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Threads of warfare: textiles in Roman scale armour

Abstract

Roman scale armour, a type of military equipment, has been part of many studies in scholarly research. Nevertheless, while textile and leather material were known to be used for the base garment, archaeological evidence is relatively rare in the Roman period. This paper presents finds of scale armour with different textile materials attached. The selection of the fabric was deliberate and tailored to the armour's construction demands, with textiles characterised by strength, thickness and durability. The weave choice was also intentional, with certain weaves associated with lighter copper alloy and iron scales, and basket weaves and tabbies found alongside heavier scales. Warp or weft-faced fabrics have only been found in conjunction with heavy, large iron scales. There is also evidence of a double layer of textile in Roman scale armour, which could even be made of two different weave types. This has implications for the interpretations of padded under-armour.

Keywords: Roman army, scale armour (*lorica squamata*), textiles, base garment, padded under-armour, military equipment

Introduction

Archaeological textile studies rarely focus on body armour, while specialists in archaeological military equipment seldom consider textiles (notable exceptions include Bishop 1995; Sumner 2009; Gleba 2012; Nosch 2012). Despite their distinct material emphases – textiles in one field and metals in the other – these materials are intrinsically linked when examining protective military gear of the past. Body armour often relied on a combination of textiles and metal to function effectively, with each material contributing unique properties. Textiles served to connect metal components, form an integral base for the armour, prevent chafing and potentially provide padding. Metal, in turn, offered resistance against sharp implements and distributed the force of impacts over a broader area (Jones 2014; Wijnhoven 2022, 165–181).

This disciplinary disconnect has left significant gaps in the understanding of Roman scale armour – an archetypal example of armour that integrated a textile base with an outer layer of metal scales. While scale armour in the archaeological record is rare, its

scarcity should not be overstated. This article compiles evidence from 74 examples of Roman scale armour that preserve both organic and metal elements (tables 1 and 2), offering new insights into the construction and use of a distinctive type of armour.

The Roman army employed scale armour for many centuries with hundreds of finds originating from military installations along the Roman frontier (for example, Bishop 2023; Groh 2023). This armour consisted of scales, typically made of iron or copper alloy, ranging in size from very small (approximately 10 mm in length) to very large (up to 90 mm in length). Roman scales were designed with multiple holes in order to assemble them into functional armour. Each scale featured pairs of holes along the sides, used to link the scales into rows. The scales overlapped their neighbours slightly and were fastened together using short, staple-like pieces of metal wire. At the top of each scale, one or more holes allowed for a 1–3 mm thick cord to be threaded through, securing the scales to a base garment. The rows were sewn in such a way that they partially overlapped vertically, resulting in armour that combined overlapping scales and a textile

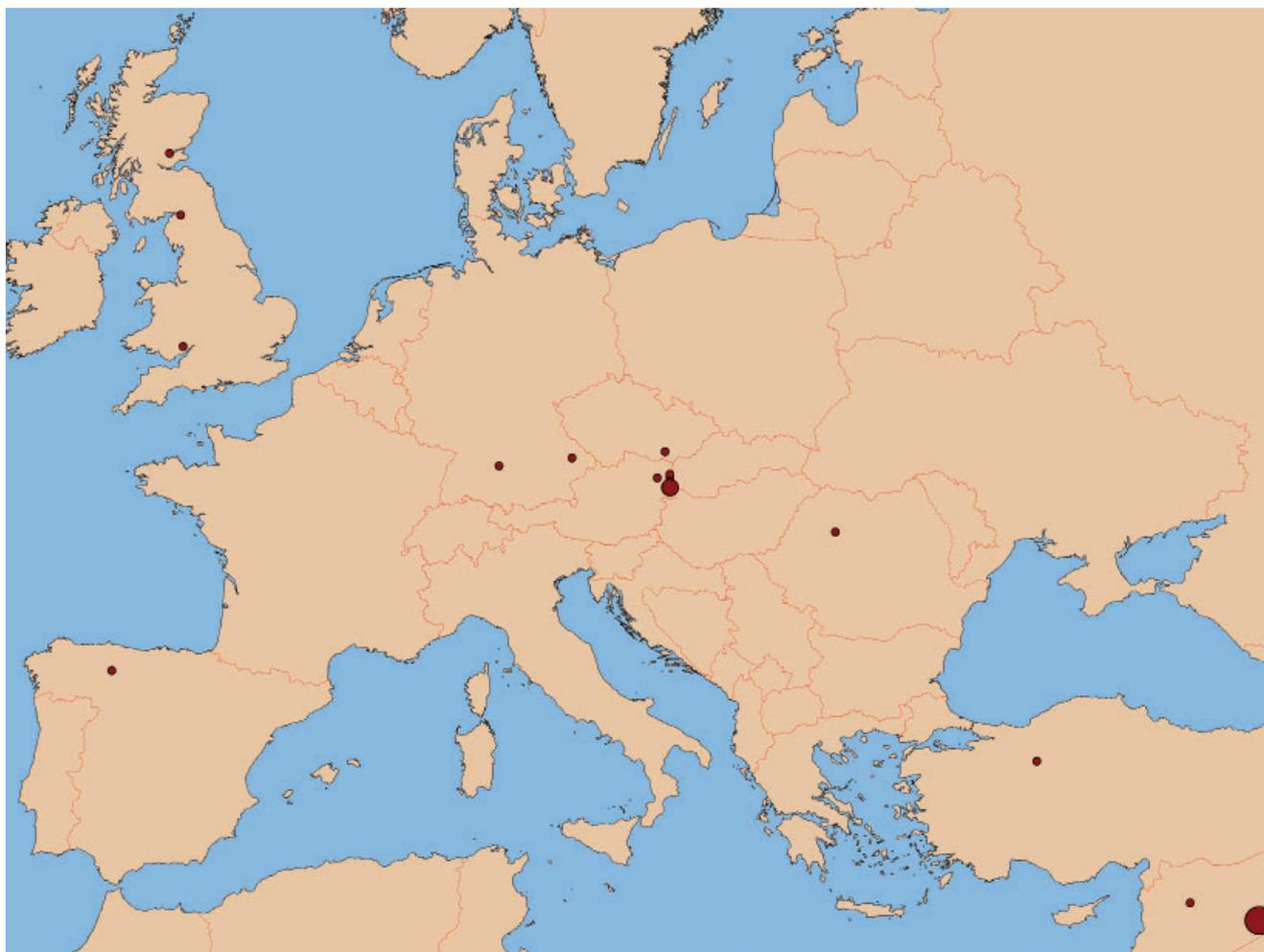


Fig. 1: Distribution of finds of Roman scale armour with associated organic remains (Image: Martijn Wijnhoven)

base to provide both flexibility and protection. This article focuses on the base garment of this armour, looking at its characteristics and how it functioned in relation to the metal scales.

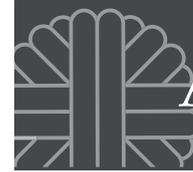
Methodology

A systematic review of Roman scale armour led to the identification of 74 examples with both metal and organic components preserved. The primary source for this review was the direct examination of archaeological collections containing scale armour. Notably, the most significant collections

were the finds from Carnuntum in Austria, in the care of Landessammlungen Niederösterreich, Archäologischer Park Carnuntum, and those from Dura-Europos in Syria held by the Yale University Art Gallery. Together, these collections account for nearly 60 examples. This analysis was further enriched by a literature review, which incorporated published data on relevant finds into the database. Additionally, the Yale University Art Gallery's photo archive provided crucial insights into several Dura-Europos finds no longer held in that collection.

Where more than one find of scale armour is

Table 1 (see opposite): Findspots of scale armour with textiles attached, references: Baumgarten an der March 1: Grömer 2014, 169–170; Schramm and Fischer 2015. – Carlisle: Bishop 2009, 689–691; Jones 2009, 1121–1229. – Carnuntum 11: Beutler et al. 2017, 267; Grömer 2014, 165–166; Groh 2023, 96–103; Jobst and Ditmar-Trauth 1992, 294; Von Groller 1901, 93. – Carpow: Coulston 1992, 21–22; Wild 1981. – Dura-Europos: Bishop 2023, 36–38; James 2004, 120–138 and unpublished (Yale University Art Gallery, New Haven). – Gordion: Bennett and Goldman 2009, 40–41. – Isriye: Gogräfe 2016, 203–204. – Mušov-Burgstal: Groh 2023, 264–265. – Potaissa: Bărbulescu 1991, 28–29; Fodorean 2020, 196, 199. – Puente Castro: Aurrecochea Fernández 2010, 85. – Stillfried an der March: Groh 2023, 227–229. – Straubing: Groh 2023, 302–303. – Usk: Manning et al. 1995, 14–15. – Vienna 10: Groh 2023, 290–292



FIND	COUNTRY	DATE	SIZE	METAL	HOLE ARRANGEMENT
Baugarten an der March 1	Austria	160-180 CE	medium	copper alloy	large hole at top, pair on each side
Carlisle 1	United Kingdom	140s CE	large	iron and brass	semi-rigid scale
Carlisle 2	United Kingdom	125-140s CE	large	iron and copper alloy	semi-rigid scale
Carnuntum 11	Austria	Roman period	medium	copper alloy	semi-rigid scale
Carnuntum 49	Austria	late 1st - late 2nd century CE	X-large	iron	vertical pair at top, pair on each side
Carnuntum 50	Austria	late 1st - late 2nd century CE	X-large	iron	vertical pair at top, pair on each side
Carnuntum 60	Austria	late 1st - late 2nd century CE	X-large	iron	vertical pair at top, pair on each side
Carnuntum 66	Austria	late 1st - late 2nd century CE	large	iron	vertical pair at top, pair on each side
Carnuntum 70	Austria	late 1st - late 2nd century CE	large	iron	vertical pair at top, pair on each side
Carnuntum 71	Austria	late 1st - late 2nd century CE	large?	iron	vertical pair at top, pair on each side
Carnuntum 72	Austria	late 1st - late 2nd century CE	large	iron	vertical pair at top, pair on each side
Carnuntum 73	Austria	late 1st - late 2nd century CE	large	iron	vertical pair at top, pair on each side
Carnuntum 74	Austria	late 1st - late 2nd century CE	large?	iron	vertical pair at top, pair on each side
Carnuntum 145	Austria	late 1st - late 2nd century CE	large	iron	four holes at top, pair on each side
Carnuntum 181	Austria	late 1st - late 2nd century CE	X-large	iron	vertical pair at top, pair on each side
Carnuntum 188	Austria	120-170/180 CE	large or X-large	iron	unclear
Carnuntum 189	Austria	120-170/180 CE	X-large	iron	unclear
Carnuntum 190	Austria	120-170/180 CE	large?	iron	unclear
Carnuntum 191	Austria	120-170/180 CE	large	iron	vertical pair at top, pair on each side
Carnuntum 192	Austria	120-170/180 CE	large or X-large	iron	unclear
Carnuntum 193	Austria	120-170/180 CE	large or X-large	iron	unclear
Carnuntum 194	Austria	120-170/180 CE	large	iron	unclear
Carnuntum 195	Austria	120-170/180 CE	large	iron	unclear
Carnuntum 196	Austria	120-170/180 CE	large	iron	vertical pair at top, pair on each side
Carpow	United Kingdom	180-220 CE	small	copper alloy	vertical pair at top, pair on each side
Dura-Europos 3	Syria	mid-3rd century CE	medium	copper alloy	semi-rigid scale
Dura-Europos 13	Syria	possibly Trajanic, 160s-256 CE	medium	copper alloy	semi-rigid scale
Dura-Europos 22	Syria	possibly Trajanic, 160s-256 CE	large	iron	horizontal pair at top, pair on each side
Dura-Europos 25	Syria	possibly Trajanic, 160s-256 CE	large	copper alloy	horizontal pair at top, pair on each side
Dura-Europos 27	Syria	possibly Trajanic, 160s-256 CE	small	copper alloy	three pairs of holes at the top
Dura-Europos 30	Syria	mid-3rd century CE	small	copper alloy	vertical pair at top, pair on each side
Dura-Europos 31	Syria	mid-3rd century CE	small	copper alloy	vertical pair at top, pair on each side
Dura-Europos 32	Syria	mid-3rd century CE	small	copper alloy	vertical pair at top, pair on each side
Dura-Europos 35	Syria	mid-3rd century CE	small	copper alloy	vertical pair at top, pair on each side
Dura-Europos 36	Syria	possibly Trajanic, 160s-256 CE	small	copper alloy	vertical pair at top, pair on each side
Dura-Europos 37	Syria	possibly Trajanic, 160s-256 CE	small	copper alloy	vertical pair at top, pair on each side
Dura-Europos 38	Syria	mid-3rd century CE	medium	copper alloy	vertical pair at top, pair on each side
Dura-Europos 43	Syria	possibly Trajanic, 160s-256 CE	medium	copper alloy	vertical pair at top, pair on each side
Dura-Europos 47 (variant 2)	Syria	255-256 CE	medium	copper alloy	vertical pair at top, pair on each side
Dura-Europos 47 (variant 1)	Syria	255-256 CE	medium	copper alloy	four holes at top, pair on each side
Dura-Europos 48	Syria	possibly Trajanic, 160s-256 CE	medium	copper alloy	vertical pair at top, pair on each side
Dura-Europos 51	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	vertical pair at top, pair on each side
Dura-Europos 62	Syria	mid-3rd century CE	medium	copper alloy	four holes at top, pair on each side
Dura-Europos 63	Syria	mid-3rd century CE	medium	copper alloy	four holes at top, pair on each side
Dura-Europos 64	Syria	mid-3rd century CE	large	iron	four holes at top, pair on each side
Dura-Europos 65	Syria	mid-3rd century CE	X-large	iron	no scales survive
Dura-Europos 66	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	four holes at top, pair on each side
Dura-Europos 67	Syria	mid-3rd century CE	medium	copper alloy	four holes at top, pair on each side
Dura-Europos 73	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	four holes at top, pair on each side
Dura-Europos 75	Syria	possibly Trajanic, 160s-256 CE	large	iron	four holes at top, pair on each side
Dura-Europos 87	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	four holes at top, pair on each side
Dura-Europos 91	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	four holes at top, pair on each side
Dura-Europos 109	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	four holes at top, pair on each side
Dura-Europos 192	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	four holes at top, pair on each side
Dura-Europos 207	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	unclear
Dura-Europos 222	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	unclear
Dura-Europos 231	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	unclear
Dura-Europos 234	Syria	possibly Trajanic, 160s-256 CE	large or X-large	iron	unclear
Dura-Europos 237	Syria	possibly Trajanic, 160s-256 CE	large or X-large	iron	unclear
Dura-Europos 239	Syria	possibly Trajanic, 160s-256 CE	iron	iron	unclear
Dura-Europos 240	Syria	possibly Trajanic, 160s-256 CE	X-large	iron	unclear
Dura-Europos 268	Syria	mid-3rd century CE			no scales survive
Dura-Europos 284	Syria	possibly Trajanic, 160s-256 CE			no scales survive
Dura-Europos 285	Syria	possibly Trajanic, 160s-256 CE			no scales survive
Gordion 3	Turkey	150-220 CE	large	iron	unclear
Isriye 1	Syria	terminus post quem 304/305 CE	medium	copper alloy	unclear
Isriye 7	Syria	early 4th century CE		copper alloy	unclear
Mušov-Burgstal 9	Czechia	170-180 CE	medium	iron	vertical pair at top, pair on each side
Potaissa 2	Romania	168-271 CE	small	copper alloy	vertical pair at top, pair on each side
Puente Castro 1	Spain	150-250 CE	medium	copper alloy	three pairs of holes at the top
Stillfried an der March 1	Austria	late 2nd century CE	medium	copper alloy	semi-rigid scale
Straubing	Germany	150/160-180 CE	medium	copper alloy	large hole at top, pair on each side
Usk 2	United Kingdom	late Neronian - early Flavian		iron	unclear
Vienna 10	Austria	Roman period	large	iron	large hole at top, pair on each side

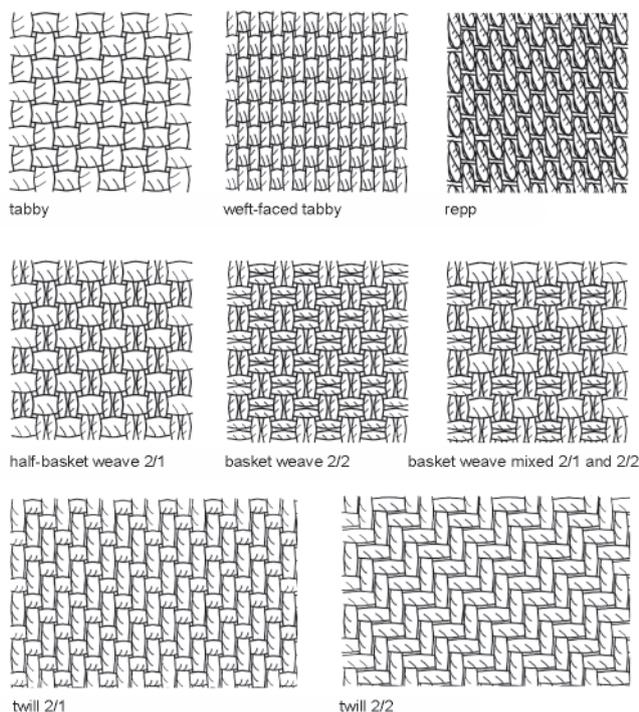


Fig. 2: Weave types that are known in connection to Roman scale armour (Image: Karina Grömer)

represented from the same site, individual examples have been assigned a number following the site's name. These numbers are not always sequential, as they correspond to a more extensive database compiled for a forthcoming monograph on Roman scale armour, scheduled for publication in 2026/2027. Where possible, the key characteristics of the scale armour were identified and recorded in a database. For the metal scales, the database included details on material, dimensions (length, width) and the number and placement of attachment holes. For the textiles, the recorded features (table 2) encompassed material, weave type, warp and weft identification, yarn plying, twist direction, yarn diameter and the number of threads per centimetre.

Results

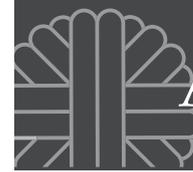
The database of Roman scale armour with organic remains comprises 74 finds originating from eight different countries (fig. 1 and table 1): 41 from Syria, 24 from Austria, 4 from United Kingdom, and one each from Czechia, Germany, Romania, Spain and Turkey. The distribution of finds is uneven, heavily influenced by the environmental conditions that favour the preservation of organic remnants. Two sites, Carnuntum and Dura-Europos, provided particularly

favourable preservation conditions and account for the majority of the documented finds. At Carnuntum, evidence for the base garments has been preserved together with iron scales through mineralisation (Grömer 2014). The survival of organic components of the armour from Dura-Europos is in large part the result of the arid Syrian climate (Snow 2011, 33–35). These are not only associated with iron scales, as in Carnuntum, but many of them belong to copper alloy scales.

The finds in the database date from the late first century CE to the third century CE, aligning with the period when Roman scale armour appears relatively frequently in the archaeological record. However, the examples from Carnuntum and Dura-Europos represent different periods in time. Most of the Carnuntum finds date from 80–200 CE (Groh 2023, 80–148), while those from Dura-Europos have a *terminus ante quem* of 256 CE (James 2004, 120–124) and mostly originate from the first half to the middle of the third century CE.

Material

Scale armour has a long history, originating in the Late Bronze Age in the Near East (Hulit 2002) and subsequently spreading to various regions, where it is found in a wide range of archaeological cultures. This includes the Roman Empire, where the army adopted scale armour during the Early Imperial period (Feugère 2002, 74; Fischer 2019, 131–132). As far as organic components are preserved, it appears that leather was the common material for the base garment. It was not only employed for an extended period but also seems to have been the standard outside the Roman Empire (for example, Agre 2011, 72; Černenko 2006, 9–25; Symonenko 2015, 128–131). The database of Roman scale armour clearly shows that the Romans departed from earlier traditions and favoured textile base garments for their scale armour. Of the 74 documented finds, 69 contained textile remains. This does not mean textile was always the only organic material present in these examples; some also contained leather (for example, Carpow, Dura-Europos 62–63, Baumgarten an der March 1, Potaissa 2). In compiling the database, the function of the preserved organic materials, whether textile or leather, was taken as the decisive factor. When multiple organic materials were present, only the material clearly used as the base garment was recorded. Materials that served other purposes, such as edging or fastening, were excluded from the dataset. If only a single organic material was found and could plausibly be interpreted as the base garment, it was registered accordingly.



Detailed examination showed that leather, when present, was typically not part of the base garment but was used as edging along the borders of the scale armour, secured by leather or rawhide thongs. This function is especially clear in the better-preserved examples. In a very small number of cases of Roman period scale armour, leather thongs were used to attach the scales to the base garment.

Leather as the only organic material, and possibly used as a base garment, was identified in just three cases. In two instances, the type of organic material could not be determined. Notably, all examples involving leather correspond to a specific type of Roman scale armour known as “semi-rigid”. This differs from standard scale armour in its construction: the scales are not only interlocked in rows but also secured in columns using metal staples (Wijnhoven 2024a; 2024b). Unlike regular scale armour, semi-rigid armour does not rely on a base garment for structural integrity. However, a leather or textile lining would likely have been added to prevent chafing against the wearer’s body or clothing. In contrast, all other types of Roman scale armour required a base garment for their structural stability. Without exception, these base garments were made of textile, which must have been a Roman innovation in the development of scale armour.

While textiles could be made from fibres of either animal or plant origin, the vast majority of the finds associated with scale armour are composed of plant fibre. Among the 69 cases with textile remnants, 46 involve bast fibres, 11 involve wool, and 12 remain unidentified. For most of the plant fibre textiles, it was not possible to determine the plant species. However, in three cases, the source was identified: two were flax



Fig. 3: Twill textiles used for the base garment: Fragment of scale armour from Dura-Europos (27) which has been folded over (Yale University Art Gallery) (Image: Martijn Wijnhoven)

(Carpow, Potaissa 2) and the third was identified as either flax or nettle (Baumgarten an der March 1).

As for wool used in scale armour, all documented examples come from Carnuntum in Austria and are exclusively 2/2 twills. Only one other find reported to involve wool originates from Isriye in Syria. However, while described in the literature as wool (Gogräfe 2016, 203, pl. 46g, 47a), photographic evidence suggests it may actually consist of plant fibres. Unfortunately, the database currently lacks sufficient chrono-geographical variation and datapoints to support definitive conclusions. The use of wool could represent a regional or temporal phenomenon or it may have been more widespread than suggested by the current archaeological record.

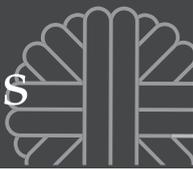
Weave types

The type of weave (fig. 2) was identifiable in 53 of the 69 finds of textile remnants. In several cases, the base garment consists of a double layer of textile rather than a single layer (see below). While the double layer was often made from the same textile, in two instances at Dura Europos, the weave of the inner layer, facing the body of the wearer, differed from that of the outer layer, facing the metal scales. This brings the total number of weave identifications to 55.

The most common type of weave observed in the finds is twill (fig. 3), identified in 23 examples. Among these, 18 feature a 2/2 twill weave (11 from Carnuntum, six from Dura-Europos, one from Potaissa), while three exhibit a 2/1 twill weave (two from Dura-Europos, one from Carpow). In two cases (Dura-Europos and Mušov), the specific twill pattern could not be determined. At Carnuntum, only the 2/2 twill variant has been found, and all examples were made of wool. In contrast, at other sites, bast fibres were used in the twills.

The second most common weave is basket weave or half-basket weaves, found in 22 examples of scale armour. Of these, the majority (14) are plain basket weaves (fig. 4). A unique variation of basket weave was identified only at Dura-Europos with eight examples (fig. 5). This variation features consistently woven double weft threads, while the warp alternates between double and single yarns.

Tabby weaves are relatively uncommon, observed in only six examples of scale armour with preserved textiles. In two of these cases (both from Dura-Europos), the identification of the weave is not entirely certain; while it appears to resemble a tabby, it could also represent another type of weave. Of the remaining four examples of tabby weave, one comes from Carnuntum and three from Dura-Europos.



Find	Double layer	Material	Weave	Warp or thread system 1				Weft or thread system 2			
				Twist	Threads	Diameter	Threads/cm	Twist	Threads	Diameter	Threads/cm
Baumgarten an der March 1		flax/nettle	basket weave	zz	paired	0.8	10-12	zz	paired	0.8	10-12
Carlisle 1		leather									
Carlisle 2		leather									
Camuntum 11		leather									
Camuntum 49		unidentified	repp-like tabby	s	single	0.8-1.0	5-6	s	single	0.8	16-18
Camuntum 50		unidentified	basket weave	ss	paired	0.6-0.7	12-14	ss	paired	0.6-0.7	12-14
Camuntum 60		plant fibres	repp-like tabby	s	single	0.8	8-10	s	single	0.8-1.0	7
Camuntum 66		unidentified	2/2 twill	z	single	1.2	7	s	single	1.3	6-7
Camuntum 70		unidentified									
Camuntum 71	yes	wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 72	possibly	wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 73		wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 74		wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 145		unidentified	basket weave	ss	paired	0.6-0.7	14-16	ss	paired	0.6-0.7	10
Camuntum 181		unidentified	Tabby	s	single	1.1-1.2	6-7	s	single	1.1-1.2	10
Camuntum 188		plant fibres	repp-like tabby	s	single	0.8	8-10	s	single	0.8-1.0	7
Camuntum 189		plant fibres	repp-like tabby	s	single	0.8	8-10	s	single	0.8-1.0	7
Camuntum 190		wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 191		wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 192		wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 193		plant fibres	repp-like tabby	s	single	0.8	8 to 10	s	single	0.8-1.0	7
Camuntum 194		wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 195		wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Camuntum 196		wool	2/2 twill	z	single	1.2-1.5	5	z	single	1.2	5
Carpow		Ffax	2/1 twill	z	single		6 to 7 (warp)	z	single		10-12 (weft)
Dura-Europos 3		unidentified	tabby?								
Dura-Europos 13		unidentified									
Dura-Europos 22		unidentified	tabby?								
Dura-Europos 25		plant fibres									
Dura-Europos 27	yes	plant fibres	2/1 twill	z	single	0.8-1.1	6	Z2s	plied	0.7-1.0	9
Dura-Europos 30		plant fibres		z	single	c. 1		z	single	c. 1	
Dura-Europos 31		plant fibres	2/2 twill	z	single	0.9-1.1	8	z	single	0.8-1.0	8-9
Dura-Europos 32		plant fibres	Twill	z	single	c. 1.2	c. 8	z	single	c. 0.8	c. 10
Dura-Europos 35		plant fibres	2/2 twill	Z	single	1.1-1.3	7	z	single	0.9-1.0	8-9
Dura-Europos 36	yes	plant fibres									
Dura-Europos 37		plant fibres	2/2 twill	Z	single	0.8-1.2 (even 0.5-1.8)	c. 11	z	single	0.9	c. 12
Dura-Europos 38	yes	plant fibres	2/2 twill	Z	single	1.2-1.5	7	z	single	1.1-1.2	6
Dura-Europos 43	yes	plant fibres	2/1 twill	z	single	1.1-1.2	8-9	z	single	1.2-1.4	7
Dura-Europos 47 (variant 1)		plant fibres	tabby	z	single	c. 1	c. 9	z	single	c. 1.2-1.5	c. 6
Dura-Europos 47 (variant 2)		plant fibres									
Dura-Europos 48		plant fibres									

Table 2: Data from textiles found on scale armour



Find	Double layer	Material	Weave	Warp or thread system 1				Weft or thread system 2			
				Twist	Threads	Diameter	Threads/cm	Twist	Threads	Diameter	Threads/cm
Dura-Europos 51		plant fibres	appears 2/2 twill	z	single	0.8-1.0	7-8	z	single	0.8-1.0	7-8
Dura-Europos 62		flax	2/2 twill	z	single		6-7	z	single		6-7
Dura-Europos 63 (layer 1)	yes	plant fibres	basket weave	zz	paired	0.7-1.0 (warp)	12 double = 24	zz	paired	1.0-1.4 (weft)	6 double = 12
Dura-Europos 63 (layer 2)		plant fibres	tabby	ss, s	paired & single	0.8-1.0	8	ss	paired	0.7-1.0	12
Dura-Europos 64	partly	flax	basket weave	z	paired			zz	paired		
Dura-Europos 65	yes	plant fibres	basket weave mixed with half basket	ss, s	paired & single	0.7-0.9 (warp)	5 double = 10	ss	paired	0.7-1.1 (weft)	8 double = 16
Dura-Europos 66	yes	plant fibres	basket weave mixed with half basket	ss, s	paired & single	0.6-0.9 (warp)	5 double = 9 to 10	ss	paired	0.8-1.2 (weft)	6 double = 12
Dura-Europos 67 (layer 1)	yes	plant fibres	basket weave	zz	paired	0.8-1.1	5 double = 10	zz	paired	0.8-1.1	5 double = 9 to 10
Dura-Europos 67 (layer 2)		plant fibres	Tabby	s	single	0.7-1.1	11 to 12	s	single	0.7-0.8	7
Dura-Europos 73		plant fibres									
Dura-Europos 75		plant fibres									
Dura-Europos 87		plant fibres	basket weave with warp-faced border (repp-like)	ss	paired	c. 0.8 (warp)	4-5 double = 10	ss	paired	0.6-0.8 (weft)	10 double = 20
Dura-Europos 91	yes	plant fibres	basket weave	s	single	0.8	6 double = 12	ss	paired	0.8	5 double = 10
Dura-Europos 109		plant fibres	basket weave mixed with half basket	ss, s	paired & single	0.7-1.0 (warp)	c. 6 double = 12	ss	paired	c. 0.8-1.0	c. 8
Dura-Europos 192		plant fibres									
Dura-Europos 207		plant fibres	basket weave mixed with half basket	ss, s	paired & single	0.6-0.9 (warp)	c. 6 double = 12	ss	paired	0.5 (weft)	9 double = 18
Dura-Europos 222	yes	plant fibres	basket weave mixed with half basket	ss, s	paired & single	0.8	6 double = 12	ss	paired	0.6	10 double = 20
Dura-Europos 231		plant fibres									
Dura-Europos 234		plant fibres	basket weave mixed with half basket	ss, s	paired & single	0.8	c. 12	ss	paired	0.8	c. 9
Dura-Europos 237		unidentified									
Dura-Europos 239		plant fibres	basket weave mixed with half basket	ss, s	paired & single	0.9-1.0	c. 9	ss	paired	0.9	c. 8
Dura-Europos 240		plant fibres	basket weave mixed with half basket	ss, s	paired & single	0.8	c. 11	ss	paired	0.8	c. 9
Dura-Europos 268	yes	plant fibres	possibly basket weave								
Dura-Europos 284		plant fibres	basket weave with warp repp-like edge	ss, s	paired & single	0.7-0.8 (warp)	5 double = 10	zz	paired	0.5-2.0 (weft)	4 double = 7-8
Dura-Europos 285		plant fibres	basket weave	zz	paired	0.9	c. 8	zz	paired	0.7-0.8	c. 10
Gordion 3		unidentified									
Isriye 1		wool or flax?	basket weave	z	single			z	single		
Isriye 7		plant fibres	basket weave								
Mušov-Burgstall 9		unidentified	possibly twill								
Potaissa 2		flax	2/2 twill								
Puente Castro 1		unidentified									
Stillfried an der March 1		unidentified									
Straubing		unidentified									
Usk 2		unidentified									
Vienna 10		unidentified									

Table 2 (continued): Data from textiles found on scale armour



Fig. 4: Scale armour (Yale University Gallery) with double layers of textile (one basket weave and the other tabby weave), and multiple scales still attached by sewing thread (Dura-Europos 63 and 67): front (top) and back (above) (Images: Martin Wijnhoven)



Fig. 5: Dura-Europos (65) is in a unique basket weave, where the warp consists of alternating double and single threads, while the weft is always a double (Yale University Art Gallery) (Image: Martijn Wijnhoven)

Of these three, two involve double-layered textiles associated with the armour (fig. 4). In these cases, one layer is a basket weave, and the other is a tabby weave. Notably, the tabby weave always faces the wearer, while the basket weave faces the scales.

A warp or weft-faced tabby weave is observed in only five finds, all from Carnuntum (fig. 6). These weaves are characterised by a pronounced repp structure, created by varying the density of either the warp or the weft. This results in one set of threads being visible on the surface, while the other set remains mostly covered.

Warp or weft-faced structures can also be used as borders for a piece of fabric. Two of the finds from Dura-Europos (87 and 284) feature a basket weave with a warp-faced border. This raises the possibility that the finds from Carnuntum either used a whole cloth made of warp-faced fabric or that only the edges survive, similar to those seen at Dura-Europos. In the first case, a unique weave is observed at Carnuntum, while in the second case, a more common phenomenon is present.

Textile qualities (see table 2)

The wool textiles, known only from Carnuntum (Grömer 2014), consist of 2/2 twills woven exclusively with z-spun single yarns (fig. 3b). These textiles are relatively coarse, with yarns measuring 1.2–1.5 mm in diameter and a thread count of five threads per centimetre in the warp and the weft, forming a well-balanced structure.

In contrast, the plant-fibre textiles associated with scale armour display a greater diversity. Although all are made with single yarns, there are both s and z-spun examples, particularly in tabbies, warp-faced tabbies, basket weaves and half-basket weaves. These textiles are finer than the wool samples, with yarns measuring approximately 0.7–0.8 mm in diameter and thread counts ranging from 7 to 12 threads per cm. In rare cases, such as those from Dura-Europos, thread counts reach up to 18 per centimetre. The higher counts are typically found in basket weave textiles and in warp-faced textiles, where one thread system has nearly double the density of the other.

Plant-fibre twills (2/1 and 2/2) from Dura-Europos (James 2004, 114) are primarily woven with z-spun single yarns measuring 0.8–1.3 mm in diameter, with some examples reaching up to 1.5 mm. These textiles exhibit a broader range of quality, with thread counts varying between 6 and 12 threads per centimetre, although a density of 8 threads per centimetre is the most common.

Sewing threads

In Roman scale armour, the individual scales are linked into rows with short, staple-like pieces of wire. The rows are attached to the base garment using binding threads (fig. 4b). This construction method was recognised early on by researchers and described in detail (fig. 7) in the case of Carnuntum:

“The thread used is made of flax, usually two-stranded, more rarely three stranded, and slightly twisted. It was passed through the row of scales in a continuous seam. Depending on the number and position of the seam holes, the stitching varied, but it was always executed using so-called front stitches” (Von Groller 1901, 90–91).

Von Groller’s analysis also revealed that the holes through which the threads were pulled were always hammered and filed smooth to prevent the organic material from wearing through. Similar binding threads have been documented in other finds, such as those from Baumgarten an der March 1 (Schramm 2023).

Scale types

The fabric used for the base garment of Roman scale armour was not chosen at random. Instead, there is a clear relationship between the textile weave and the type of scales (fig. 8). Two key scale characteristics influence this choice: size and material. For this study, scale size has been categorised into four groups: small (≤ 20 mm long), medium (>20 mm and ≤ 40 mm long), large (>40 mm and ≤ 60 mm long) and X-large (>60 mm long). The scales are made of either iron or copper alloy. Additionally, though to a lesser extent, the type of textile also correlates with the number and arrangement of holes in the scales – features commonly used to establish typologies of Roman scale armour (for example, Komoróczy 2000, 80; Groh 2023, 22–26, fig. A11–12; Von Groller 1901, 86–95, pl. 15).

Twill fabric is primarily associated with two specific variants of scale armour. The first comprises small copper-alloy scales, which are found exclusively in combination with a twill textile base. In all cases where textile remains are preserved, these scales are attached to twill fabric, with no evidence of alternative weaves. Each scale features three pairs of holes: one pair at the top for stitching the scale to the underlying garment, and two pairs on the sides for linking adjacent scales into rows using small, staple-like metal wires (Groh type IV). A variation of this type has the same number of holes but arranges all three pairs near the top edge, positioning the side holes directly beside the upper pair (Groh type X).

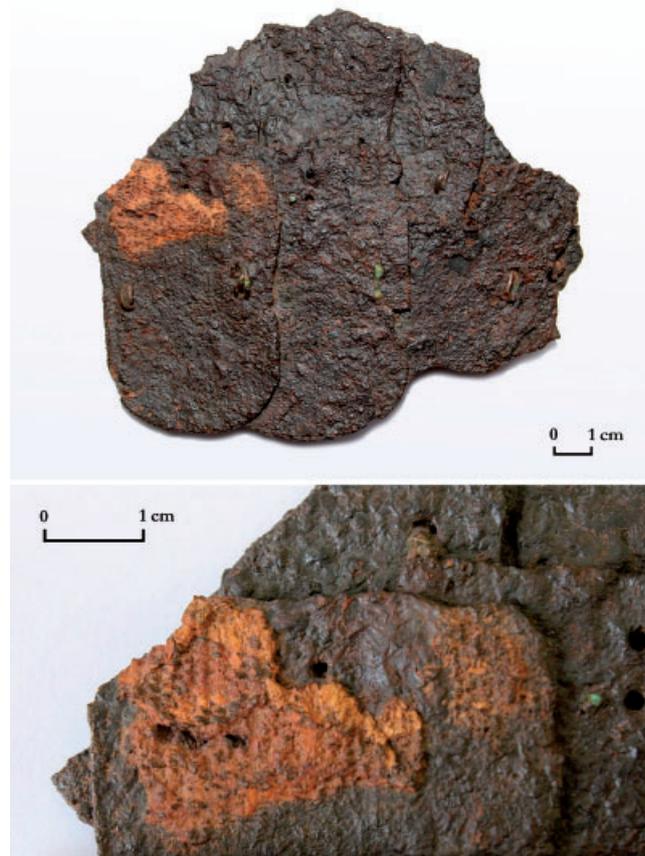


Fig. 6: Armour fragment from Carnuntum (49) consisting of very large iron scales and preserved remnants of a warp or weft-faced tabby weave on the inside of one of them (Landessammlungen Niederösterreich, Archäologischer Park Carnuntum): complete item (top), detail with textile (above) (Image: Martijn Wijnhoven)

The second type of scale associated with twill fabrics consists of large iron scales, which share the same hole arrangement as the small copper-alloy scales described above (Groh type IV). More broadly, Roman scale armour reveals a distinct size pattern based on material. Copper-alloy scales tend to be small, rarely exceeding 40 mm in length, and are almost entirely absent in the large and extra-large size categories. In contrast, iron scales are generally larger and are not represented among the smallest category at all. Although instances of medium-sized iron scales have been recorded, such as those from Mušov-Burgstall, these are rare exceptions among the predominant large and extra-large examples.

Taking this pattern into account, it is significant that twill fabrics are consistently associated with the smaller scale variants of each material. Small copper alloy scales are exclusively found with twill, while

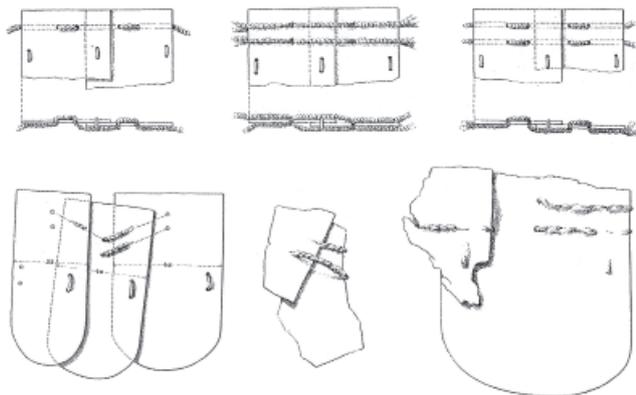


Fig. 7: The use of sewing threads as identified among the scale armour in Carnuntum (Image: After von Groller 1901, table XVI)

among iron scales, only the large types show this association. The extra-large iron scales, by contrast, are never linked to twill fabrics.

In addition to the two main groups of scales associated with twill fabrics, a third variant is occasionally observed. This consists of medium-sized copper-alloy scales that share the same hole arrangement as the smaller copper-alloy types. In one instance (Dura-Europos 62), a different hole configuration is attested, featuring two pairs of holes at the top rather than a single pair (Groh type VIII). There is also a single example of an extra-large iron scale (Dura-Europos 51) for which the identification of the underlying fabric is uncertain, although it may have been twill. This suggests that, on rare occasions, twill could have been used with larger scale types as well.

Base garments woven in a basket weave are associated with a different range of scale types than those found with twill fabrics. Basket weaves correspond to larger – and therefore heavier – scales. As with twills, two main groups can be identified. The first consists of medium-sized copper-alloy scales, which represent the largest examples within their material category. The second comprises iron scales, the vast majority of which fall into the extra-large category, although occasional examples of large iron scales have also been recorded.

The scales associated with basket weaves display greater variation in hole arrangements compared to those linked to twill fabrics. Most commonly, they feature two pairs of holes at the top and a pair on each side (Groh type VIII). However, a single specimen with only one pair of top holes has also been recorded (Groh type IV). In addition, a single find from Baumgarten an der March 1 in Austria consists of copper-alloy scales with a single large hole at the top (Groh type III), rather than the usual paired configuration.

As previously mentioned, tabby weaves are less commonly observed in base garments for scale armour. When present, they are almost exclusively associated with medium-sized copper alloy scales featuring two pairs of holes at the top and one on each side (Groh type VIII). Notably, two examples come from finds where a double layer of fabric was present: the layer facing the inside of the scales was a basket weave, while the layer facing the wearer was a tabby (figs. 3 and 7). There is a single occurrence of a tabby weave from Carnuntum (181) where a different type of scale is observed – in this case an extra-large iron scale. Additionally, there are two single occurrences of other scale types where the associated textile may be a tabby but cannot be determined with certainty.

Taken together, the types of scales linked to tabby weaves are similar to those observed with basket weaves. In both cases, they correspond to the heavier scale variants within their respective material categories. The presence of a double-layered fabric – combining a tabby with a basket weave – may be significant.

Although this combination has only been documented twice among the exceptionally well-preserved material from Dura-Europos, it would not be surprising if this practice was far more widespread. There could be an issue of survival bias. The layer closest to the scales (the basket weave) has a greater chance of preservation, as it is protected on both sides: by the scales on one and an additional textile layer on the other. Moreover, when the scales begin to corrode, the fabric in direct contact with them has a higher likelihood of survival, as it becomes incorporated into the corrosion products. In contrast, the textile facing the wearer (the tabby weave) would have been more vulnerable to decay and may have survived in fewer instances.

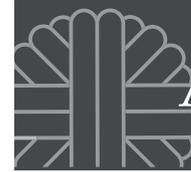
Warp-faced fabrics have so far been observed exclusively among the material from Carnuntum. All of these examples concern extra-large iron scales with the same hole arrangement (Groh type IV). Given the weight of these scales, a sturdy warp or weft-faced fabric would be particularly suitable.

Discussion

Textiles for scale armour in the Roman world

It is remarkable that all these textile linings for scale armour consist of different types of fabric (twills and basket weaves of different variants, tabbies, warp-faced tabbies) and that the connection between the scales and the carrier fabric is also different.

The diversity of weave types (including the use of z- and s-spun yarn) is particularly striking, given

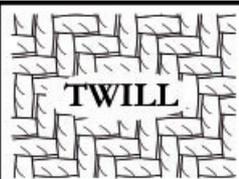
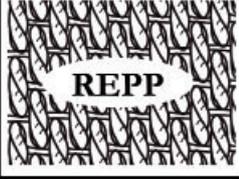


the presence of distinct textile traditions in different regions of the Roman Empire. This is well illustrated in a case study of Austria during the Roman period (Grömer 2014, figs. 17–19). Coarse fabrics, such as those found on the scale armour, are relatively uncommon; the predominant weave type is tabby, with only a few examples of basket weave or warp-faced variants. In this context, the textiles on the Roman scale armour found in Austria strongly suggest non-local production.

In general, the northern Roman provinces show a clear preference for z-twisted yarns, which are consistently interpreted as indicators of local production (Bender

Jørgensen 1992, 58–62). In contrast, s-twisted yarns occur primarily in regions around the Mediterranean, particularly in the eastern provinces of the Empire, including Syria and Egypt. Linen fabrics in s/s twist in particular, are associated with regions around the Mediterranean Sea (Wild 1970, 38, 44–45; Bender Jørgensen 1992, 128).

The variety of textile materials used indicates that there was no standardised “construction scheme” for scale armour. The only consistent feature among these textiles is their relatively coarse and firm quality. There is, however, a clear relationship between the type of scales and the chosen textiles, suggesting deliberate

WEAVE TYPE	COMMON SCALE TYPES	SINGLE OR UNCERTAIN
 TWILL	   	  
 BASKET	   	
 TABBY		  
 REPP		

copper alloy
 iron
? uncertain

small
 medium
 large
 X-large

Fig. 8: Weave types and their associated types of scales. Common scales are those of which two or more examples are known. As an exception, two single finds of scale types have been added to the “common types” column. In both cases, there is only one find of that scale type in the entire database, meaning that all available evidence points to one type of fabric. This concerns the small scale with a triangular tip in the top row (Dura-Europos 27) and the medium scale with the larger hole at the top in the second row (Baumgarten an der March 1). All other single associations of weave and scale types are shown in light grey. An additional question mark is added to the single finds where the type of fabric has possibly been determined but remains fairly uncertain (Image: Martijn Wijnhoven)

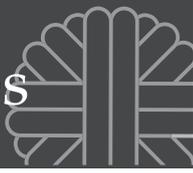


Fig. 9: Recreation of Roman scale armour: a) full-length view worn by a horse rider; b) close-up of the armour in wear; c) displacement of scale rows during movement; and d) reverse side of the textile lining showing the stitching for the attached scale rows (Image: Ursi Aurei, Leona Kohl and Nina Zajicek)

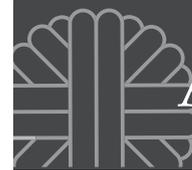
selection. Unlike leather, these textiles offer elasticity, which improves the pliability and flexibility of this type of armour. It is worth noting that such defensive equipment was also used for horses, as shown by complete examples of horse scale armour from Dura Europos. However, the armour from Baumgarten was clearly intended for a human body, as indicated by the presence of chest plates.

Textile properties in relation to armour construction

Textiles from the Roman period often show evidence of reuse and recycling (for example, Wild 2020). It is not uncommon to find garments that have been patched up or made entirely from re-used pieces of clothing.

However, this is not the case with the fabrics used as base garments for scale armour. Among the available evidence, there is no indication that these fabrics were made from recycled materials. This suggests that the fabrics were likely specifically produced with their intended use as armour in mind. This approach may also explain the consistent use of certain scale types and textile weaves.

Unlike most other fabrics used in antiquity, these textiles were not intended to be seen. They were purpose-made to serve as the base garment, with only the metal scales visible when the armour was worn. The textile would have only been observed during the process of donning the armour. Aesthetics likely



played a very minor role, if any, with function being the primary concern.

As previously noted, two finds with remnants of base garments exhibit a double layer of textiles woven in different weaves. However, several other finds also indicate the use of a double-layered textile construction. In 11 additional cases, both layers consist of the same type of fabric (fig. 9). Notably, double layers are often observed in more complete or better-preserved finds. While this already represents a substantial proportion of the evidence, their occurrence was likely more frequent than the archaeological record suggests. Some examples may have originally featured a double layer, with the inner fabric – facing the body – now lost due to preservation biases. It is even possible that the majority of scale armour originally incorporated a double-layered base garment and that it was likely a standard practice.

A double layer of fabric would not only have reinforced the base garment, allowing it to better support the weight of the scales and endure the demands of warfare, but it would also have provided essential padding. While metal armour (fig. 9) is highly effective at preventing cuts and penetration from sharp weapons, it offers little protection against blunt force trauma. Without sufficient padding, the impact of a blow could still cause significant injury to the wearer. To function effectively, metal armour therefore needed to be combined with some form of organic padding (Jones 2014, 70; Wijnhoven 2022, 165). Numerous historical examples of such padding exist, either integrated into the armour itself or worn as a separate garment underneath (for example, Blanc 1997; Kelly 2013). Most of these examples date to the Late Middle Ages or later. There is broad consensus that the Romans also used padded under-armour (Bishop 1995; Ubl 2006; Wijnhoven 2022, 165–181). This assumption is primarily based on iconographic and historical sources. Archaeological evidence does exist (for example, Deschler-Erb et al. 2004; James 2004, 116) but remains extremely scarce.

The identification of a double layer of sturdy, thick fabric as the base garment in Roman scale armour could reshape the understanding of Roman padded under-armour. If it also served as padding, then what was once considered an elusive element of Roman military equipment is now supported by a substantial body of archaeological evidence.

The technical characteristics (table 2) of the base textiles for metal scales suggest a well-considered functional choice. The fabrics are relatively thick and stable, with notably robust yarns and carefully balanced thread counts. Particularly interesting are the wool twills,

which, while slightly more open in structure, remain strong. The twill weave offers a degree of flexibility, as it allows for some diagonal stretch. Interestingly, twills were almost always used with the smallest of scales of each material (iron and copper alloy). These properties would have been advantageous for use in armour.

Conclusion

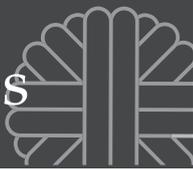
The organic components of Roman scale armour have received relatively little scholarly attention. However, a wealth of information can be gained by examining the collective evidence.

Many studies on Roman military equipment state that the base garment of scale armour was either leather or textile. While leather was widely used for this purpose by other cultures, the archaeological evidence overwhelmingly indicates that the Romans exclusively employed textiles. This distinction represents a Roman innovation and provides a useful criterion for differentiating Roman from non-Roman scale armour. The selection of fabric was not arbitrary or based solely on availability; rather, it was deliberate and tailored to the demands of armour construction. The textiles used were specifically produced for this purpose, characterised by their strength, thickness, and durability. In addition, the choice of weave appears to have been intentional and adapted to the type of scales it supported. Twill weaves are associated with lighter copper alloy and iron scales, whereas basket weaves and tabbies appear alongside heavier copper alloy and iron scales. Warp or weft-faced fabrics have only been found in conjunction with heavy, extra-large iron scales in the examples studied so far.

Finally, the observation that a significant proportion of Roman scale armour preserved a double layer of textile may have implications for the debated existence of padded under-armour. Such a construction would not only have reinforced the base garment but also provided additional padding. This evidence suggests that the presence of padding in Roman armour may be far more archaeologically tangible than previously assumed.

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