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Fascicolo 6. Marzo 2021

Storia Militare Antica

Società Italiana di Storia Militare

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Scutum di Dura Europos, unico esemplare pervenuto.
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The onager, according to Ammianus Marcellinus: a critical reconstruction

by Marc Cherretté

Abstract. - The onager was a special Late-Roman one-armed stone-thrower and totally different from the existing and more common two-armed artillery of that era, the *ballistae* and *catapultae*. The name 'onager' appeared in Ancient texts of the 4th C.A.D. (Ammianus Marcellinus; Renatus Vegetius). Until now Ammianus' description (Res Gestae, XXIII, 4) is the only existing technical and accurate report of this type of one-armed stone-thrower.

Based upon his description, from the 19th century on it has been studied by a lot of scholars and it led nearly all of them to that typical image of the onager, nowadays living a life of its own in many similar replicas. They all usually show the throwing-arm hitting a wooden buffer. As to me, I found that modern scholars maybe too quickly passed over some parts of his text, - in my opinion important parts but to them apparently rather uninformative- so their translations could leave room for imagination and speculations. That prompted me to a revision of the Ancient text, combining linguistic and technical considerations and partly based upon my handmade scale-models- call it a kind of experimental archaeology. Hereby the translations and concepts of aforementioned scholars were examined, criticised and contrasted with my alternative ideas. My research concluded with a final concept of an onager, to be strained with sinew-ropes albeit for this case, with skeins of horsetail hair. This paper will now focus on that final version. It surely might be controversial since totally breaking with all the prevailing ideas.

Keywords: Ammianus Marcellinus, the Late Roman onager, *nervi torti*, Ligamentum Nuchae, *machina serratoria*, *repagula*, *gibba*, *fulmentum*, *tormentum*, Roman technology & warfare.

Summary:

0 Latin text by Ammianus. 1 Status quaestionis. 2 The Latin vocabulary, examined in a different way. 3 Elucidations for the benefit of a new translation. 4 On the way to a final concept of Ammianus' onager. 5 Overall conclusions. 6 Epilogue

NAM, Anno 2 – n. 6
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Marzo 2021

liber XXIII, caput IV (4-7): Descriptiones muralium machinarum, ballistae, scorpionis vel onagri, arietis, helepoleos, ac malleoli.

§

4.

Scorpionis autem, quem appellant nunc onagrum, huiusmodi forma est. Dolantur axes duo quernei vel ilicei curvanturque mediocriter, ut prominere videantur in gibbas, hique in modum serratoriae machinae connectuntur, ex utroque latere patentius perforati; quos inter per cavernas funes colligantur robusti compagem, ne dissiliat, continentes.

5.

Ab hac medietate restium ligneus stilus exsurgens obliquus et in modum iugalis temonis erectus ita nervorum nodulis implicatur, ut altius tolli possit et inclinari; summitatique eius unci ferrei copulantur, e quibus pendet stuppea vel ferrea funda. Cui ligno fulmentum prosternitur ingens, cilicium paleis confertum minutis, validis nexibus illigatum. Et locatur super congestos caespites vel latericios aggeres. Nam muro saxeo huiusmodi moles imposita disiectat quidquid invenerit subter concussione violenta, non pondere.

6.

Cum igitur ad concertationem ventum fuerit, lapide rotundo fundae imposito quaterni altrinsecus iuvenes repagula, quibus incorporati sunt funes, explicantes retrorsus stilum paene supinum inclinant; itaque demum sublimis adstans magister claustrum, quod totius operis continet vincula, reserat malleo forti perculsum; unde absolutus ictu volucri stilus et mollitudine offensus cilicii saxum contorquet, quidquid incurrerit, collisurum.

7.

Et tormentum quidem appellatur ex eo, quod omnis explicatio torquetur; scorpio autem, quoniam aculeum desuper habet erectum; cui etiam onagri vocabulum indidit aetas novella ea re, quod asini feri, cum vena(n)tibus agitantur, ita eminus lapides post terga calcitrando emittunt, ut perforent pectora sequentium aut perfractis ossibus capita ipsa displodant.

LATIN TEXT BY AMMIANUS MARCELLINUS:

1
THE ONAGER: STATUS QUAESTIONIS

In contrast to their achievements and treatises about the more common classic artillery, the translations/interpretations of Ammianus' text by authors like Sir Payne-Gallwey, Oberst E. Schramm, E.W. Marsden a.o. – although trendsetting - struck me as rather uncertain and somewhat deficient. Their ideas were based on recurring common principles and characteristics of the two-armed torsion *ballistae* and *catapultae* –more familiar to them. Probably the lack of accompanying Ancient drawings has led to their typical replicas with but weak performances.

Invariably, they used two beams (*axes duo*) interconnected by cross beams, based on the sentence ' *in modum serratoriae machinae connectuntur*' which they interpreted as a frame-construction, somehow resembling a carpenter's frame-saw. But that is a somewhat unfortunate comparison, since the tensioning-rope of that saw is located at the front of it – thus not in the middle which is alas the case in their onagers.

The phrase '*curvanturque mediocriter'* meant to them that the beams were fashioned and given a moderate curvature. In these beams two large holes (*patentius perforati*) were bored in each side (*ex utroque latere*) through which powerful ropes (*funes … robusti …*) were stretched preventing the structure from falling apart.

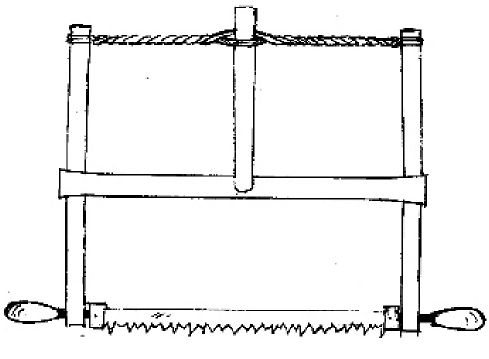


Fig.1 : A carpenter's frame- saw

But further on in their translations suddenly these ropes are considered as the resilient twists of sinew ropes (*nervi torti*). Indeed, they then deduced from the sentence '*ab hac medietate restium'* that 'in' or 'from' those ropes (*restium*) a stem or sling-arm (*stilus*) rose up (*exsurgens …ita nervorum nodulis implicatur…*) So, they had to conclude that these ropes had suddenly too become the sinew-ropes or *nervi torti* in which the arm was fixed.

Another misapprehension is their translation of '*cui ligno ful(ci)mentum prosternitur*' suggesting the existence of a huge (wooden) buffer (*fulmentum*) as part of the onager and in front of the arm (*cui ligno*), fitted with a sack (*cilicium*) of chaff (*paleis minutis*) used as a cushion to muffle the recoil of the released arm.

Then they got somehow stuck again with the arrangements to pull down the arm. Indeed, they consistently translated '*repagula'* as the 'handspikes' of the winch, used by the 2 teams of 4 men (*quaterni iuvenes … altrinsecus*) to lower the arm. Finally, they positioned the presumed winch at the back of the onager, which alas made it physically impossible for the 4 men on each side to work together at the same place and time as one team.

Despite these unclarities, many replicas were built following the above-mentioned principles, including those by Payne-Gallwey, Schramm and Marsden, to mention some of the most renowned ones.

It should be mentioned, they remained indebted to the common principles of construction and torsion-power of the two-armed *ballista*. Indeed, although they provided only one bundle of sinew, one must remark that their onager was just an enlarged version of one half of the torsion-frame of that *ballista*. Their onager's arm was also hammered into the bundle of sinew and they even used washers (*modioli*) and levers in their replicas to tighten the bundle.

Their sole real 'innovation' was the use of a huge buffer with a muffling cushion, intended to soften the recoil of the arm (*mollitudine offensus cilicii*), once released.

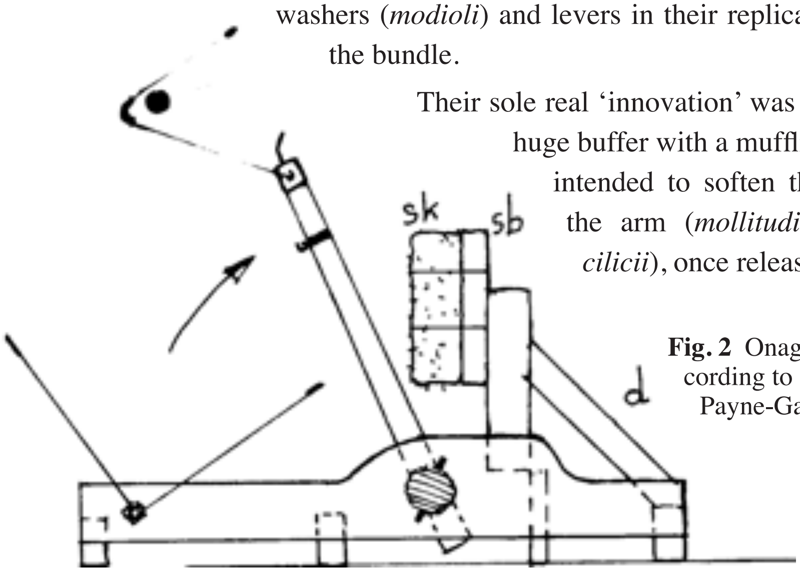
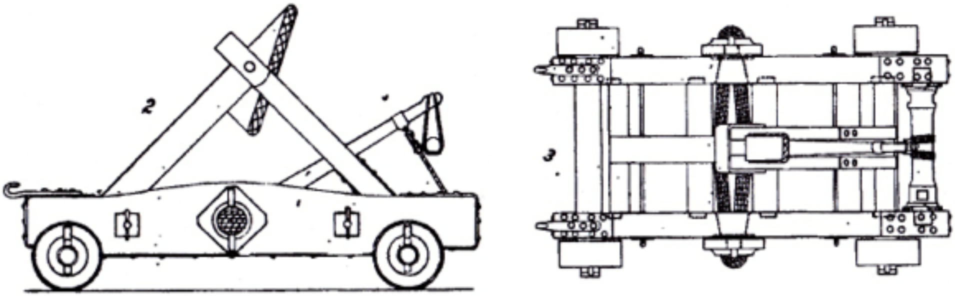


Fig. 2 Onager according to Sir Ralph Payne-Gallwey[1]

1 More about Sir R. Payne-Gallwey: see E. W. MARSDEN; 1971 *Greek and Roman Artillery Technical Treatises;* VIII the Onager – p.249-265

In Payne-Gallwey's model the recoil of the arm (*stilus*) is absorbed via the buffer (sb) and its muffling cushion (sk) (stuffed with chaff) mainly by a few struts (d) which are by that subject to compressive forces and stress.

At first the buffer had an oblique position, but the arm broke too often and in the end Payne-Gallwey had to bring the buffer into a simple vertical position. His biggest model weighed 2 tons and hurled a stone of 8 pounds (± 8 Minae) over some 500 yards.



Figures 3. Onager built by Oberst E. Schramm [2]

Notice the middle part of Schramm's drawings, showing the strong resemblance to the spring-frame of a *ballista*. His engine could hurl stones up to 300 m far, but it should be mentioned that these stones hardly weighed 4 pounds. Compared to the size of the weapon, it's a rather poor result, certainly in battle conditions.

While Payne-Gallwey had some troubles with the buffer which got loose by the force of the recoil, Schramm had a lot of problems with the arm (*stilus*) which tended to break at the recoil, by smashing against the buffer at a certain angle. He therefore had to seek the right angle which he calculated to be optimal at > 65° (for more info, also see Marsden[3]).

Schramm failed to manufacture the *nervi* of sinew either, but he used ropes

2 E. SCHRAMM; '*Griechisch-römische Geschütze. Bemerkungen zu der Rekonstruktion*': 1910 - Metz Verlag -G. Scriba, Tafel 10

3 MARSDEN E.W. ; *Greek and Roman Artillery - Technical Treatises* – 1971 (Oxford at the Clarendon Press) p.*262*.

of horsehair (*Rosshaarbespannung*)[4] as he also did for all his *ballistae* and *catapultae*[5].

Another remarkable feature in his onager was that he needed to twist and tend the resilient bundle up to a combined tractive force of ~60 Ton (!) in order to gain the required throwing-power. So the cross beams of his frame must have been extremely necessary to help the side beams withstand this enormous force… Ammianus by contrast, mentions no cross beams at all …

Marsden[6] built an onager respecting most of the principles of Schramm (as in Fig. 3). Here too the shock of the recoiling arm is absorbed, via a buffer (sb) and a cushion (sk), mainly by a pair of longitudinal, parallel bars or beams (t), subject to tractive forces. These tensile bars (t) start from the two main beams and come together near the buffer (sb) (Fig. 4).

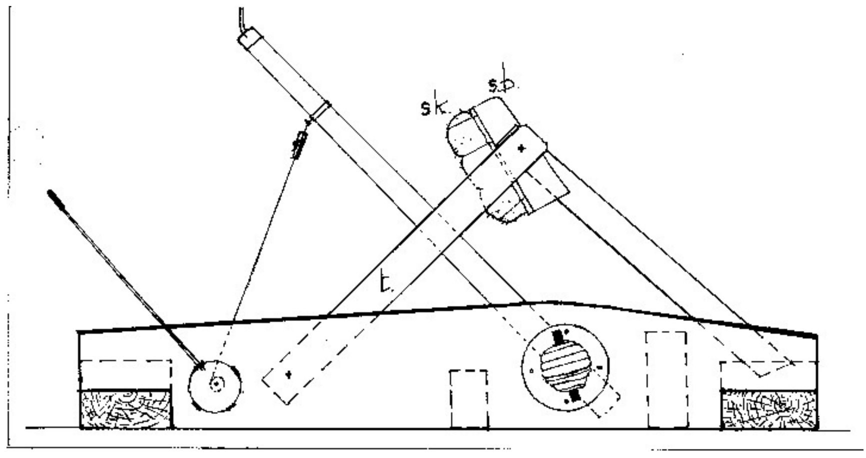


Fig. 4

The schematic figure 4 shows how Marsden too, just as the former authors, was struggling with Ammianus' text:

- '*curvanturque mediocriter*': he solves this 'problem' by fashioning the big side beams into a slightly curved shape.

4 Diels H. & Schramm E.; *Abhandlungen d. Kön. Preussischen Akademie d. Wissenschaften*, 1918 (Berlin) , nr. 2 /48

5 Schramm's replicas were built (1903-1908) for the Saalburg, Bad Homburg– Germany.

6 Marsden. E.W. *Greek and Roman Artillery- Technical Treatises* – 1971 (Oxford at the Clarendon Press) p.251-265

- ‘*patentius perforati’* means to him the existence of large spring-holes.
-‘ *Ab hac medietate restium’* is translated as: ‘from this tangle of ropes, ‘from the middle of the cords …’.

So, Marsden – just as his predecessors – also makes these cords (*restium*) function as the bundle of *nervi*. Moreover, he adds cross beams to connect the side beams (he needs them for the stability of the whole) and this ground-framework reminds him too of a frame-saw.

There are still a lot of other reconstructions possible: e.g. in Fig. 5, which is inspired by contemporary models.

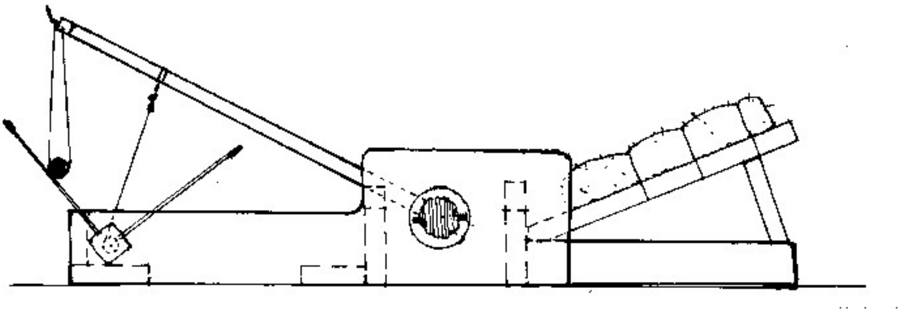


Fig. 5

Another interesting variant is the one by Professor J. Fontaine[7]. Compared to his predecessors, his design is innovative. He situated the muffling cushion on the ground, in front of and also disconnected from the onager : thus without a buffer construction. To him, the ground was the *fulcimentum*. He also paid more attention to details that were neglected by his colleagues: e.g. the ropes (*funes robusti*), holding his construction together so he did not use cross beams either. But at straining his onager, the engine would simply collapse.

I can conclude that most of these onagers, as constructed by the aforementioned scholars may be feasible concepts - though not necessarily powerful- of one-armed stone-throwers and valuable as such. They however don’t fit with that special type of onager as described so accurately by Ammianus.

I will now discuss the aforementioned models with their rather stereotypical representations in more detail and demonstrate that they all have, to a certain extent, linguistic or technical shortcomings.

7 Fontaine J., *Ammien Marcellin, Histoire*, 1977 (Paris) Tôme IV, figure II.

2
Vocabulary, examined in a different way

The previous conclusion encouraged me to review Ammianus' description linguistically as well as technically.

The first and foremost necessary step was to set the previous interpretations aside and then re-translate the Latin text. While doing that, I considered all kinds of plausible alternatives for certain Latin words and verbs, especially where they gave way in the past to rather deficient translations. Besides I paid special attention to some apparently unnecessary but yet so important sections (*marked with* *) of the text.

- *curvanturque*.
- *mediocriter*:
- *prominere in gibbas*.
- *in modum machinae serratoriae*.
- * *ex utroque latere patentius perforati*
- * *funes robusti*, *quos inter per cavernas colligantur compagem, ne dissiliat continentes*
- *ab hac* .
- * *in modum iugalis temonis erectus*
- * *ita nervorum nodulis implicatur, ut altius tolli possit et inclinari*
- *fulmentum* /*fulcimentum*
- *repagula*
- * *explicantes retrorsus*
- * *et tormentum quidem appellatur ex eo, quod omnis explicatio torquetur*

3
Elucidations for a new translation

My new and alternative interpretations wouldn't have been possible without a critical approach of the pre-mentioned models, combined with technical considerations from the theories of mechanics, dynamics and the strength of materials. Consequently, the standard models of Payne-Gallwey, Schramm, Marsden will be subjected to this critical examination.

My new translation is also the result of experimental research, whereby I've built and tried out a lot of scale models, some of which were soon abandoned while others gave birth to new insights and to other new models and so on. Eventually I retained 3 scale-models which were hardly different from each other due to being based on the same working-principles. Of them, both Version-1 and Version-2A were already discussed and described in detail in some of my earlier articles[8]. Although they already led me to the definitive translation they were later on surpassed by a last and final scale-model, Version-2B, for reasons which I shall explain in this paper.

About Ammianus' Text, Liber XXIII, Caput IV : §4

Lines 2-3

Schramm interpreted '*machinae serratoriae'* – and thus the main construction of the onager – as a frame-saw. Additionally he had the beams sawn until they had a light curved hunchback: '*curvanturque mediocriter*' (Fig. 3). Marsden too compared the construction with a frame-saw and he too had the side beams fashioned till they were slightly curved (Fig. 4). These side beams are hereby interconnected with cross beams.

Critical reflections on figures 2 to 5

1. First of all we have to remark that Ammianus mentions two beams only – *duo axes*. He never wrote about other beams nor cross beams.

8 - JRMES : Volume 12/13 2001/2 (ISSN 0961-3684) ; p.117-133
- VOBOV-Info nr.55- juni 2002 (EMKA Kruishoutem –Belgium) p.3-29
- M. Cherretté, *Artillery in Ancient Times, the Onager a critical reconstruction*; 2018 (P.A.M. Velzeke – Belgium)

2. Sawing or cutting the side beams out into a lightly curved form does not provide a technical advantage nor is it necessary. On the contrary, it weakens those beams by cutting through the wood fibres which happens to be in a heavily loaded zone (by flexion and by torsion) caused by the wrenching of the sinew bundle (*nervi torti*) while pulling the arm (*stilus*) down backwards. There is also a lot of unnecessary debris and waste of valuable wood, an issue the ancient engineers were anxious about.
3. Moreover, their interpretations are not in accordance with the original Latin text: *gibba* actually means a hunchback and not a curvature or a bow-shape.

Alternative translation

Serra = saw; serram ducere; serra secare = to saw. *Serrarius* (and not *serrator*, which we could have expected anyway but isn't a Latin term) means 'carpenter'. Therefore *serratorius* is not derived from 'serrator' , a non-existing word, but rather from '*serratus'* which means 'serrated, indented' as e.g. ancient coins sometimes were: *nummi serrati*. Hence I'm convinced that '*machinae serratoriae'* refers to a construction 'resembling' a gear mechanism with indented wheels. We may not forget the Romans were familiar with these kind of tools and constructions, using them in hoisting apparatus, watermills et cetera (Vitruvius: *De Architectura, Liber X*).

Curvanturque should be understood as 'being provided with a rounding, a curved aspect or a curved item'. Therefore Ammianus at the same time mentioned the word '*gibbae'* (humps or hunchbacks) to complete the idea.

Combining all these alternative translations/ interpretations leads me to a totally new design: Ammianus definitely alludes to two halves of indented cylinders, gripping in each other like cog-wheels do. The following question was now where to situate these indented half-cylinders : … *mediocriter* … *prominere*…

1. *Mediocriter*: an adverb of *mediocris* (*medius*/middle & *ocris* /height)

   This adverb means literally 'in between the highest and lowest point of the cross-section of that *axis* (=log/beam), or 'at mid-height'; as a consequence of my design, the *gibbae* lay 'in between' the two beams (logs) / duo axes (Fig. 6).

2. *Prominere: pro-eminere*

   Once again this verb gives the answer: they are implanted at one end or extremity of each beam: '*pro*-'. Their protruding like a hunchback is confirmed by '-*eminere*' and '*gibbae*'. Hereby, the only remark or question– but with important consequences for the final design – is whether they are implanted approximately or completely at the end of the beam.

Depending on these choices two different versions of an onager are possible: a Version–1 (Fig. 6) versus a Version-2 (Fig.7).

Figures 6: Version-1

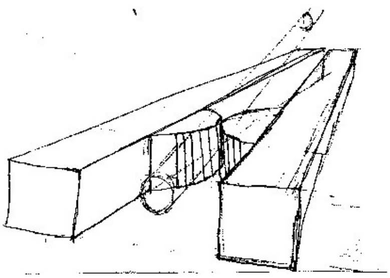


Fig. 6A

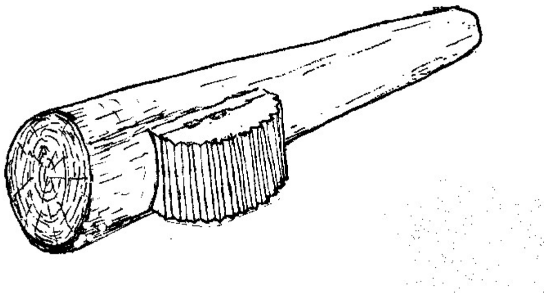


Fig. 6B

Figures 7: Version-2.

In the Version-2 the half-cylinders are positioned at the far end of the beams, which better corresponds to the meaning of the verb '*pro-eminere*'. '*Pro*' indeed indicates a forward position.

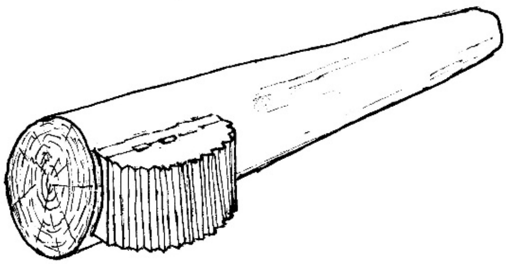


Fig. 7A

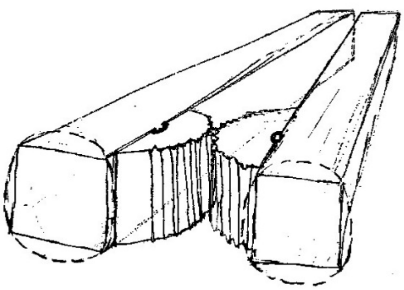


Fig. 7B

LINES 4-5

Schramm, Marsden among others seem to neglect the deeper meaning or relevance of the phrase ‘ *funes robusti … ut compagem ne dissiliat* ..’ They pass over it in relative indifference, not giving a conclusive explanation. My research led me to 2 possible alternative versions.

The alternative Version-1 (Fig. 6 & 8) : In this case the far ends of the beams are pulled together (Fig. 8 & 9) by means of built-in tackles. For more information about operating this model see P.A.M. Velzeke [9] .

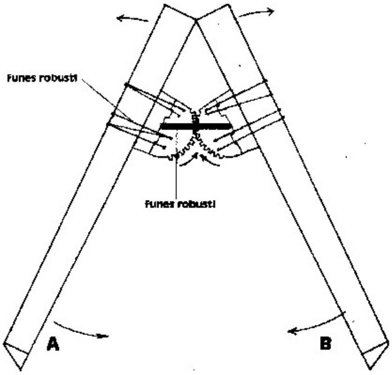


Fig. 8

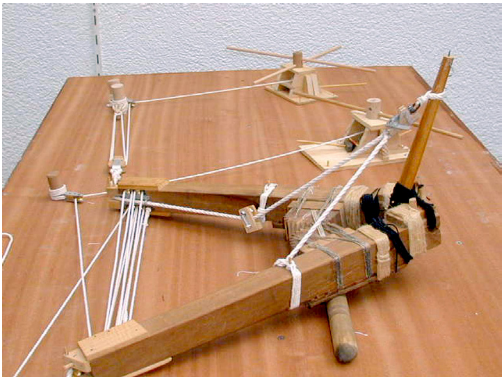


Fig. 9

The alternative Versions-2 (Figures 10A & 10B)

In the case of Version-2, due to the implantation of the half-cylinders at the front ends of the beams, the rotating manoeuvre will evolve in the reverse sense as can be seen in figures 10. Of course, the indented half-cylinders or wheels need to be securely attached to the beams. Yet, these half-cylinders also have to be joined together so that they won’t lose mutual contact at rest as well as during the operation – i.e. the rotating manoeuvres, necessary to stretch the resilient bundles of my onager.

9 M. Cherretté: *Artillery in Ancient Times– the Onager, a critical reconstruction*, 2018; P.A.M. Velzeke

Fig.10A

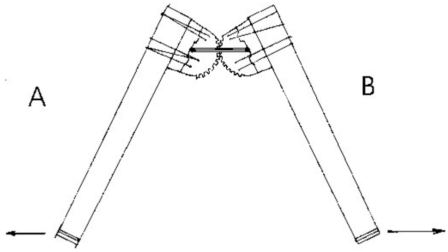


Fig.10B

In Fig.10A my onager is still under construction: the two *axes* with their *gibbae*, provisionally lying down, still without the throwing-arm and its bundles of '*nervi torti*'. The beams A and B are the *duo axes* with rectangular or circular cross-section (logs) which will be straddled (Fig.10B), once the bundle of *nervi* and *stilus* in place (Fig. 11). Ammianus will call them '*repagula*' (see further Lines 17-18) because of the suggestive hinged manoeuvre at straining the onager.

Here, the straining will be realized by 'unfolding' the onager, pulling at the free ends of its beams (*explicantes retrorsus*) by means of capstans (see further).

In Figures 11-12 all connections are realized just by using strong ropes: *funes robusti*. Ropes to tighten the half-cylinders to the beams (*axes duo* or *repagula*) and ropes, laid around and being put through a centered hole in the two half-wheels.

These ropes are repeatedly pulled through holes and are at the same time an explanation for '*patentius perforati …*'. At first the indented half-cylinders are to be fitted rigidly onto the beams for evident constructional reasons, especially at rest. But they also are to be held together in a strong but fluid way (by ropes/*funes*) to allow, without losing their mutual contact (*compagem*) the rotating manoeuvres necessary for straining the onager under full tension. Note that the ropes, connecting the half-cylinders to each other, must pass through their geometric centres.

By that the whole system can easily rotate without intricate wooden or iron components or additional gadgets. All my scale models (scale 1:15) proved the effectiveness of this simple rotating-mechanism. Finally we have here a clear and simple design of the onager.

Line 7 - *Ab hac medietate restium*

In line 7 '*ab*' does not mean 'out of ' for in that case, Ammianus whould have used '*ex'*. The reality however is different: '*ab'* clearly and simply means 'beyond'. Therefore, '*ab hac medietate restium'* means that the arm is turning up somewhere beyond (before or after) the ropes holding the beams and half-cylinders together. This seems to me the mistake repeatedly made by former authors. Consequently, they had the *stilus* turning up 'out of' the middle of 'their' ropes (*funes robusti*) while at the same time they considered these ropes as the resilient bundle of sinews (*nervi torti*).

My statement gives a totally different image of the onager, as illustrated in figure 8 (Version-1) and in figures 10-11 -12 (Versions-2). Here the arm/*stilus* does not turn up out of the middle of the cords / ropes but at a certain distance from/ beyond (*ab hac*) the middle of them. It must be clear that Ammianus provided this text-section only to emphasize "*ab*" and that the main purpose of the ropes (*funes*) and holes (*amplius perforati*) is just the tight fixation and connection of the half-cylinders and the beams as a whole.

The so-called '*nervi'* of my scale-models of the Version-1 and Version-2A were made of rubber skeins, for reasons explained later in this article. Figures 11 & 12 A show a Version-2A, with 'nervi' made of rubber skeins.

Fig. 11: ***Ab hac medietate restium***

LINES 7-8 - *stilus exsurgens obliquus et in modum iugalis temonis erectus*

Obliquus can be an adjective for the oblique position of the throwing-arm, but then '*oblique'* should better fit since related to the verb '*exsurgens'*. So I would rather use '*obliquus'* as it is related to the tapering form of the wooden stick or arm.

In any case, '*in modum jugalis temonis erectus'* marks an inclined position (figures 12) derived from the comparison with the oblique, slightly up-tilted position of the yoke-pole of ox-carts:.

Fig. 12A
Version-2**A**: 'nervi'-skeins of rubber.

Fig. 12B:
Version-2**B**: 'nervi'-skeins of horsetail-hair.

In the figures 11-12, I apply the same reasoning about '*Ab hac* ..' so the *stilus* is wrapped in the *nervi*-bundles, just beyond (*ab*) the cogwheels and tightening ropes (*funes robusti*).

As I already said, at first I used rubber strands for they could be a good alternative for the supposedly highly resilient *nervi* (e.g. of Ligamentum Nuchae): Version-2A. Later on, resuming my research for a similar model of Version-2A, I explicitly used *nervi*-strands made of horsetail hair, a suitable alternative for ropes of real sinew as I shall explain more in detail in the following sections. It will become my final design: Version-2B.

LINES 8-9 - *ut altius tolli possit et inclinari*'

These lines are very important for both Versions-1 and -2, for Ammianus here reveals the forwards-orientated oblique or nearly horizontal position of the arm. The phrase *'ut altius tolli possit et inclinari*' cannot have a different meaning.

Indeed, during the straining action the arm is at first lifted into a vertical position and then pulled down in a nearly horizontal position, all in one smooth, fluid movement. Particularly for Versions-2A and -2B, you will easily picture that swaying movement of the arm during the engine's straining.

As to the former scholars, a vertical or an inclined mounting of their wooden buffer is not in line with Ammianus' text - which indicates a swaying movement of the *stilus* - since their buffer will just prevent the arm from doing so. That is especially regrettable because the ample sway of the arm by Ammianus' onager gives it the opportunity to make full use of the supposed elastic and mechanical features of the '*nervi torti*'.

Beyond doubt the elastic and mechanical characteristics of '*nervi torti* ' must have been uncommon. According to Heron's artillery manual (*Belopoeica*), their artificers used a stretcher to impart great tension to each strand of the sinew-bundles in the frames of their *ballistae* and *catapultae*. These strands were so intensively tightened that their 'diameter was reduced by one-third' which must include a remarkable elongation. However, this way the ancient artificers in advance wasted a great deal of the total available power of their bundles of sinews, by pre-stressing them in their frames or cases, thus even before starting to pull back the bowstring and so the arms of their artillery pieces.

In my design of an onager, there is none of this waste, here the required throwing-power is gradually built up by lifting and then pulling the throwing-arm backwards and down over more than 120° (*paene supinum*), combined with the elongation in the *nervi* caused by closing (Version-1) or straddling (Versions-2) the onager-beams (*repagula*). At the same time I avoid the complicated process of pre-tensioning the sinew-bundles as happens e.g. by Schramm's replica.

LINES 8-9 - *ita nervorum nodulis implicatur, ut altius tolli possit* ét *inclinari*

In the case of Ammianus' onager several separate strands or bundles of sinew (*nervi*) are fastened to the arm: *nodulis* = plural. Versions-2 show how this can be done. It's evident that the method of fixing the arm by hammering it into the sinew-bundles – as is the case for the arms of *ballistae* and *catapultae* – is no longer applicable to this kind of onager: the arm is now wrapped (*implicatur*) in the strands (*nodulis*).

LINES 11-12 - *fulmentum = fulcimentum*

Here again, my new translation will deviate thoroughly from the commonly accepted interpretations so far. I myself have always had serious doubts about the practical utility, necessity and technical feasibility of a wooden buffer. First of all, I don't see any advantage (ballistic nor technical) of the premature interruption of the recoil of the throwing-arm in the middle of its sway. After all, the stone by effect of the centrifugal force is yet slung before the arm is stopped by the muffling cushion and buffer.

A buffer may only make sense if the *stilus* would end in a spoon instead of a sling. Indeed the stone can only be launched by the spoon if the arm is stopped in its course at a certain aimed angle - here the angle of the buffer- so that the stone will fly off at that angle. However, Ammianus clearly mentions a sling (*funda*), not a spoon.

Moreover, the former scholars made things difficult for themselves and their replicas. Their vertical or slanting buffers underwent a tremendous force at each recoil and hit of the arm, which only caused troubles. The arm often broke or the buffers came loose. As a solution, they varied the angles of the buffer or reinforced their buffer constructions which made them heavier too. It is also important to recall they were launching only small stones. Payne-Gallwey's onager, for instance, weighed about 2 Tons while it was able to sling a load of 3.5 kg, albeit over 450 m. Thus what kind of colossus would be needed to sling a stone of 2 *Talenta* (~ 52 kg) ?

However, the above-mentioned authors provided their onagers with a buffer. The only advantage was to gain a kind of pre-straining force in the sinew-bundle, balanced by the buffer which aim was to hold the arm in place during this straining process.

Nevertheless, stocking available energy in the onager can also be obtained without a buffer: if from the start one fits the arm into the sinew-bundles (*implicatur nodulis*) in a forward-orientated and slightly oblique position (*obliquus … in modum temonis iugalis erectus ut* …) the required force can be built up by pulling back the arm, because now possible over > 120° (*ut altius tolli possit et inclinari* …).

Based on these technical and linguistic considerations, I am convinced that there is no need for that kind of buffer- alas generally accepted so far. So I have discarded it from my reconstructions moreover since my rotating system was difficult to match – or even incompatible with – the above-mentioned buffer constructions.

For sure Ammianus did mention a '*fulcimentum*' and a cushion/ sack, stuffed with fine chaff: *cilicium paleis confertum minutis*. Therefore I will now first try to find out the real meaning of *fulcimentum* and the necessity of the cushion too.

Fulcimentum in Latin also means 'trestle, trestle table or something like the support of a bed', and thus is something with a horizontal and supporting function, certainly not an obstacle, such as a buffer. Ammianus also uses the verb '*prosternitur*' and that can only indicate that the construction (*fulcimentum*!) supporting the onager (*cui ligno*) is spread out horizontally. In addition it was '*ingens*', thus 'huge' compared with the onager itself which implies that the *fulcimentum* is no part of the onager. Therefore it is not a buffer but a kind of a vast wooden workbench, supporting the onager, the soldiers and the assisting capstans, at the same time muffling its recoil as a whole.

Fig.13

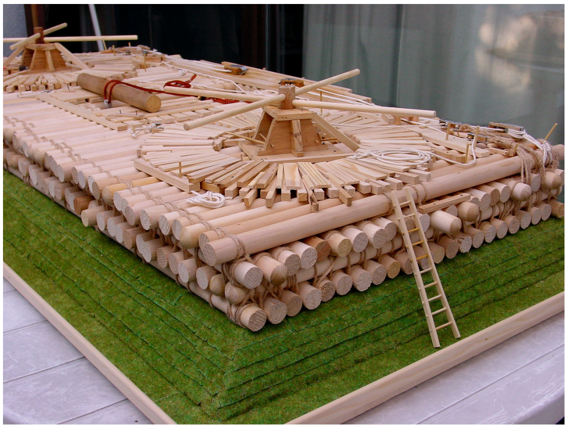


Fig. 14

Figure 13 (Column of Trajan) shows soldiers operating a *ballista* or a *catapulta*, placed upon a wooden platform or construction, consisting of multiple layers of timbers, laid cross-wise as a lattice. Probably the *fulcimentum* was constructed in the same way. In addition it was in turn laid upon a supple base of several layers of sods or turf (Fig. 14) or bricks (*et locatur super congestos caespites vel latericios aggeres*) for it may be of some interest to recall that the Romans were used to building turf-faced ramparts around their military camps.

Such *fulcimentum* was very useful , Fig.14 speaks for itself. Upon platforms of this size, one can place the onagers of Versions-2, the capstans or treadmills, the ropes and tackles, a roller beam beneath the onager, the personnel, etcetera without any problem while the platform rests upon piles of turf or brick layers to provide a supple base.

Cilicium was in the former interpretations of Schramm, Marsden and others a muffling cushion, stuffed with fine chaff and attached to the buffer by strong binding.

My alternative translation offers two possible interpretations: the Cilician goat-skin or cushion can be either attached to (or laid upon) the *fulcimentum* (only for Version-1) or laid somewhere upon the onager (= *cui ligno* = dative), precisely where the stilus will recoil and hit. It's the case for both onager-Versions-2 : e.g. see Figures 18, 25, 26).

With my onager of Version-2B – which will become the ultimate version – the muffling cushion is fastened to the half-cylinders because they are part of the onager (*lignum*) and are to be protected against a probable hit by the arm at its recoil: Fig.26. Moreover, from the grammatical point of view, this interpretation is the best translation: *cui ligno* (= dative) *illigatum cilicium*.

Line 14

Concussione doesn't mean 'by the blow' (according to former authors) but 'by the reaction' of the onager as a whole, namely the concussion afterwards, as a result of the recoil; hence the necessity of placing the onager upon a consistent wooden platform, the *fulcimentum*. The Romans were used to build such massive wooden stacks of crossed timber layers (e.g. column of Trajan), some placed in turn upon a supple base of several layers of sods or bricks. Such resilient bases of bricklayers have been found e.g. at the Roman fort of Bremenium by Sir I. Richmond[10].

In my opinion *Concussione* also implies the evidence of the use of a wooden roller under the onager. Indeed, that roller will allow the concussion ànd eliminate all kind of friction forces between the *fulcimentum* and the onager when in operation.

10 Richmond I.A. *The Romans in Redesdale*, *History of Northumberland,* XV Newcastle, 1940

LINE 17

Once again, my new translation deviates thoroughly from the former ones. Payne-Gallwey, Schramm and Marsden assumed a priori that a winch was used to pull down the arm and that it was always situated at the rear of the onager, although Ammianus didn't mention anything on that kind. However, by doing so they made a consistent translation rather difficult. Indeed, because of that 'a priori' they were then inclined (not to say obliged) to translate the word '*repagula'* as 'the handspikes' of that winch.

But the Latin text is immediately inconsistent with this kind of interpretation for ' *repagula, quibus incorporati sunt funes* ' can in that case only be translated literally as follows: '*the sticks or handspikes into which the pulling ropes are fitted*'…?

It's clear that this makes no sense at all: at the best the ropes are to be attached into the winch-axle, but not into the handspikes, unless the Ancients – in this case Ammianus too – used the word '*repagula'* in the metaphorical sense and meant the winch into which the handspikes were put. I think this isn't the case either, since the Romans used specific terms for this kind of devices and tools: *succulae* (winch), *vectis* (levers), *ergatum* (capstan) etc.

LINES 17-18 - The alternative translation for *repagula*

In Latin, *repagula* are locking-bars, as used in the Ancient town gates. Figures 15 show this more explicitly.

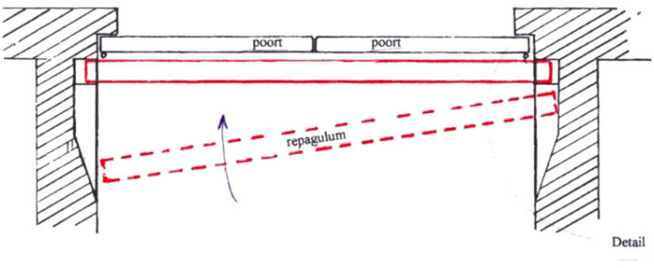


Fig.15A

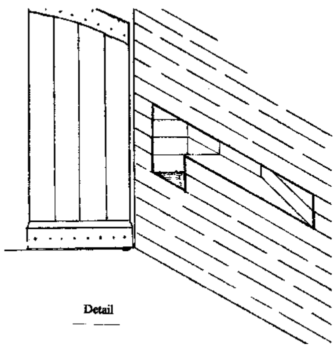


Fig.15B

Well, the way these *repagula* are manoeuvred is very suggestive for the analogue hinged movement of the two beams of my onager during its straining phase because - as I will explain further on - the straining of the onager of Versions-2 is done by a rotation of the beams around the *gibbae*. That's the reason too why Ammianus compared the beams (*axes*) of his onager with '*repagula*'. On each of both sides of the onager, four young stalwarts (*quaterni iuvenes*) are straddling the onager-beams (*repagula …explicantes retrorsus*) and are pulling down (*inclinant*) the arm nearly horizontally (*stilum paene supinum*).

Lines 17 and 18 - The key-clauses for operating the onager.

Here for the first time a clearly causal relation becomes obvious between on the one hand the widening movement (as to the Versions-2) or the closing manoeuvre(as to Version-1) and on the other hand the pulling backwards down of the *stilus*. Indeed, by using the present participle '*explicantes*' Ammianus emphasized the simultaneity of both actions: the displacement of the beams and the pulling down of the arm. So there must be a causal and technical link between these two motions.

How to realise that important principle of synchronism will be explained further in this paper. This principle will be feasible in both Versions, but especially well if the clause '*repagula …explicantes retrorsus*' is interpreted as 'opening or widening the position of the beams at their other end in a moving-backwards manoeuvre (*retrorsus*) (Fig. 10B): Versions-2. Linguistically, this is also the most correct interpretation.

I may say that the two slightly different possibilities (the 'widening as well as the closing of the beams) were interesting enough to me to be fully examined and I have to admit that in the beginning Version-1 (see Fig.9) seemed attractive. Nevertheless, through my experimenting with other scale models and thanks to the thereby growing insights into the matter itself, I gradually became convinced that Version-2 (Fig.10B) was the most plausible design. The pros and cons will become clearer in the following paragraphs.

The clause '*quibus incorporati sunt funes*' may now get more attention and can again be interpreted in two meanings, depending on whether version we choose.

Version - 1

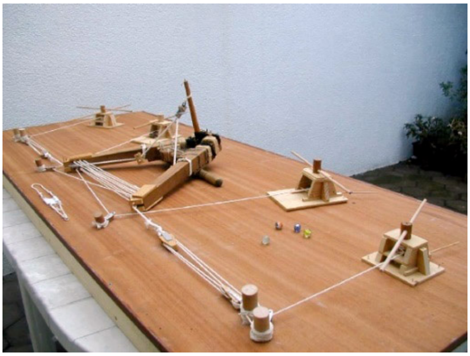


Fig. 16A

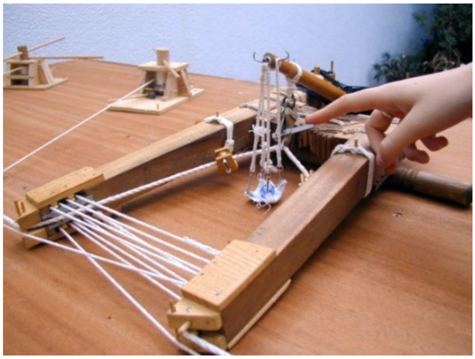


Fig. 16B

My first interpretation, was a literal one of '*quibus incorporati sunt funes*' as shown in figures 16. Here we talk about ropes incorporated and fitted into the rear ends of the beams themselves. They help, via built-in pulleys forming a tackle, the operating crews to pull the beams towards each other, at the same time straining the onager by this motion. Alas, the deployment and operating of this onager-model turned out to be too intricate. As one can see, I needed at best 4 capstans (2 at each side) which isn't really what Ammianus described as '*quaterni altrinsecus iuvenes* ', indicating probably just 2 capstans.

Also in the trial settings of this Version-1 the emplacement of the throwing arm into the resilient skeins (*nervi torti*)' appeared to be rather difficult to realise.

For all these reasons I got more and more motivated to abandon Version-1 – as being too far-fetched - for the more realistic design of the following Versions-2.

Versions-2

Here, the operating ropes are simply attached to the rear ends of the *repagula*/ beams or logs (see Fig.18 & further 29-30). In that case the operating teams will by means of capstans and tackles unfold the onager-beams gradually until the arm is pulled down *paene supinum* , and so at the same time straining the elastic bundles.

But due to Ammianus' text we know too there is a causal and technical link between the rotating movement of the *repagula* and the simultaneous downwards movement of the *stilus*. Figures 17-18 show how this synchronism can be realized for Version-2A: by a special anchorage device or for Version-2B by an adequate use of a pit in the platform (Fig. 30). The soldiers/ *iuvenes* first lift the arm in a more vertical stand, for fixing the claustrum to its anchorage ropes, and then pull it down by straddling the beams at the same time by means of the main-tackles and capstans.

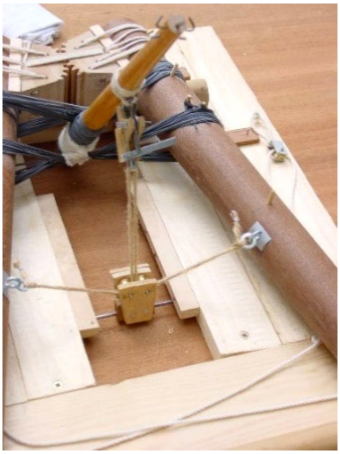


Fig. 17

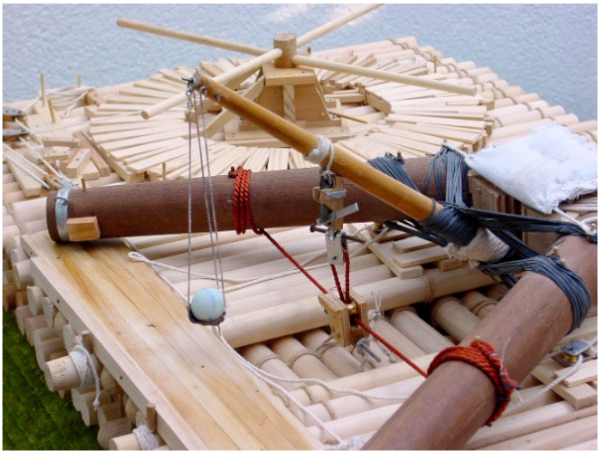


Fig. 18

Ammianus doesn't give any description of the apparatus, the operating crews had to do their job. This is not so surprising since Greeks and Romans had a whole range of devices and apparatus at their disposal, such as capstans, pulleys, tackles, levers and treadmills to activate their cranes, artillery and so on. In his *De Architectura* - Liber X/ Caput 11,1 Vitruvius gives a summary of these systems which were handy and necessary to strain the big catapults and stone-throwers he describes in his other capita. The advantage of such apparatus was it could be installed and activated separately from the *ballistae* and *catapultae*, certainly in the cases of the bigger ones. This is evidently the case for all my onager-Versions too. Actually, these technical, auxiliary accessories were so familiar to the Romans that there was no the need for further clarifications as Ammianus must have thought too.

The word '*quaterni*' isn't accidental either: it means that 2 teams each of 4 young and strong soldiers are needed to bring about the straining of the onager and that indeed they have to work all together at the same moment. This can only be the case if they operate capstans, treadmills or similar apparatus. In contrast, in

Schramm's, Marsden's and their predecessors' design, at best, only 2 soldiers at each side of the onager can operate the 'handspikes' of their winches at the same moment, due to the lack of manoeuvering space.

Moreover, as for my onager it isn't far-fetched to state that the operating capstans may be fixed into that big *fulcimentum*, becoming so a vast operational platform. For good reason Ammianus called that *fulcimentum* '*ingens'*: huge and vast.

That work platform proved to be of great utility for the ease of the operation and functioning of my scale models. Not only made it the principle of synchronism possible and did it absorb the effects of the recoil, it was also useful to fasten the capstans, the wooden posts holding the main-tackles and all the other operating devices. It created a higher degree of manoeuvrability for the onager and its supporting wooden roller.

Lines 19-22 - *demum sublimis adstans magister*

The adjective '*sublimis'* can mean: a 'magister' or a person with a higher rank than his assistants. Another possible interpretation of '*sublimis'* is related to the position the magister may need to handle: on a higher level, not too close to the claustrum (for security reasons) but still enabling him to strike it with his sledge-hammer. Yet, in that case we would rather expect the adverbial form '*sublime'*, for it is connected to the verbal form '*adstans'*. Maybe this was the case in the original text, and *sublime* was afterwards copied by mistake as '*sublimis'*. Still, if we maintain '*sublimis'* as an adjective describing the noun 'magister', it can also be describing his posture, namely 'with upraised arms' ready to lower the sledgehammer and hit the claustrum. Nevertheless this discussion does not really affect my design of the onager.

Lines 24-28 - *et tormentum quidem appellatur ex eo, quod omnis explicatio torquetur*

Those lines aren't subject to any problem, neither do they add special information or elements to the new translation nor do they affect my reviewed design of the onager. Possibly Ammianus did not add this obvious sentence to his description by coincidence. The onager has *nervi torti* indeed, just as the better-known *catapultae* and *ballistae*, also named '*tormenta'*. However, unlike these more classical stone-throwing or arrow-shooting engines which get their strength from twisting the bundles of *nervi* and from there their name '*tormentum'*, the onager gets its throwing capacity mainly from stretching its *nervi*-strings combined with some distorting of their bundles.

Hence, the way the onager uses and operates its bundles of *nervi* into action is significantly different from the way the more common *tormenta* as the *ballista, cheiroballistra* or *manuballista* do.

Perhaps Ammianus had the same appreciation and for that reason was feeling a bit uncomfortable, looking for a justification for the name '*tormentum'*, a name his fellow citizens obviously gave to this engine too. His justification may rely on the fact that the onager in its entirety seems to be three-dimensionally loaded during the straining and so leaves the impression of being strongly distorted (Fig. 17 & 18).

REFLECTIONS

Has Ammianus' text been corrupted throughout the past centuries? If so, this is only partly true since we're dealing with just a small number of hardly mutilated words. Luckily, those words can easily be reconstructed, e.g. *fulmentum / fulcimentum*; *perculsum/ percussum*; *quos/ quas*; *sublimis/ sublime*.

In my view, Ammianus' description is precise, even very accurate. There was just one ambiguity which could lead to two different interpretations, namely the expression '*repagula … explicantes retrorsus*', in close relation to the two possible interpretations of *'pro-eminere'* or the exact setting of the *gibbae* upon the *repagula*. As already mentioned, that had led me to a Version-1 as well as later on to two Versions-2: A VERSION-2A and something later a Version-2B. I eventually saved Version-1 just as a valuable possibility but the later Versions -2A and -2B proved to be more realistic.

4
On the way to a final concept of Ammianus' onager

At the very start of my investigation, I thought that the *nervi torti* could be very elastic cords, as e.g. the Ligamentum Nuchae can be (a very elastic bond in the neck of grazing cattle and horses). Indeed, a fragment of a text by Vegetius Renatus can somehow be behind that line of reasoning.

Renatus Vegetius: *Epitoma Rei Militaris*; Liber IV, 9: *NERVORUM QUOQUE COPIAM SUMMO STUDIO EXPEDIT COLLIGI, QUIA ONAGRI VEL BALLISTAE CETERAQUE TORMENTA NISI FUNIBUS NERVINIS INTENTA NIHIL PROSUNT. EQUORUM TAMEN SAETAE DE CAUDIS AC IUBIS AD BALLISTAS UTILES ADSERUNTUR. INDUBITATUM VERO EST CRINES FEMINARUM IN EIUSMODI TORMENTIS NON MINOREM HABERE VIRTUTEM ROMANAE NECESSITATIS EXPERIMENTO.*

In this quote, Vegetius clearly states that *onagri* and *ballistae* must be "*strained with nervi, otherwise they are useless"* but, as to the *ballistae*, he writes *"horse hair (from the tails and manes) should also satisfy"*. Possibly he meant that horse hair too could fit for onagri, nevertheless he didn't mention it as such. Is that an obscurity or an oblivion on his part or is it well intended and purposeful ? If well intended, one could conclude that employment of the so-called *nervi* for the *onagri* might be somewhat different from the usual *nervi* of sinew or horse hair: e.g. Ligamentum Nuchae? Therefore my first scale models (Version-1 and Version-2A) were fitted and strained with bundles of rubber, due to practical considerations: rubber has the same elastic and strength-characteristics as Ligamentum Nuchae.

But since the excavation of a nearly intact *manuballista* at Xanten (1999 -Germany), in which rests of animal sinew were found, I became more sympathetic to the idea that *nervi*, made of sinew (or of horsetail hair) were used to strain the onagri. Hence, that motivated me after some time to resume my research and finally build an new onager, i.e. the Version-2B.

In the following sections only that Version-2B will now be explained in some detail.

However, who's still interested in all details about the early Versions (-1 and -2A) will find more ample explanation in my book 'Artillery in Ancient Times, the Onager - a critical reconstruction (2018), available at the Provincial Archaeological Museum at Velzeke (Belgium)

AN ONAGER STRAINED WITH *NERVI TORTI* OF SINEW

ABOUT THE USE OF RESILIENT SKEINS

In the Ancient literature, especially by Philon of Byzantium and Heron of Alexandria, one can indirectly find indications, albeit vaguely, about the nature and properties of the so-called *neura* or *nervi torti*, the 'resilient' skeins of the spring-frames of *catapultae* and *ballistae*. Heron (Belopoeica): …*You must use the back and shoulder sinews of all animals except pigs, their sinews are useless … you must realize that the back and shoulder sinews of other animals are the most efficient. It has been stated that the more frequently exercised sinews of an animal proved to be more powerful*. I hereby think *e*.g. of a deer's legs or of a bull's neck.

In addition, in their respective Artillery Manuals (*Belopoeica*), Philon and Heron mention that the *neura* are stretched in such way their diameter has diminished by $1/3^{d}$. That means the diameter became 2/3 of the original one and it means too that the cross-section of the rope is diminished to $4/9^{th}$ of the original section. A simple calculation shows that the corresponding prolongation of the *nervi*-cord then must be $9/4^{th}$ of the original length for perfectly elastic materials, since their volume anyway stays constant by deformation. Reality might be different but it indicates a tremendous possible prolongation of the Ancient *nervi*.

Only pure Ligamentum Nuchae - an elastic bond in the neck of grazers- can easily cope with an important elasticity and prolongation. Nevertheless its ultimate permissible tensile stress at the utmost prolongation (about 100%) is barely 30 kg/cm^2. That makes it not suitable for the spring-cords of the catapult frames, nor for *ballista*-frames since we know that the tensile stress in their skeins may be estimated near to 400 kg/cm^2 *(Schramm's skeins of horsetail-hair were strained as such [11])*. In contrast, Ligamentum Nuchae would fit perfectly for my early Versions -1 and -2A.

11 Schramm E: *Bemerkungen zu der Rekonstruktion griechisch-römischer Geschütze*, 1904.

Sinew is mainly composed of collagen. Pure collagen is very strong but not always that elastic. So there can be some problems with the text of the Ancient writers for I think sinew will not be able to cope with prolongations up to 100%, being not entirely elastic. But there is sinew (e.g. from oxen) and sinew (e.g. from deer, elk, even racehorses etc.). So is the superficial digital flexor tendon (SDFT) of race horses capable of remarkable extensions, even up to 20%. Of course the manufacture of sinew into rope plays an important role too and may influence its extensibility. For instance, architect and archaeologist Digby Stevenson states in his remarkable work "Heron's Cheiroballistra [12] that he managed to make sinew spring-cord. His rope was made from elk leg sinew. Apparently he had no problems too -while arming his *Cheiroballistra*- to significantly reduce the diameter of his sinew-cords by 1/3. At stretching, their extension was large (but not 100%), so we may conclude that sinew-rope (i.e. the *nervi torti*) is indeed a separate and special material. Overall, the Ancient authors will keep us busy until remains in good shape might be found in archaeological excavations.

My early onagers Version-1 and Version-2A relied upon models (scale 1/15), strained with 2 bundles of ropes of rubber, corresponding with ropes of Ligamentum Nuchae which is mainly composed of elastine.. When I operated these scale models, the prolongation of the rubber threads at stretching was at maximum about 50% with tensile stresses between 6 to 8 kg/cm^2. That made the rubber here a valuable alternative for the Ligamentum Nuchae. However, having regard to the foregoing section, maybe sinew would have fitted too…

In 1999 a nearly intact *manuballista* was found in Xanten with rests of spring-cords of animal sinew, with restauration and publications in the early 2000s. So the idea of building a model with sinew cords came gradually back in the picture. After all Vegetius had mentioned in his *Epitoma Rei* Militaris (IV, 9) that '*onagri vel ballistae ceteraque tormenta nisi funibus nervinis intenta nihil prosunt …*'. Thus onagers could also be armed with the same *nervi torti*.

That is why I finally resumed my earlier research with building a Version-2B.

It has the same design as the Version-2A, but is now provided with spring-cords of sinew. For practical reasons – I am not an expert in rope-making – I decided not to fabricate the so-called *nervi torti* out of real sinew, but to use equivalent

12 Stevenson D.: *Heron's Cheiroballistra*, with an appendix on the manufacture of sinew rope, BA dissertation 1995, university college London.

material: skeins of horsetail hair which I braided into ropes. This cannot be an obstacle either, referring to Vegetius: '…*equorum tamen saetae de caudis ac iubis* '.

Evidently, I always had to respect the basic principles of Ammianus' design, which may not be changed at all. They still are: a construction with two rotating indented half-cylinders, the wrapping of the *stilus* in the *nervi*-cords so the throwing arm could be inclined before the factual straining of the onager and finally a straining of the *nervi*-bundle which originates from the simultaneous action of pulling down the arm and straddling the two *repagula*.

But this time I absolutely had to limit the elongation of the spring-cords to 5% for horsetail hair (versus values > or < 20% in the case of sinew), because of the restraint possible elongation of hair and its possible relaxation or creep phenomenon. This conclusion was reached through my experimental tests of allowable elongation of the horsetail hair at my disposal. Therefore the *repagula* were to be straddled to a much lesser extent than for Version-2A while yet the *stilus* had to be pulled sufficiently down at the same time.

At present, the bundles are composed of just a few skeins because sinew and horsetail hair are very strong and the tensile stress at a far smaller elongation (5% to 10%) can become enormous (>300 kg/cm^2). By that we can reach the same necessary forces or even stronger forces than in Version-2A.

As to the textual condition '*ut altius tolli possit et inclinari* ', that was not so fluently realised in the earlier Versions, even not at Version-2A and for me another reason to leave them out. Therefore I should now try to do better with a Version-2B.

THE ONAGER VERSION-2B
A FIRST DEMONSTRATION MODEL (1/15).

I certainly had to adapt the way of wrapping the arm in the resilient horsetail ropes as well as the technique of straddling the *repagula* while simultaneously pulling down the *stilus* in a sufficient way (*paene supinum*).

<u>1. Fixing the resilient skeins</u>

For practical reasons, due to the small scale of my model and for ease of construction, I decomposed its arm into two pieces: a main block which will be wrapped up in the cords and has a groove/slot into which the rest of the long arm will be fixed afterwards. It's evident that with a full-scale model, one can do this twisting work with a *stilus* in one piece instead of a bipartite arm, by managing an adequate way of wrapping. Note that each braided skein of horsetail hair was about 60 cm long.

I started wrapping up that block of the throwing-arm which, as usual, hangs in a forward-leaning position: ' *stilus … in modum iugalis temonis erectus* '. I intentionally say 'hanging': indeed, at the beginning of the construction phase, the arm hangs rather loose in the skeins, in between the two beams (Fig. 19) which lay at rest in a little spread-out position.

Fig. 19

With the aforementioned preconditions in mind, I know that the skeins may have a very restricted elongation when operating. So, it would make a difference if we spread this very limited elongation over a maximum of developed length of the skeins, running around the *stilus*-block and around and over the *repagula*. Figure 19 demonstrates this very well, it also shows the block at the start hanging very loose between the *repagula* with the only intention of achieving as much length in the skeins as possible. The justification for that why will become clear further on.

Fig.20

Fig.21

In this example the opening of the slot is positioned horizontally. Nevertheless, this positioning may vary depending on the characteristics and length of the 'elastic' cords (horse-hair/ sinew). I started to turn the block 90°– seen from the left: clockwise (Fig. 20). By continuing to do so, the skeins may rather quickly get twisted into a kind of bundle, rotating around two virtual points in between the *repagula* (Fig. 21).

Then I continued turning the block over more or less 180° (Fig. 22) until the slot in the block pointed towards the *gibbae* (Fig. 23).

Fig.22

Fig.23

As one can imagine, I had to retry several times to determine the most suitable length of the skeins, which will permit to find the right turn of the block in order to gain some tensile strength. Once I got that result I gave the block a little turn to allow me to slide the rest of the throwing arm into its groove.

By pulling the throwing-arm gradually further backwards into a slightly up-tilted position, the horsetail-hair skeins now came slowly under more tensile stress, albeit not yet spectacular, while the tail ends of the onager-beams (*repagula*) were drawn together so these two beams now came in a closed position touching each other.

At the same moment, I saw that by this special way of wrapping, the arm could still be easily pulled further into a yet more backwards leaning position: *ut altius tolli possit et inclinari* : that allowed me to easily attach the *claustrum* (with its claw) onto the throwing arm (see Fig.25). This is probably due to the rotating manoeuvre around the 'virtual' points in the bundle in between the *repagula* – functioning as hinges – and also because at this phase of operation we were not yet creating a too great tensile stress in the skeins.

In battle conditions, this feature means an enormous advantage for a supple operating, because the sling with stone(s) could under this situation be easily and quickly attached to the far end of the throwing-arm, as described by Ammianus '*cum igitur ad concertationem ventum fuerit, lapide rotundo fundae imposito*' .

This was not so the case for Version-2A where one should at best need a second pair of capstans to lower the arm a bit, before fixing the claustrum and straining…

From now on, the effective straining of the onager could start. By pulling the arm further and further down into a backwards-leaning position (*paene supinum*) the tensile stress in the skeins now became tremendous (Fig. 24).

Fig. 24

Fig.25

That's due to their elongation caused by the combination of straddling the beams and turning the block, while their widespread implantation upon the block-rim realises a torque and so the energy to sway and sling the stone.

With these experimental results in mind, I could finish my onager Version-2B with the same configuration and constructional principles as those for the earlier Version-2A. It only differs in the wrapping of the *stilus* in the resilient skeins (Fig.24).

Again a *cilicium*- here a small leather cushion- has been laid at the level of the joint between the two *gibbae* : Fig. 25. During my experiments, it got never entangled in it.

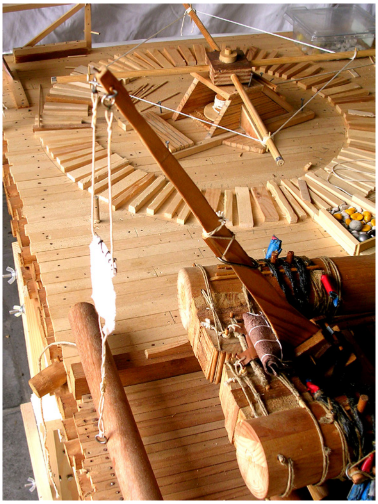


Fig.26: Another scale-model of Version- 2B at rest, the arm lies loosely on the leather cushion.

2. The necessity of limiting the elongation of the horsetail-hair skeins

Out of my series of tensile tests on separate and different horsetail hairs it became clear to me that I had to limit the elongation of the skeins at stretching to ~5%. The main question was how to do so in my model ?

When the *repagula* are being straddled, they actually rotate around the momentary point of tangency S of the indented half-cylinders (*gibbae*), as demonstrated in Fig. 27.

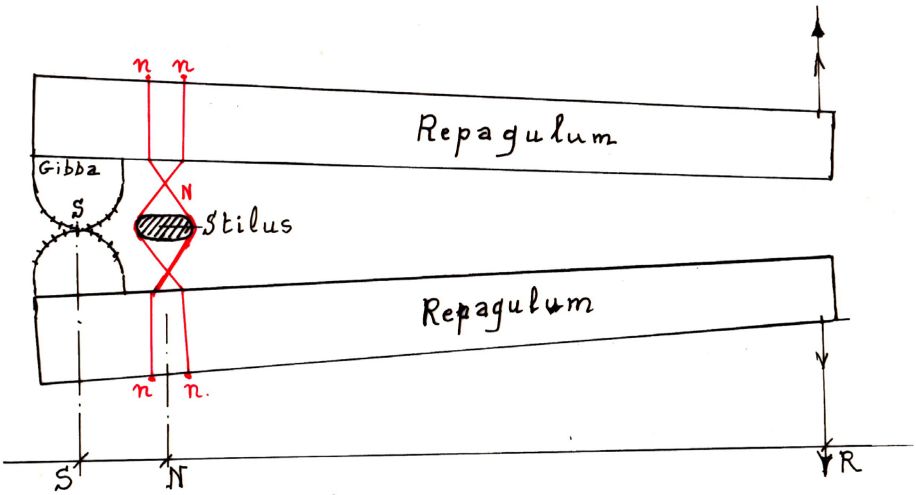


Fig. 27: SNR

Here SN stands for the distance between the centre of ‘gravity’ of the horse-tail-hair (‘*nervi*’)-bundles (N) and the rotating point (S), while SR means the distance between that point (S), centre of rotation and the far ends of the *repagula* (R).Because the bundles of horsetail-hair skeins/ *nervi* (N) lay much closer to the rotating point S than the far ends (R) of the *repagula*, they will be elongated proportionally far less than the openness of the ends ‘R’.

That happens in the proportion SN/SR and we’ll name this ratio for the sake of convenience as SNR. In my first demonstration model of Version-2B, with onager-beams of 48 cm length, the ratio SNR was 1:6. In the zone of the ‘*nervi*’-bundles, the distance between the enveloped *repagula* is A, see figure 28.

The developed length of one skein is marked in red (Fig. 27 - 28). Its upper part is the line 1-2-3-4-5-6-7-8-9.

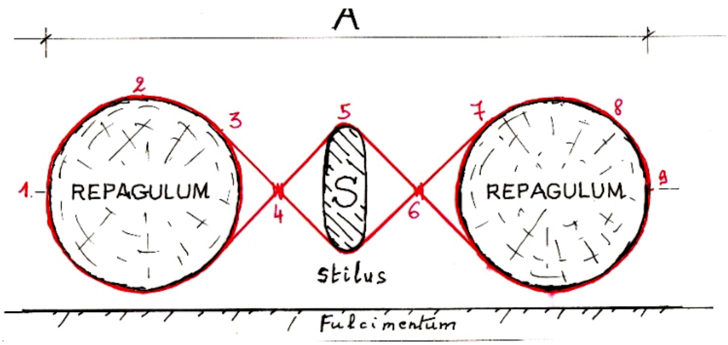


Fig. 28: Cross-section of Fig.27

By widening the gap between the far ends of the *repagula*, the distance A in the zone of the resilient bundle becomes A + **Δ**. This increase **Δ** is responsible for an elongation in the skeins too: Δ_{nervi}. That will be less than Δ since the developed length (1 – 9) of the skeins is greater than A. According to figure 28 we perhaps may estimate it by about 1,5 x A under ideal circumstances. Ideal circumstances mean no inhibiting friction between the skeins and the wooden surface of the *repagulum* in the area of 1-2-3 and around the area 5.

In that ideal case we even should– under opportunistic circumstances – dare to estimate Δ_{nervi} = **Δ**/1,5. However, by an important friction the active part of the developed length of the horsetail-hair skeins might be restricted to the area 2 – 8. In that case the active length might become equal to or even smaller than A ! In addition, the wringing in zones 4 and 6 may account for a limited part of that estimated elongation. That's why I found it appropriate to ultimately equate the $\mathbf{\Delta}_{nervi}$ with 1,5 Δ (instead of Δ / 1,5).

In this case, at straddling the far ends of the onager-beams over about 6 cm (3 cm to the left and 3 cm to the right) this should mean a 10mm (= 6 cm/6 – see the ratio SNR) increase of Δ for the distance A. This 10 mm may now be corrected for the skeins up to 1,5 x 10 mm, to say 15 mm. This elongation of the skeins at 15 mm is approximately 5% of the developed wrapping-length 1-2-3-4-5-6-7-8-9.

Indeed, the horsetail-hair skeins I used in the enveloping manoeuvres were about 60 cm long and thus I could account 30 cm or more for the upper part of the wrapping. In fact, 15 mm elongation of 30 cm means an elongation of 5%.

I'm aware this is a very simplified reasoning and calculation of Δ. But since the provoked and related displacements at the operating of my onager are rather small for this model, I think this rough approach is acceptable to determine some order of magnitude. Moreover, operating my model proved it a right approach.

Concerning my demonstration model (scale 1:15) at straddling the *repagula* about 2x3 cm (one 3 cm to the left, another 3 cm to the right) it was indeed possible to limit the elongation in the skeins under the allowable 5%. This was sufficient to get a very great tensile stress and a lot of resilient power in the bundle of horsetail-hair skeins and to pull the throwing-arm down in a satisfactory way (*paene supinum*), realising the swaying manoeuvre as suggested by Ammianus' text. Suppose an onager at scale 1:1 that would mean a straddling of only 2 x 45cm to strain the onager.

First Conclusions at the Construction of the Version-**2B**

It is very important to realize a ratio SNR as great as possible: e.g. by using longer onager-beams, while the bundle of horsetail-hair skeins is kept at the same distance from the rotating point S.

The more skeins are stocked in the bundle, the more powerful the bundle can be.

The gap between the *repagula* at the place of the resilient bundle is important. The greater it is, the more length can be stocked in the bundle of skeins. Through that, the elongation (1,5 Δ divided by the length of these skeins) can be proportionally diminished to a safe limit.

So I built a second demonstration model, with the rather same positioning of the indented half-cylinders upon the *repagula* but which were a bit broader (therefore the skeins of horsehair were now 66 cm long) and with the same positioning of the horsetail-hair-bundle vs. the momentary rotating point S. Moreover, the *repagula* were now 62 cm long (instead of the 48 cm of the previous model). The ratio SNR became now 1: 8,1. To experiment with the first conclusions above, the elongation in the skeins, at an identical displacement of the far ends of the repagula (6 cm), was now –according to the reasoning above- diminished to 3,4%. That again was very acceptable while still obtaining a lot of power in the resilient bundle.

3. How to pull down the arm to achieve '*stilum paene supinum inclinant*'.

As demonstrated above, it was clear to me that I could not spread the ends of the *repagula* as wide as in the case for Version-2A (see Fig. 17 & 18). Nevertheless, the arm had to be pulled down simultaneously and sufficiently.

Luckily, there was already one advantage, which stands in sharp contrast to Version-2A. In Version-2B, due to the new kind of wrapping the arm in the bundle of skeins, it became now possible to pull almost effortlessly the arm in a slightly backward leaning position in the phase before starting the real straining. So, a part of the needed downward positioning of the *stilus* was already realised with just a little effort (Fig.25) and there was no need of a secondary pair of capstans to enable the personnel to attach the *claustrum* with its claw to the arm.

Once the *claustrum* was attached to the arm, one could start the full straining of the whole construction. Yet I still had to search a solution for the further pulling down. To do so, I adapted the system of anchoring the *claustrum* directly to the tackles -see Fig.29 - rather than to the middles of the onager beams (as could be seen in the Figures 17 &18 of Version-2A). Here, for my ease of operating at scale 1:15, these tackles are incorporated in two bogies - figures 29-30.

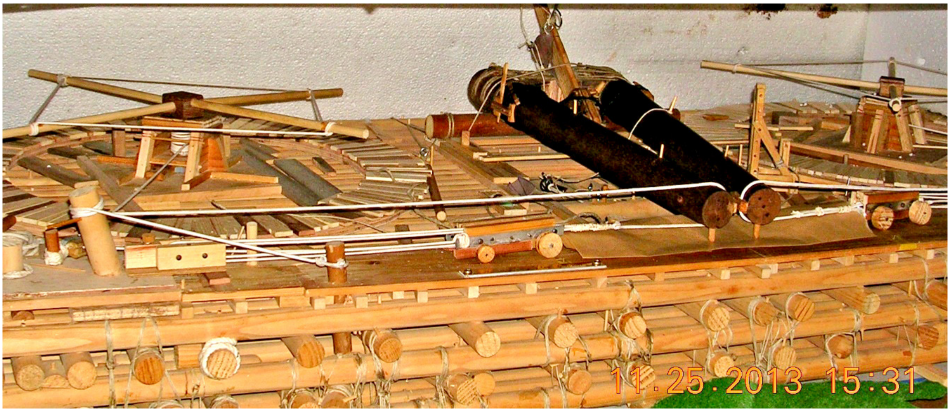


Fig. 29: A model of Version-2B,
with the bogie-tackles upon the slide-table of the fulcimentum.

As to the straddling of the *repagula* by the capstans: at displacing each of the bogies 6 cm, the far ends of the beams were now displaced just about half this distance (3 cm). This is because the displacement of the strong cord (is also 6 cm) is spread over the two parts of this cord, since it is turning around the rounded far end of the *repagulum*, so acting as a kind of pulley ! Indeed the strong cords by which the onager-beams are straddled run from a fixed point at each end of the slide-table over the rounded ends of the *repagula* toward the same bogie tackles: Fig. 29 clearly demonstrates this principle, so 6 cm divided by 2 makes 3 cm.

Evidently, according to Ammianus' text, the far ends of the *repagula* are to be displaced simultaneously with the pulling down of the *stilus*. The trick was to pull the *claustrum* downward with its own anchorage rope which is guided around a horizontal beam in a small pit in the platform (Fig.30), just beneath the onager. From there it runs via two rotating points upon the slide-table directly to the bogie-tackles (left and right) to which it is attached. When I now displace, with the help of the capstans these two bogie tackles e.g. with each 6 cm, the arm is evidently dragged equally downwards over 6 cm (Fig.30) while the displacement of the *repagula* remained limited at just 3 cm as explained above.

Fig.30: Detail showing the 'trick with the small pit' and its horizontal beam.

The Last straining phase

With only two capstans the *repagula* are further straddled so that the tensile stress in the skeins grows quickly and very high, combined with their tensile stress caused by the simultaneous pulling down of the throwing arm that hereby twists the resilient bundle. Again one can remark how useful the *fulcimentum* is for the whole operation. The relatively small straddling of the *repagula* was sufficient to build up an enormous force in the bundle of horsetail-hair and yet to pull the throwing arm down almost horizontally while respecting the permissible elongation of the horsetail-hair skeins: *quaterni altrinsecus iuvenes …. stilum paene supinum inclinant*

Finally, the magister unleashes the *claustrum's* claw with a blow of his sledge-hammer (.. *claustrum* .. *reserat malleo forti perculsum*..) and the arm is freed, hurling the stone(s) away with its sling. It slashes forward against the cushion tied upon the *gibbae* to protect these and this *stilus* too.

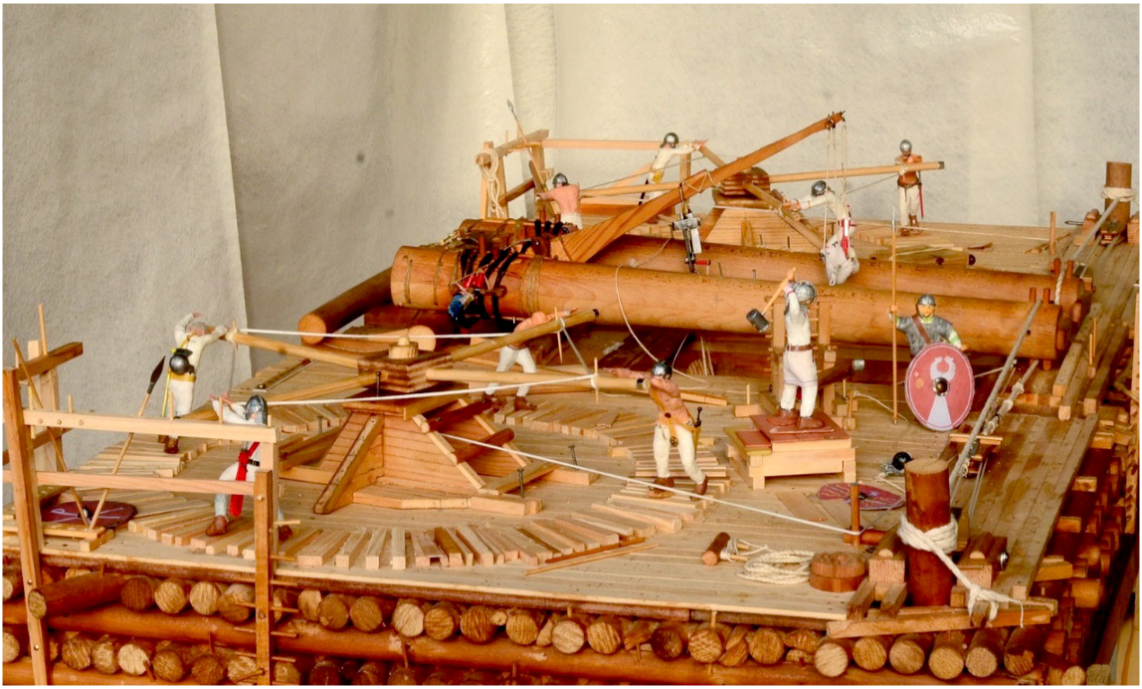


Fig.31: A scale-model of Version- 2B in action.

5
Overall conclusions

So, to conclude my search for the real design of the onager according to Ammianus' text, both of Versions -2A and –2B led me to my new alternative translation of his text. Version 2-A is a possible design, however I greatly prefer the Version-2B as the most realistic solution.

Indeed, this onager-Version -2B was the first to completely match Ammianus' text sentence by sentence: *stilus … ita nervorum nodulis implicatur, ut altius tolli possit et inclinari … cum igitur ad concertationem ventum fuerit, lapide rotundo fundae imposito, quaterni altrinsecus iuvenes repagula, quibus incorporati sunt funes, explicantes retrorsus stilum paene supinum inclinant* .

The necessary tensile forces and stresses in the '*nervi'* of Versions-2 are generated exclusively by the combined action of the spreading out of the far ends of the *repagula* and the simultaneous pulling down of the *stilus*.

The swaying movement (*ut altius tolli possit et inclinari*) is always ensured. The same goes for the twisting aspect of the entire construction when in operation : *et tormentum quidem appellatur ex eo, quod omnis explicatio torquetur* …

With these mechanisms there isn't any more an operating problem for the personnel in raising the -at rest forward leaning- *stilus* until the *claustrum* can be attached (Fig. 25): this is a very interesting asset for a smooth and quick operation in battlefield conditions.

Especially the construction of the onager Version-2B is very simple: just a wooden construction of 2 logs and 2 *gibbae*, some ropes to hold the onager parts together, '*nervi'* made of sinew or of horsetail-hair, two capstans or treadmills, the *claustrum* and tackles are the only parts that are made of iron. Moreover, its weight can be estimated at about 7 Tons, which is comparable with a ballista of 60 Minae. Of course, there is the need of a fulcimentum, certainly since Ammianus clearly states an onager may not be placed upon a stone-wall !

Operating Version-2B proceeded smoothly, even easier to do than for my scale-models of Version -2A. Aiming the onager wasn't that difficult at all, due to the nearly frictionless use of the roller, combined with an occasional different straining by the left and right capstans, forcing the onager to move a little to the left or to the right and by that, turning the throwing-arm too into the desired direction.

Maybe important too: no more discussions are needed concerning the way of wrapping the arm (*stilus… implicatur…*) as well as concerning the nature of the *nervi* (*nervorum nodulis*). The nervi-skeins of Version-2B are made of horsetail hair, which is a good and acceptable substitute for sinew. Indeed, the allowable elongation for sinew ropes probably lies in-between the values acceptable for horse hair (about 5%) and those for ligamentum nuchae of the Version-2A (50 % or more). Of course if we were to use real sinew, the achievements of a Version-2B onager might even be improved.

An onager of a Version-2B may have good throwing results too since my scale-models (1/15) launched a marble of 8 grams over >20 m. It could possibly be an indication for a throw at scale 1:1 of a stone of 27 kg over >300 m..

THE NEW TRANSLATION OF AMMIANUS' TEXT

§ 4. Of the *scorpio*, which they now call 'the onager', the design is as follows. Two tree-trunks (logs) of oak or holm-oak are fashioned and in between them (at their mid-height) they are provided with a kind of rounding (*curvanturque mediocriter*) in a manner they seem to bulge at their ends into humps. These trunks are connected as a machine with cogwheels (*machinae serratoriae*) and on both sides they have quite a lot of perforations. And between these elements through their perforations powerful ropes are stretched, to hold these structures and their interconnections (so these wouldn't burst open).

§ 5. Just beyond these ropes, an inclined (*also possible:* a tapered) wooden stick (*stilus*) rises, being set in the way of a yoke-pole and is so wrapped into skeins of *nervi* (e.g. sinew) in such way that the *stilus* can be raised higher and (then) lowered, leaning backward. To its tip iron hooks are fitted from which hangs a sling of hemp rope or of iron. Under this wooden assembly (i.e. *the onager*), a huge platform is spread out and a Cilician cushion, stuffed with very fine chaff is attached to it (i.e. *the onager* itself) with strong binding. Moreover, the platform (of logs) is placed upon piles/layers of sods (*turf*) or layers of bricks. Because a mass of this kind, if set on a stone wall, will disrupt / dislocate whatever is underneath it, not because of its weight but due to its violent concussion.

§ 6. When it finally comes to combat, after a round stone has been put in the sling, four young men (*to say: in the strength of their youth*) taking place at each side of the onager, pull the *stilus* down almost horizontally by – at the same time – straddling the two tree-trunks (i.e. the beams of the *onager*), on which tractive ropes have been attached rearwards. Finally, the master of the personnel standing higher up aside (*or the highest ranked man / or the master standing with upraised arms*) strikes the bolt with a sledgehammer and so unlocks the *claustrum* that contained all the fetters. Whereupon the released arm – which will collide with the muffling cushion, with a swift sway slings the stone. This stone will smash everything it meets on its course.

§ 7. And for sure, it is named a *tormentum* (a torsion engine) for the whole operating action is based on wringing and it is called *scorpio* because it has an upraised sting; and in our era also the name of '*onager'* is applied to it because wild asses, when startled by the hunters, throw up stones from afar by kicking behind their backs so these stones even penetrate the chests of the pursuers or smash their heads to pieces.

6
Epilogue

According to Sir Ian A. Richmond[13] this type of one-armed stone-thrower might already have existed before the 3th C.A.D. Other scholars attribute it to the 4th century, since the onager was just mentioned by the 4th C.A.D.-authors, Ammianus and Vegetius at that time. However, it must have been a heavy weapon because only one onager was specifically allotted to each cohort of the legion (*Vegetius*), due to its immense resilient platform upon which it had to be installed and operated.

Onagers were intended to be offensive but more specifically defensive weapons to defend the walls -but not to be placed upon the stone-walls ! Ammianus (Liber XVIII - the siege of Amida) and Vegetius too are useful witnesses of the latter strategy of deterring the enemy, not only by launching clouds of pebbles but even by the noise of onagers while being actuated! Indeed, they could throw one heavy stone but– thanks to its sling- also a lot of pebbles against attacking infantry.

This reminds me what the one-armed stone-thrower with counterbalance of I. Caesar could do, as indisputably described by him in his book *De Bello Gallico,* Liber VII, 81, s.4. " *nostri, ut …..ad munitiones accedunt; fundis librilibus sudibusque, quas in opere disposuerant, ac glandibus Gallos proterrent* ."

13 Richmond I.A... «*The Romans in Redesdale*», *History of Northumberland,* XV Newcastle, 1940, pp. 73;98*;* plate pg. 96

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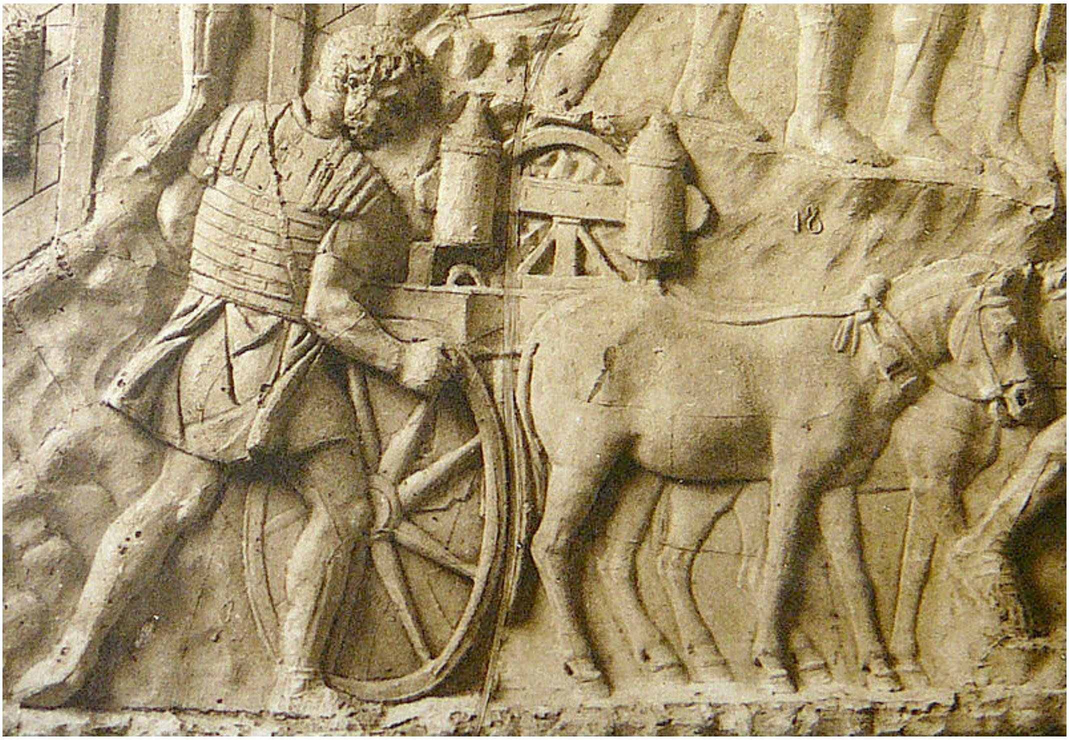

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Storia militare antica

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