IN THIS ISSUE: THE START OF ALEXANDER'S CAMPAIGN AGAINST THE ACHAEMENID EMPIRE (334 – 333 BC)

AW
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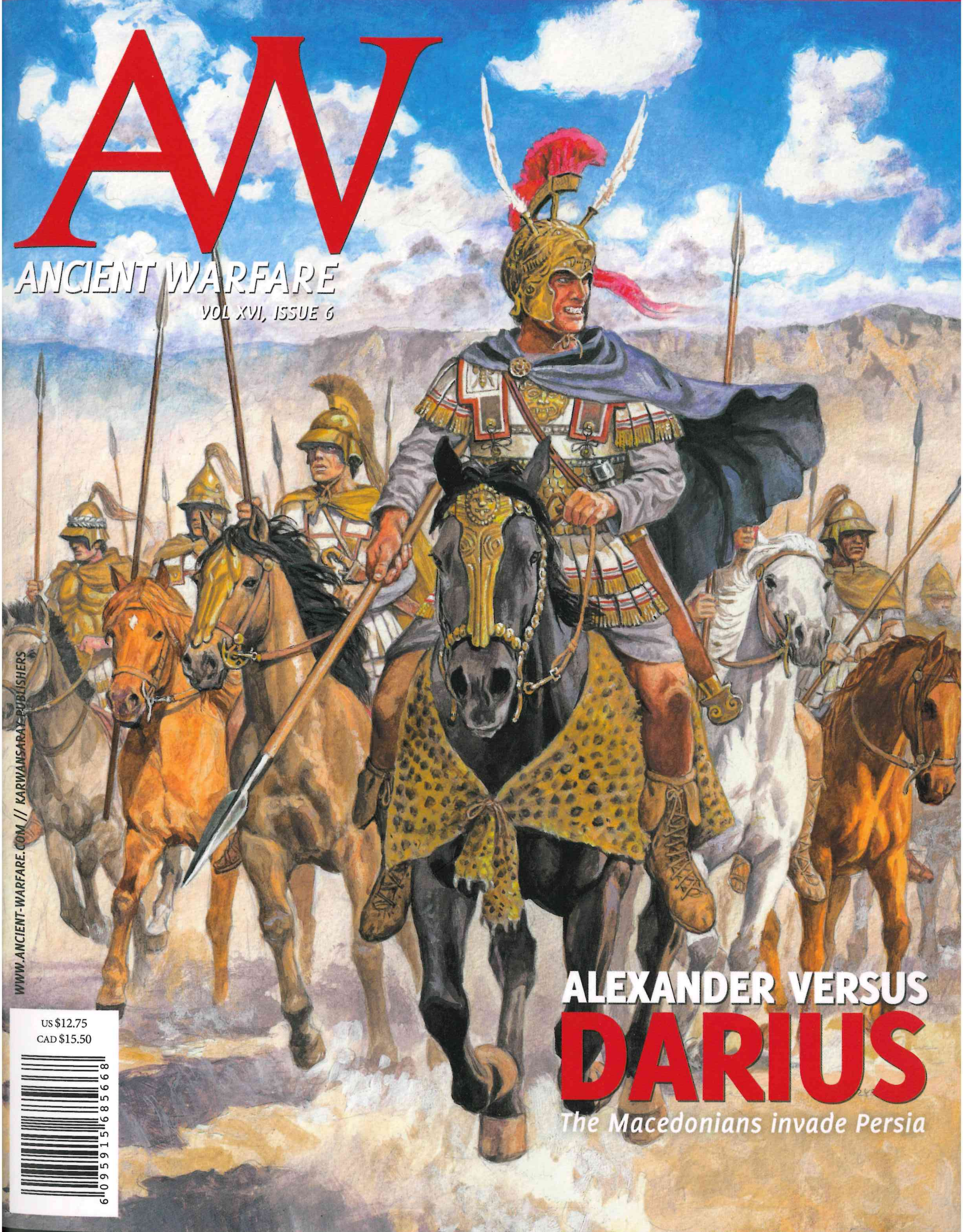

ALEXANDER VERSUS DARIUS
The Macedonians invade Persia

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THEME – PHALANX COMMANDERS // THE BATTLE OF THE GRANICUS // PIKES, SPEARS, AND JAVELINS
SPECIALS – TESTING OUT BALLISTAE // SCANDINAVIAN MASSACRE // A PACIFIST PHARAOH AT WAR

Scene from Trajan's column showing the later torsion catapult in use. Note how the design of the *scorpio* matches the surviving material.

TESTING RECONSTRUCTED ROMAN BALLISTAE

By Boris Dreyer

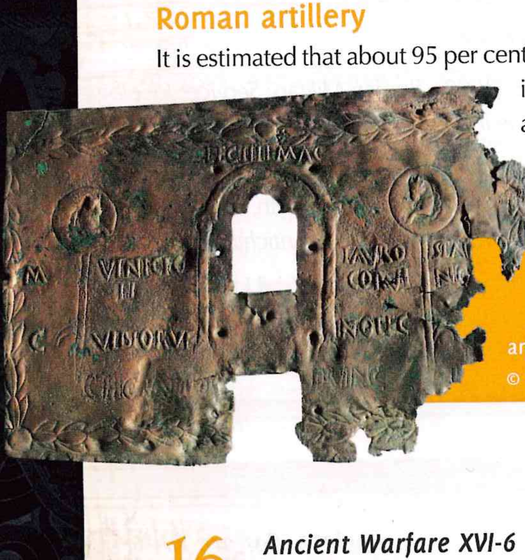
IN THE ENGINE'S SIGHTS

The evidence for Roman bolt-throwing engines, both literary and archaeological, is scarce. Reconstructing and testing them based on the available evidence can illuminate their capabilities, however. Boris Dreyer reports, with help from Alexander Hauenstein and Wolfgang Wilsch.

Since 2016, replicas of ancient Roman products have been reproduced at the Department of Ancient History of the Friedrich Alexander University of Erlangen-Nuremberg (FAU). In addition to the successful construction of two patrol boats, the *Fridericiana Alexandrina Navis* and the *Danuvina Alacris*, two *moneres* of the second and the fourth century AD were completed (see *AW* XII.4 and XIII.2). Roman catapults of different categories and periods are currently being built and tested.

Roman artillery

It is estimated that about 95 per cent of ancient literary and archaeological material has been lost. This also applies to products of the Roman military. In addition to their core military tasks, Roman soldiers were excellent craftsmen who, with specialist instruction, manufactured and maintained the weaponry of Roman armies, including artillery. In the Imperial era, the legions had units to provide and maintain the respective artillery batteries (see also *AW* XII.6).



Decorated, protective sheet from the front of a catapult of *Legio IIII Macedonica*, discovered at Cremona, and undoubtedly deposited in AD 69. © Sistema Museale della Citta di Cremona.

Roman torsion engines were state of the art. They were invented in the fourth century BC and reached their peak development in the Hellenistic period, with a degree of specialization that has not been achieved since. Scientists such as Philon of Byzantium (late third century BC) described the (theoretical) operation of sophisticated long-range shooting machines. Later Roman writers such as Vitruvius, in the first century BC, and Vegetius, who presented the military conditions of the early Imperial period as an ideal for Rome in the

late fourth century AD, discussed such artillery in treatises with a more practical bent.

This meant that a standard of technology was reliably available, with everything that goes with it: supplies, logistics, and personnel. According to Vegetius (2.25.4), an Augustan legion could field about 55 torsion engines, most of which were bolt throwers with a smaller number of stone throwers. There were 28 legions at that time, so the Roman army could theoretically field some 1500 artillery pieces, though a certain percentage likely was not available for service due to mechanical issues. Vitruvius describes a torsion engine as used by the Roman army in his *On Architecture* (10.10.1), and examples, or at least their metal parts, have been preserved in Spain, Italy, and Germany.

Iron catapult points from different sites around Xanten with varying cross-sections (trilobate, triangular, and square).
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This type of armament is usually referred to as a *scorpio* and its design can vary greatly, depending on the field of operation, but also on the person in charge on site. We rebuilt this weapon according to the remains of Ampurias in 2017 (FAS I). This type of catapult was certainly in use from the late second century BC until the late first century AD. On Trajan's column, however, another type of artillery can be seen, which is noticeably different to the *scorpio* and its use can be traced into Late Antiquity.

The second type of artillery, evidenced by the surviving iron parts discovered in Lyon (second century) and in Orșova (fourth century), was apparently used as a field artillery piece, placed on a cart, and as siege artillery. It is much heavier because the iron content is higher. We reconstructed the engine in 2021/2 (FAS II).

Each type of artillery had a different purpose, and could be used either on walls, covering the area in their front, or in the field.

Field testing

Only documented tests can testify to the potential of these engines and the logic behind them, and to verify, or correct, ancient reports if necessary. Our tests are in the tradition of replica torsion artillery and tests from the German imperial era by the artillery officer Erwin Schramm at the beginning of the twentieth century.

The tests, which began in each case after completion of the engine, were carried out according to the principle of emulating the fields of use. The first step was to understand the firing-unit and to configure it optimally.

In contrast to other reconstructions, we moved away from permanent loops in the torsion bushes and introduced single loops. This reduced the time of commissioning and made it easier to repair. In antiquity, hair, animal tendons, silk, and hemp ropes are documented as torsion material. We soon realized that horsehair was not suitable as the ropes tore substantially faster than hemp. We have not yet used animal sinews, however.

Reconstructed late-antique torsion engine (FAS II), after the Orşova-type.
© Alexander Hauenstein

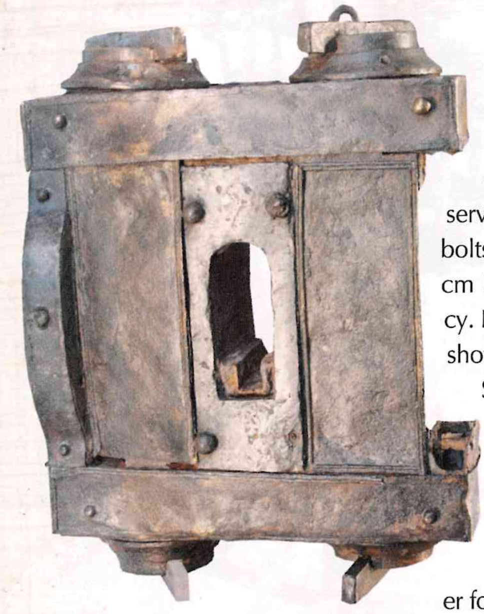
Speed shooting

The artillery of the Late Republican and Early Imperial period, reproduced as *Fridericiana Alexandrina Spina* (FAS) I, and the torsion ordnance of late antiquity, reproduced as FAS II, were both submitted for testing. The torsion bushings were not twisted to their maximum for this test (about 1 ¾ turns: 7 x 10 mm loops in the FAS I with a socket height of 55 cm, and 10 x 8 mm loops in the FAS II with a socket

Dummy wooden wall with merlons and targets on a field near the Raetian Limes at Gunzenhausen (Germany).
© André Werner

Surviving fourth-century iron frame and bushing holder from Orsova, Romania.
© ChristianChirita / Wikimedia Commons

Conditions at Dura-Europos preserved the shafts and wooden fins of these bolts perfectly.
© Yale University Gallery



Tension frame of a small Roman torsion engine from the first century AD, found in Xanten, Germany.
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height of 50 cm; the torsion material of FAS I had a weight of 210g and FAS II had a weight of 225g), so we kept the ejection velocities at 22–39 m/s, to preserve the material. We shot with dummy bolts (beech, diameter approx. 2.5 cm and 20 cm long, 120 g), which reduced the accuracy. Nevertheless, at short (15 m) distances the shots all struck within a 30 cm square.

Speed tests were carried out. It was possible to fire 6–8 shots per minute safely and with an easy routine in the case of the FAS II. In the same tests, the FAS I achieved 9–12 shots per minute. The explanation is that the pull-length was shorter for the FAS I than for the FAS II. Two people were sufficient as operators. The routine could be achieved after short exercises and some rationalization of the procedure. The duration of the set-up at the beginning was unsatisfactory. It took 45 minutes to set up the FAS I, while FAS II only took half as long. With training and exercise, we finally ended up at about 10 minutes to prepare the catapults.

Accuracy

Marksmanship tests were recently carried out with the FAS I and II. The distance was 30m to a dummy wooden wall with merlons, and with targets attached in the intervals of each merlon. The bushings were turned tighter (about 2 turns at the top and bottom of each socket of 55 cm height in the case of FAS I and 50 cm height in the case of FAS II) and the projectiles were designed according to the Dura-Europos finds with wooden fins (about 38 cm long, including the 10 cm iron tip and the 27 cm wooden tail, 125–140 g). These bolts had greater in-flight stability than the dummies of the speed tests.

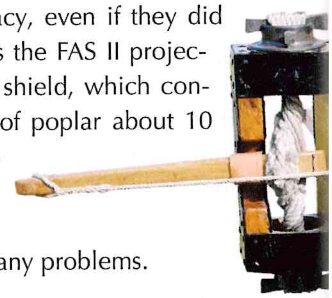
A scene of a field artillery piece in a wagon on the Column of Marcus Aurelius – from the 'Miracle of the Rain' scene, ca. AD 174.
© Public Domain

We achieved fast aiming accuracy in the case of the FAS II and always shot reliably into the black centre area of the target. The shots were each so powerful that they went through the hay bales and impacted about 30 m further behind the wooden wall.

The scales continuously showed an extraction weight of about 170 kg, with a 'muzzle' velocity averaging about 60 to 70 m/s. The maximum speed we attained was 77 m/s (FAS II), i.e. 277.2 km/h with, however, 11 loops per bush, i.e. 275 g torsion loops. Note that the string could not be fully tensioned because the iron-strengthened arms would have broken.

This results in a projectile energy of just over 444 joules, about the same as a modern 9 mm pistol. In direct comparison with modern ammunition, however, there is one major consideration. The cross-sectional load on a soft body increases linearly with the size of the calibre. Due to the length and the recoiling weight, the effect is proportionally much greater for the same energy. That is, our bolts would have a greater impact. Out of 80 cm of a collective mass of Styrodur, 60 cm were penetrated. The results are surprising and, as in the case of the boat tests, scientifically trendsetting.

The shots with the FAS I were also surprising. Its bolts were slower, with an exit velocity of about 50 m/s, but hit the target at 30 m with deadly accuracy, even if they did not penetrate as far as the FAS II projectiles. The shots at the shield, which consisted of three layers of poplar about 10 mm thick, were also remarkable. The FAS II projectiles penetrated the shield without any problems.



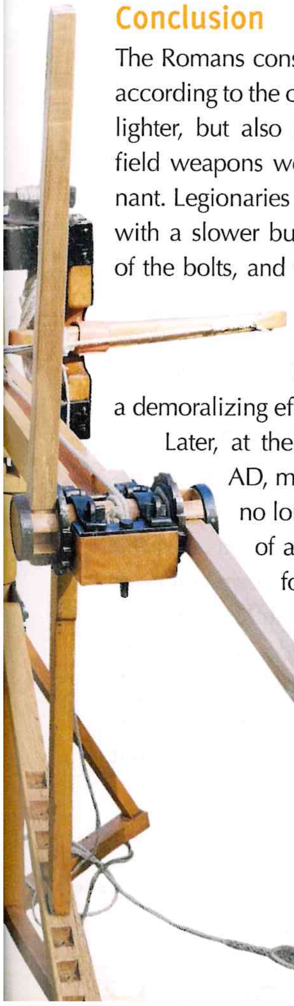
Long-range shooting

Long shots have been the focus of our tests for a long time, as a derivative of the attempts to assess and optimize the launching speed. With the completion of the FAS II, we gained comparative certainty: with the Northeim and Dura-Europos bolt replicas, we found that the shorter and narrower Dura-Europos

Roman scorpio (FAS I) – the reconstruction was mainly based on the finds from Ampurias.
© Alexander Hauenstein

bolts produced better values on both catapults, travelling much farther than the 200 m length we had marked. With the FAS I we reached average exit velocities of 54 m/s, with the FAS II average velocities of 75 m/s, which would give us a theoretical distance (at 45 degrees elevation) of almost 600 m.

Conclusion



The Romans constructed specialized weapons according to the challenges they faced. Mobile, lighter, but also more vulnerable, long-range field weapons were initially seemingly dominant. Legionaries could load these faster, albeit with a slower but still lethal launching speed of the bolts, and they were accurate to 30–50 m (FAS I). When combined into 'batteries' shooting volleys, they were bound to have a demoralizing effect on massed enemies.

Later, at the turn of the second century AD, more durable torsion catapults, no longer produced in masses and of a heavier design, came to the fore. This weapon was also used in the field until at least as late as the third century (attested at the battle of Northeim in AD 235). Both weapons were in fact used on fortifications as well. The FAS II could shoot bolts at velocities of 77 m/s at a range of max 600 m more reliably and further than its FAS I competitor, with reliable, lethal accuracy as far out as at least 50 m.

Preliminary tests on the one-armed torsion engine, which, according to Ammianus Marcellinus, was called 'onager' after the sound and movement it made when it was fired, and which resembled the cry and kick of a wild ass (23.4.4), and used primarily against enemy walls, have just begun. In antiquity, this engine is said to have reached a range of 600 m. Future tests will bring further insights here. AW

Boris Dreyer is professor of Ancient History at the Friedrich-Alexander-University of Erlangen-Nuremberg. He leads the Römerzentrum at Altmühlsee on the Raetian Limes.

FURTHER READING

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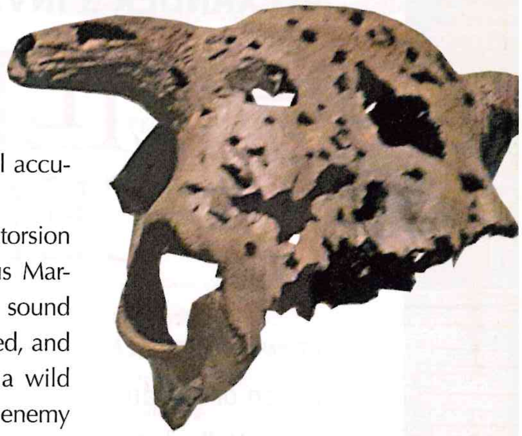

(Top) **Tests of FAS II (left) and I (right) in the field with measuring equipment at the ready to gauge performance.**
© André Werner

(Bottom) **Fragment of a cow's skull found along Hadrian's Wall at Vindolanda. The skull has apparently been used for target practice, as holes from *ballista* bolts and other smaller projectiles are both in evidence.**
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