind drag, as well as by having the elasticity and strength to bend and return to upright position. This latter adaptation is critical as arrowshafts need to be able to bend round the bow during shooting, and flex so the tail swings clear of the bow before swinging back into line as the arrow travels along the line it was aimed at the moment of release (Fig. 4; Paterson 1984: 44).

Figure 4 Arrow bending around bow during release.



Reed arrowshafts can be extremely light (Moseley 1792: 119) and often require a heavier foreshaft for balance (Mason 1893: 660–1; Heath and Chiara 1977: 47–50). The necessary weight at the head could be supplied by a hardwood foreshaft or point such as the ebony tips found in Egyptian tombs and referred to in a Mari letter (McLeod 1982: 55; McEwen and McLeod in press; ARM 18 42, Rouault 1977: 63), or by mounting one of the many types of tanged stone, or bone arrowheads used in the Near East from c. 6000 BC on a hardwood foreshaft. Metal points with long tangs could have been stuck straight into the arrow reed (cf. Leakey 1926: 273).

Arrow reeds were often needed in extremely large quantities. Even during brief engagements large numbers of arrows could be used in arrow showers to soften up and demoralise attacking or defending forces. A quiverful of 30 arrows can be shot in three minutes, and in a fifteen minute sustained arrow shower some 150 arrows could be shot by a single archer (Heath 1980; Miller 1985). Large numbers of arrow reeds would have been needed after engagements to mount arrowheads recovered from the battlefield after their reed shafts split on impact. While reeds were also needed for matting and

basketry, the demand for reed arrowshafts could be enough for special stands of arrow reeds to be grown where archery was practised (Moens 1984: 24; Roth 1970: 156), and a cultivated stand of reeds may have been needed to provide the 'twenty thousand reeds for making arrows' recorded on a Nuzi text (CAD Q 87).

Projectile points

Arrowheads appear in the archaeological record more often than the bows or arrowshafts which delivered them to their targets. Much of the excavated evidence for ancient archery consists of arrowheads, so that little can be deduced about the type of bow that shot them, even though something may be learned of the tactics and organization of warfare from the circumstances of discovery.

As composite bows enabled archers to make a choice between short- and long-range tactical options, it is perhaps significant that large numbers of arrowheads occur in the Mesopotamian culture area from the middle of the third millennium BC and in the Levant a millennium later (Mallowan 1947: 180–2; Dajani 1962: 63). In both areas the introduction of the composite bow appears to be related to the tactic of softening up defenses with an arrow shower from a distance; attacking archers could move out of range of the defenders without the latter having the same freedom of movement or the accuracy needed to respond. This problem may have led to the introduction of double lines of defensive walls at the appropriate periods (Parr 1968) so that attackers would eventually have to cross open ground of known range, at a considerable disadvantage.

Quiverfuls of arrows can sometimes be identified in tombs (Woolley 1934: 160, 553; Cross and Milik 1956), and in buildings (Lenzen 1959: 10, plate 19a; Ussishkin 1982: 54). Where individual arrowheads are found they may show impact damage or may occur at strategic points of the defenses which came under attack, such as defensive ditches (Miller 1983), siege ramps (Ussishkin 1982: 54) or fortified buildings within the defensive perimeter (Mallowan 1947: 180; Lagarce and Lagarce 1974: 10).

While different types of projectile point may reflect cognitive styles rather than function (Wiessner 1983); military archers usually carried more than one type of arrowhead in their quivers so they could use heavy arrows at short range to pierce armour, or lighter arrows to harass an enemy at long range (Paterson 1984: 44; Heath 1980; McEwen 1974). This range of arrow weights needed in different contexts is seen in a Mari text where the king, faced with the need for more arrows for a prolonged siege, orders fifty heavy 40 gram bronze arrowheads, fifty 24 g arrowheads, one hundred 16 g arrowheads and two hundred ultralight 8 g arrowheads (Dalley 1984: 63; ARM 18 5, Rouault 1977: 23–4). The range of projectile point weights in one order could also be related to the different bows being used in the siege, as archers are careful to construct or select particular sets of arrows adapted to a particular bow.

Attempts to distinguish, solely on the basis of arbitrary size and weight limits, between 'arrowheads' and points assumed to be 'javelin' or miniature 'spear heads' found in the same assemblage should be avoided, in the absence of supporting evidence. A wide range of head sizes and designs can develop among contemporary groups of archers in the same region (Wiessner 1983) and the tendency of archers to trade and exchange

arrows or recover fallen arrows during battles would further complicate attempts to define arrowheads as uniformly small projectile points and ignore the historical and ethnographic evidence for wide ranges of acceptable point size. As Hamilton (1982) observes:

It is not the weight or the over-all dimensions of the projectile point which determine how large it can be to be shot in a bow, but how it is to be mounted on the arrowshaft.

One of the simplest forms of arrowhead, although it is not always recovered when it is made of wood, is the pointed or shaped foreshaft of organic material such as hardwood, bone, antler or ivory. Ebony-tipped arrows have excellent powers of penetrating shields and protective clothing (McEwen and McLeod in press) and are known from Mari, although the Mari text may refer only to ceremonial items given to the ruler (Rouault 1977: 63). Since arrows ordinarily kill by bleeding, such shafts may have been poisoned, a practice common enough in antiquity for the word toxin to be derived from the Greek word for arrow, *toxos*. Poisoned arrows are known from Egyptian tombs (Clark *et al.* 1974) and cuneiform texts (CAD Q 148b), and effective plant alkaloids were available in western Asia (Miller *et al.* 1982). However, tetanus spores would be easily introduced into any wound, and blood poisoning would have been the result of projectile penetration in many instances (McEwen 1974; Codrington 1890; Hoffman 1891).

Both arrow showers and poisoned arrows often had more psychological than practical effect, as roofs, walls and armour would limit their effectiveness. At close range, projectiles which could open up a large wound on an unarmoured opponent could be useful, such as the hand-sized broadhead depicted on Egyptian scenes of warfare against Asiatics (Yadin 1963: 215–16, 228–9).

Armour-piercing arrows would also have been most needed at short range, and the ogival ellipsoidal points found in the late second millennium BC (Cross and Milik 1956) have been found to be effective as both broadheads and bodkins, an early multipurpose weapon (McEwen and McLeod in press) of a design which continued into the Middle Ages (Latham and Paterson 1970: 26, fig. 15.3). Elongated armour-piercing bodkins have been noted in the arrowheads from Lachish of the first millennium BC (Rothenberg 1975: 79–80). Heavy armour-piercing arrowheads are effective at short range but tend to topple at longer distances (Latham and Paterson 1970: 25), so the mixture of heavy and light heads found in a group of 26 points from a 12th century BC quiver found near Bethlehem (Cross and Milik 1956) probably represents a range of weights needed for different distances and purposes.

Arrows did not need to be directed exclusively against people in order to be effective in warfare, for the use of fire arrows made it possible to set light to the supplies of fuel often stored for security on the flat roofs of Near Eastern houses (Forbes 1838: 427). When houses, roofs and whole quarters had been set alight, the defenders would be distracted from their primary task. Fire arrows are recorded as gifts along with other types of arrows in the Amarna correspondence (CAD I 231a), and an Early Dynastic III siege scene (Fig. 3; Parrot 1971: pl. 14.4; Yadin 1972) shows tongues of triangular flames depicted below the barbed and tanged arrowhead (Miller 1982). These parallel the way flames are depicted on a Middle Assyrian seal (Parker 1974: fig. 1). Barbed and tanged flint arrowheads were made at the time of Mari siege scene or a little later (Miller 1985),

and one was found in the centre of a heavily burnt destruction level at Demircihüyük in Anatolia, dated to the late third millennium BC (Korfmann 1983: 113). While metal barbed and tanged arrowheads were also being produced at this period, flint would have provided a cheap, expendable material for this job, and ovate shouldered flint broadheads were noted in the destruction of Tepe Hissar's Burnt Building (Mallowan 1947: 180). Whether or not flint or metal arrowheads were used for fire arrows is less important than the effectiveness of this tactic.

In our experiments with fire arrows we found that a simple bow could shoot a fire arrow high enough to set the roof of a two-storey house on fire from a distance of thirty metres and that a naphtha-soaked ball of twine with wood splints, similar to that represented in pictorial sources for fire arrows (Moseley 1792: 185; Tucker 1960), could be shot from a composite bow at less than full draw, like that shown on the Mari ivory. At full draw on a more powerful bow, the flames were extinguished. The estimated 30m height and 40m distance achieved with the composite would have been sufficient to set fire to houses inside most single trace defenses, but the type of fortification developed in Anatolia in the third millennium BC and in the Levant a millennium later, with a double line of defensive walls separated by sloping dead ground (Parr 1968), might have been an effective defense measure against incendiary arrows, particularly when combined with the characteristic Late Bronze Age covered tunnel to groundwater springs which could be used to put out fires started within the defensive perimeter.

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Abbreviations

ARM *Archives Royales de Mari*, G. Dossin et al. Paris: Geuthner. 1950.

CAD *The Assyrian Dictionary*, (eds. A. L. Oppenheim et al.). Chicago: Oriental Institute, University of Chicago. 1956.

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Abstract

Miller, R., McEwen, E. and Bergman, C.

Experimental approaches to ancient Near Eastern archery

Replicas of ancient Near Eastern archery tackle can be used to investigate the performance of different types of bows. The velocity of projectiles from spear throwers, simple wooden bows and composite horn-wood-sinew bows shows a clear linear trend in increased efficiency. Mechanical properties of bow and arrow design and performance can be related to archaeological, art historical and textual sources for the use of archery in warfare.