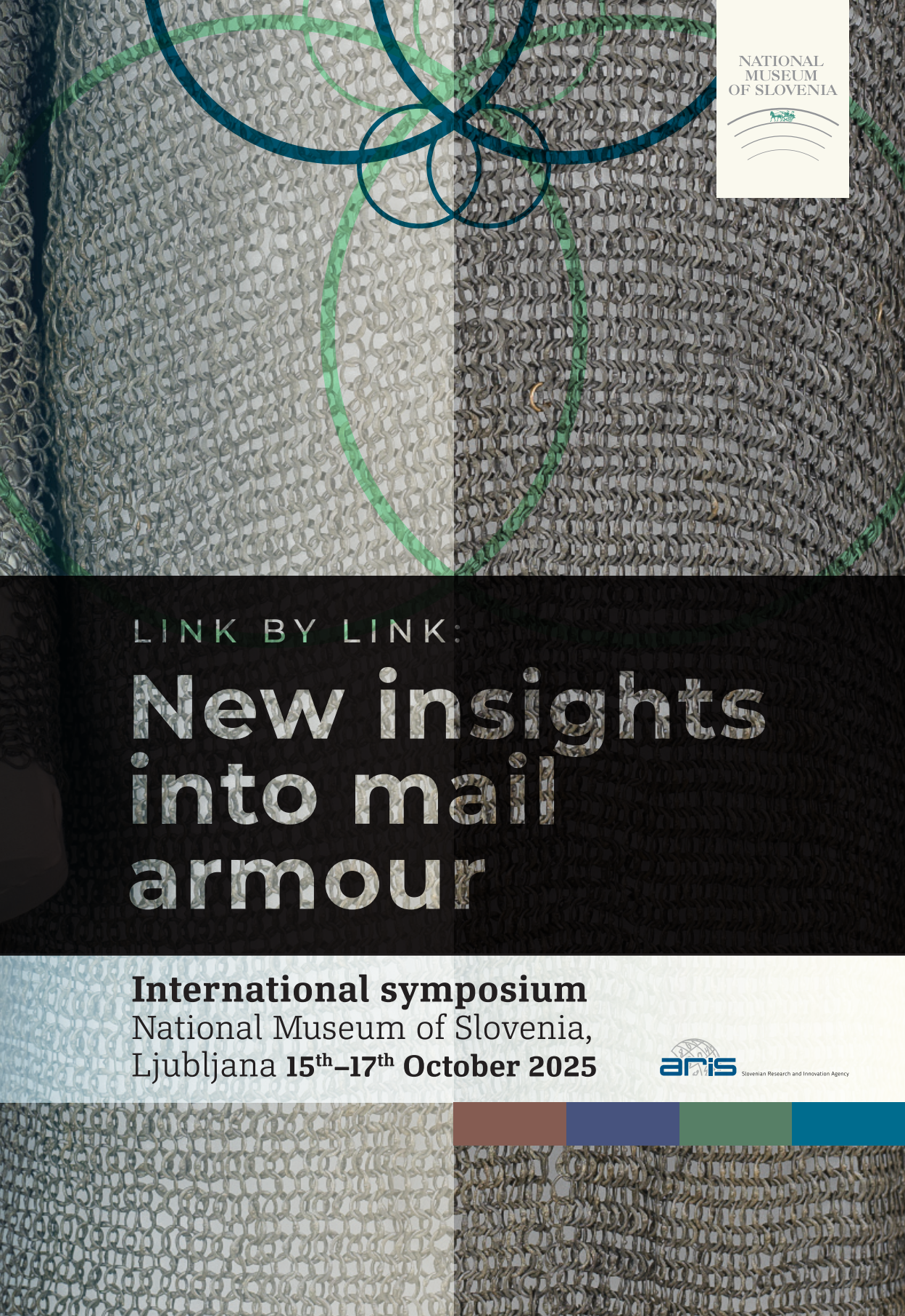




NATIONAL
MUSEUM
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LINK BY LINK:

New insights into mail armour

International symposium
National Museum of Slovenia,
Ljubljana **15th–17th October 2025**



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Slovenian Research and Innovation Agency

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New insights into mail armour

International symposium

National Museum of Slovenia,
Ljubljana **15th-17th October 2025**

The invention of mail armour ranks among the more fascinating achievements of Iron Age technology. Combining the rigid strength of metal with the seemingly incompatible suppleness of woven fabric, the concept of a protective garment composed of interlocking rings has truly stood the test of time. Since its adoption by Celtic warriors and Roman legions, mail became the primary form of metal armour worn in Europe for almost two millennia. In various, sometimes quite distinct, forms, its use would spread throughout Africa and Asia, as far as the Indian subcontinent and Japan. Though eventually made obsolete by the advances of early modern warfare, the unique properties of mail have ensured its survival in niche applications to the present day.

In contrast with other, perhaps aesthetically more attractive, types of armour, the study of mail defences was long neglected by scholars. Even the knowledge of their origins and manufacture became lost to obscurity. During the 1950s, many of these omissions were addressed by the work of E. M. Burgess and his contemporaries, whose pioneering efforts have been continuously revised and improved upon by later generations following in their footsteps. Even so, the study of mail armour remains a rather under-reported field.

Due to a major surge of renewed interest and activity in recent years, the time seems right to bring together fellow mail armour scholars and enthusiasts interested in sharing the results of their work. In the spirit of friendly discussion and an exciting exchange of information, you are warmly invited to the mail armour symposium hosted by the National Museum of Slovenia in Ljubljana between 15th and 17th October 2025.

Yours sincerely,

The organising committee:



Tomaž Lazar, PhD,
Curator of arms & armour,
Symposium chair



Nataša Nemeček, MA,
Senior metalwork conservator-restorer



Eva Menart, PhD,
Head of Department of Conservation
and Restoration

**Mednarodni simpozij
o raziskavah verižnega
oklepa** / Narodni muzej
Slovenije – Metelkova,
Ljubljana / **15.–17. oktober 2025**

Verižni oklep se uvršča med zanimivejše dosežke železnodobne tehnologije. Njegova zasnova iz prepletenih žičnih obročkov v sebi združuje na prvi pogled izključujoče se lastnosti – togo trdnost kovine in gibkost tkanine.

Vse od tedaj, ko so verižnino posvojili keltski bojevniki in rimske legije, se je v Evropi skoraj dve tisočletji obdržala kot najpomembnejša zvrst kovinskega oklepa. V različnih, včasih zelo samosvojih izpeljankah se je razširila v Afriko in Azijo, do Indijske podceline in Japonske. Čeprav je ob razvoju vojskovanja v zgodnjem novem veku postopno doživela zaton, jo zaradi enkratne kombinacije lastnosti v nekaterih nišnih aplikacijah uporabljamo še danes.

V nasprotju z drugimi, estetsko morda privlačnejšimi vrstami oklepov raziskovalci verižnini zelo dolgo niso posvečali skoraj nobene pozornosti. V pozabo je utonilo celo védenje o njenem izvoru in izdelavi. To praznino so v petdesetih letih 20. stoletja zapolnile raziskave britanskega izvedenca E. M. Burgessa in njegovih sodobnikov, njihovo pionirsko delo pa odtlej nadaljujejo in nadgrajujejo mlajši rodovi.

Kljub temu proučevanje verižnega oklepa ostaja izrazito zapostavljeno področje orožjeslovja. Zaradi vse živahnejšega zanimanja za to tematiko in tudi vrste pomembnih novih spoznanj v zadnjih letih



pa je vendarle napočil čas za organizacijo posveta, na katerem bodo svoje izsledke lahko predstavili raziskovalci in ljubitelji verižnine. V duhu prijateljske razprave in zanimive izmenjave znanja vas zato prisrčno vabimo na simpozij v Narodnem muzeju Slovenije, organiziran med 15. in 17. oktobrom 2025.

Dogodek, izveden s finančno podporo Javne agencije za znanstvenoraziskovalno in inovacijsko dejavnost Republike Slovenije, bo potekal v novi stavbi Narodnega muzeja Slovenije na Metelkovi – zaradi mednarodne udeležbe sicer v angleškem jeziku, odprt pa bo tudi za javnost.

Pripravljalni odbor:



dr. Tomaž Lazar,
kustos zbirke orožja in bojne opreme,
predsedujoči



mag. Nataša Nemeček,
konservatorsko-restavratorska
svetovalka



dr. Eva Menart,
vodja Oddelka za konserviranje
in restavriranje



NARODNI
MUZEJ
SLOVENIJE



Javna agencija za znanstvenoraziskovalno
in inovacijsko dejavnost Republike Slovenije

DAY 1

WEDNESDAY,
OCTOBER

15th

13:00-14:00	Registration		
14:00-14:15	Opening address		
14:15-15:00	Keynote address	Alan Williams	Investigating the joining of mail by complementary techniques – metallography and neutron imaging

SESSION 1 Between the Alps and the Adriatic

15:00-15:25		Tomaž Lazar	Mail in the Slovenian territory between the Middle Ages and the early Modern Period
15:25-15:50		Tomaž Nabergoj	Material remains of mail defences in Slovenia
15:50-16:15		Janka Istenič, Lidija Korat Bensa	Mail armour from Neviodunum (Drnovo near Krško, SE Slovenia)
16:15-16:40		Leon Bošnjak	Mail armour in the Croatian History Museum
16:45-17:30	Guided tour	NMS Metelkova – Arms & armour collection	
17:30-19:00	Buffet dinner		

DAY 2

THURSDAY,
OCTOBER

16th

SESSION 2 Between the Baltic and the Black Sea			
9:00-9:25		Arkadiusz Michalak	Between rings and realms. Technology and use of medieval mail in the borderland of Silesia, Brandenburg, Greater Poland and Lusatia
9:25-9:50		Piotr Kotowicz	'Lorice antique zerdzeviale'. Notes on the mail armour in Red Ruthenia region
9:50-10:15		Valeri Yotov	About the leg mail armour of skeleton No. 3 in grave 80 of Kyulevcha necropolis
10:20-10:40	Coffee break		
SESSION 3 Investigative approaches			
10:40-11:05		David Nicolle	Mail in medieval India
11:05-11:30		Marco Faccio	Mail armour in the Marzoli Museum in Brescia. Presentation and brief insights
11:30-11:55		Mark D. Chapman	Mail: Evaluation of techniques of manufacture vs. historical examples
12:00-13:00	Lunch		
SESSION 4 Construction and manufacture			
13:00-13:25		David Edge	Investigating solid mail links
13:25-13:50		Martijn A. Wijnhoven	Repair and recycling on the Roman frontier. Insights from the Bonn hoard of mail armour
13:50-14:10		Sebastian Völk	Counting in tens. The mail hauberk from Berane
14:10-14:20		Sebastian Völk	Mail armour terminology
14:25-14:40	Coffee break		

DAY 2

THURSDAY,
OCTOBER

16th

Keynote
address

SESSION 5 Conservation and restoration

14:40-15:05		Phil Parkes	The role of conservation ethics and decision-making in the care of mail armour
15:05-15:30		Nataša Nemeček	Historical approaches to conservation and restoration of armour in the National Museum of Slovenia
15.30-15.45		Lea Legan, Klara Retko, Polonca Ropret, Eva Menart	Analytical evidence of multiphase conservation treatments on mail armour from the National Museum of Slovenia
15:45-16:10		Zala Uršič	Documentation and conservation-restoration challenges in the case of mail defences in the National Museum of Slovenia
16:15-17:00	Stroll through the historical city centre towards the old museum palace		
17:00-18:00	Guided tour	NMS – Old Museum Palace, archaeological collections	

DAY3

FRIDAY,
OCTOBER

17th

9:00-18:00	Bus tour to Celje and Ptuj		
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Alan Williams

Wolfson School of Engineering, Loughborough University
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David Edge

Armourer Emeritus, Wallace Collection, London

Simon Metcalf

King's Armourer, Windsor Conservation Centre

Francesco Grazzi

Professor of Physics, IFAC, Sesto Fiorentino

Nikolai Kardjilov

Institut Laue Langevin, Grenoble

Anna Federigo

Institut Laue Langevin, Grenoble

Investigating the joining of mail by complementary techniques – metallography and neutron imaging

There has been much debate about the mass production of mail during the Roman Empire, Middle Ages and early Modern Period, with special attention to the questions of forming and then joining links rapidly, when heat treatment may have been involved.

The principal scientific technique employed to date to study the manufacture of mail has been metallography; that is the microscopic examination of prepared sections – a most informative technique, but micro-invasive.

Recently, however, neutron imaging techniques have been developed, which, being entirely non-invasive, are particularly suitable for cultural heritage science.

MAIL IN THE SLOVENIAN TERRITORY BETWEEN THE MIDDLE AGES AND THE EARLY MODERN PERIOD

Situated on the political periphery of medieval and early modern Europe, the Slovenian territory illustrates a rather complex reality of military technological transfer. Apart from the Adriatic coastline, dominated by the Republic of Venice and influenced by Italian fashions, its continental parts had adopted the South German military traditions and equipment, though with increasingly widespread acceptance of the Hungarian-style light cavalry. In the absence of significant domestic production capabilities, the supply of arms and armour largely depended on imports – in some cases from Lombardy and the Veneto, yet the majority coming from South German workshops that also set the standards followed by the local elites and professional soldiers.

Much like elsewhere across Europe, mail represented the primary means of defence throughout the medieval period. The long mail hauberk seems to have served as a universal torso defence until the turn of the 14th century, usually complemented by a coif perhaps more commonly worn separately rather than joined to the hauberk itself. Heavily armed men-at-arms would complement it with chausses and mittens, again sometimes integral but just as often designed as stand-alone items.

Archaeological finds from the period are consistent with typical Western mail, characterised by a combination of fairly large whole and riveted links. There is little doubt that a significant quantity of mail used during the late 13th and well into the 15th century must have been procured from North Italy as attested to by the documented arms

purchases of the Counts of Gorizia (Görz) and other leading noble families from the Eastern Alps.

While the Eastern Alpine men-at-arms were quick to incorporate rigid limb defences, they were slower to embrace the coat-of-plates, presumably perceived as a cheaper alternative to the hauberk. Images of mail-clad knights continue to appear in Eastern Alpine artwork quite regularly throughout the first quarter of the 14th century, and the more complete transitional armour including rigid torso protection only seems to have been adopted en masse towards the middle of the 14th century.

Nevertheless, the shift was quite rapid. From the late 14th century, the artwork is dominated by images of mounted knights and footsoldiers in a more or less complete suit of armour. Until the middle of the 15th century, the latter was still commonly worn over a mail haubergeon, though increasingly combined with mail gussets and breeches as well as neck defences and sabatons, the latter perhaps a mark of Italian trends despite the overwhelming preference for German-style plate armour. Physical examples from this era consist almost exclusively of fully riveted mail with flattened links typical of Nuremberg or South Germany.

Even so, mail defences remained popular among more lightly armed troops, particularly 'hussar' cavalry that from the late 15th century onwards became the principal countermeasure against the newly emerging Ottoman threat. Their armament typically consisted of a long-sleeved mail shirt worn with a helmet, gauntlets, and sometimes a rigid or articulated (anime) cuirass. Ideally suited for the needs of fast-paced frontier warfare, its concept also inspired a gradual transformation of heavy cavalry during the later half of the 16th century, as fully armoured men-at-arms were largely replaced by mounted arquebusiers wearing a cuirass and a pair of mail sleeves, generally of fully riveted construction and with rings flattened only along the overlap.

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MATERIAL REMAINS OF MAIL DEFENCES IN SLOVENIA

Within the realm of personal protective equipment from the Middle Ages and the early Modern Period in the museum collections in Slovenia there are not many preserved examples of mail. This is due to two main reasons. First, there are almost no collections of arms and armour from the last two centuries, either in private possession nor in public museums, where such pieces could have been preserved. One notable exception is the National Museum of Slovenia where the majority of mail armour is kept, the most complete and very well preserved specimen being a 15th century German mail shirt acquired from the Baron Hans Kometer's collection at the Pukštajn Manor (north-eastern Slovenia) in 1935. Some mail sleeves and fragments of mail armour complete the museum collection. Many objects of historic armour and arms must have been sold and taken out of the land, lost, or destroyed in the upheavels of the 19th and 20th centuries. This regards especially World Wars one and two, nationalization of castles and their collections, ideological biases towards nobility from the past, and consequent neglect of medieval and modern era military legacy from the Slovenian territory.

On the other hand, there have been almost no systematic archaeological explorations of sites which could have yielded remnants of mail, like castles and other fortifications, not to speak about battlefields. The lack of investigations of such sites is a consequence of the late development of systematic archaeological research devoted to the epochs after the early Middle Ages, and of a low interest of scholars dealing with the Medieval and early modern periods in military history as well as arms and armour specifically. There are a few mail fragments in museum collections which have been found by metal detectorists.

The preserved objects are nevertheless interesting from the typo-chronological and technological aspects of their manufacture. Several analyses have been made from the archaeometalurgical point of view, as well as efforts to reconstruct accurately the making of riveted mail. The specimens of mail in Slovenian museum collections shed light on some historical aspects of its production, supply and use in the territory of Slovenia, at the crossroads of geographic regions, political and military spheres and fashion trends.

MAIL ARMOUR FROM NEVIODUNUM (DRNOVO NEAR KRŠKO, SE SLOVENIA)

Among the artefacts from the Roman town of Neviodunum (modern-day Drnovo near Krško in SE Slovenia) are a lump of corroded iron mail or a large part of it, and a small piece of another iron mail. In the talk, we will present and discuss the characteristics of both mail finds, as revealed through macroscopic examination, inspection under optical microscope, and X-ray computed microtomography (micro XCT). Particular attention will be given to the diagnostic features relevant for the dating of the mail.

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MAIL ARMOUR IN THE CROATIAN HISTORY MUSEUM

The Croatian History Museum houses a relatively small collection of mail armour, which includes well-preserved shirts as well as fragments of both European and Asian origin. Notably, several of these pieces were among the earliest entries in the Museum's inventory books. Despite their significance, many items have received limited curatorial attention. Recent restoration, completed in 2024, has allowed for a detailed examination of most of these mail pieces for the first time. One especially notable item is a mail shirt recently (re)discovered in the Museum's depot. All mail artefacts have been systematically re-evaluated with the aim of providing as accurate as possible classification in preparation for the Museum's first permanent exhibition. Given the absence of documented archaeological contexts and, in some cases, unknown provenance, comparative analysis with published extant examples has been essential in this effort. The current level of classification together with the configuration and defining features of the collection's most interesting mail pieces will be presented with the aim of providing enough data to encourage discussion and further research on these pieces.

Between the Baltic and the Black sea

BETWEEN RINGS AND REALMS. TECHNOLOGY AND USE OF MEDIEVAL MAIL IN THE BORDERLAND OF SILESIA, BRANDENBURG, GREATER POLAND AND LUSATIA

This lecture will explore the evolution, application, and gradual decline of mail in the borderland of Silesia, Greater Poland, Brandenburg and Lusatia, from the 12th to the 15th century. Drawing on both iconographic and archaeological evidence, it will demonstrate the shifting role of mail in medieval military equipment under increasing pressure from advancing weaponry, such as crossbows. Despite its proven vulnerabilities, mail retained a crucial protective function well into the late Middle Ages, often used in conjunction with textile gambesons and later with plate reinforcements, such as brigandines and cuirasses.

Iconographic sources, including effigies and altar panels, confirm the widespread use of complete mail shirts and accessories – coifs, collars, sleeves, and armpit guards – well into the 15th century. Detailed descriptions of knightly effigies, such as that of Prince Henry IV of Żagań, provide insights into the integration of mail with emerging plate elements, and the adaptation of mail to new tactical needs, including its use as a connector between rigid armour components.

Archaeological evidence further substantiates these observations. Nineteen examples of mail recovered from Krosno Odrzańskie, Międzyrzecz, Santok and Żagań reveal diverse manufacturing techniques – riveting, welding, and punching – and a broad range of ring sizes and construction methods. Notably, the Międzyrzecz castle yielded fragments from five chronological phases (from

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1269 to the end of 15th century), mirroring the historical trajectory of mail armor use: from its dominance to its relegation as supplementary protection. These finds align with broader Western European trends in mail technology and usage.

The data presented enhances our understanding of regional military practices and technological transitions in armour development, emphasising not only the resilience of mail as a functional defence over centuries but also its dynamic adaptation in the face of evolving threats and materials. The study contributes to the growing body of knowledge on transitional armour and the interplay between archaeological material culture and martial iconography in medieval Europe.

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'LORICE ANTIQUE ZERDZEVIALE'. NOTES ON THE MAIL ARMOUR IN RED RUTHENIA REGION

The paper focuses on presenting the problem of mail armour in the territory of medieval Red Ruthenia, the southeasternmost part of the Polish Kingdom, formed after 1340. Information about this type of armour is known primarily from written sources, mainly documents regarding the military duties of local nobility, mayors, and village heads. There are also mentions of the L'viv makers of such defences and their prices. Unfortunately, the archaeological base for the existence of mail from this territory is very modest. We know almost nothing about the mail recovered from the Styr River (Ukraine), which is broadly dated to the 15th and 16th centuries. The only find confidently dated to the second half of the 14th century is

a fragment discovered during excavations of the Market Square in Krosno (Poland). This source base is supplemented by a presentation of iconography, connected with both Latin and Orthodox circles, where we have the representation not only of hauberks but also other parts of mail armour, such as collars, mail breeches or chausses.

ABOUT THE LEG MAIL ARMOR OF SKELETON No. 3 IN GRAVE 80 OF KYULEVCHA NECROPOLIS

Of the dozens of studied Proto-Bulgarian pagan necropolises and single graves from the time of the First Bulgarian Kingdom, there are relatively few cases of deposited weapons and equipment. The offensive weapon is represented by a total of 12–15 sabers, battle axes and spears. The equipment of the horse and rider is represented by the same number of stirrups, spurs and bridles. The least numerous are the defensive weapons, consisting of single plates of armour.

Against this background, one find, at skeleton No. 3 in mass grave 80 of the Kyulevcha necropolis (not far from the first capital Pliska), is an exception. It represents a tight weave of iron rings that covers the upper part of the sole of the left foot to the ankle of a male individual.

Two main hypotheses have been advanced to explain the mass graves (only two cases in total) in Proto-Bulgarian pagan necropolises. In the case of the circular structure in the Devnya 3 necropolis, not discussed further in the present paper, women and children were beheaded and buried in connection with the dramatic events surrounding the conversion of the Bulgarians after 866.

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The second case concerns the mass grave in the Kyulevcha necropolis, directly relevant to our discussion. In a pit about 10 m long and at a shallow depth, the skeletons of 25 young men (most of them in a distorted anatomical order) were placed and the hypothesis is that they were killed during the invasion of the summer of 811 by the Byzantine emperor Nikephoros I Genicus north of the Balkan Mountains before the capture of the capital of the Khanate of Pliska.

This hypothesis is very likely and is supported by what was also studied in this necropolis: the grave of a warrior with a horse; two spurs (not typical of nomadic horsemen); details of a warrior's belt, etc.

Investigative approaches

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MAIL IN MEDIEVAL INDIA

Mail armour was certainly used in medieval India and had also been widely used by those who influenced Indian military technology before the Islamic invasions of the 9th to 15th centuries CE. Furthermore, there are reasons to believe that Sassanian armour styles and technologies had a significant impact within the north-western provinces of the Indian subcontinent. Whether this extended further south and east, and to what degree, remains problematical. Thereafter mail became increasingly important across much of the Indian subcontinent during

the medieval period, largely as a result of Islamic military pressure, cultural influences and trading links.

A widespread belief that, while only light armour was used in India during the early medieval centuries, Indian armour later became heavier – along with an increased use of mail – appears to be justified. In a clear attempt to combine the flexibility of mail with the anti-penetration and shock-absorbing capabilities of plate armour, a new form known as mail-and-plate was developed within the eastern Islamic lands during the latter part of the medieval period. This style would become very popular throughout India among both Islamic and non-Islamic forces, presumably because it was relatively light and could even be described as well ventilated.

Archaeological and Textual Evidence

Very little mail remains from this period within the Islamic Middle East and eastern regions and none, as far as I am aware, have been found within a medieval Indian context. Meanwhile, those ancient and early Indian texts which refer to armour rarely offer much detail. In contrast, eastern Islamic and Indo-Islamic written sources are easier to interpret. For example, the specifically Indian *loha-jāl* and *loha-jālikā*, literally meaning 'iron net' or 'little iron net', was a form of armour probably of mail rather than scale or lamellar construction. The term *kavaca* or *kavacha* was more commonly and perhaps more broadly used, but the contexts could indicate a lamellar, scale or mail construction. Nevertheless, this armour's vulnerability to arrows might indicate mail rather than scale or lamellar.

Pictorial evidence

Representations of arms and armour in ancient and medieval Indian art are notoriously difficult, and sometimes impossible, to interpret with confidence. With rare exceptions, the question of whether any such materials were mail or mail-lined remains a matter of interpreta-

tion. One exception is a superb 7th or 8th century CE wall painting of magnificently attired military figures from a Buddhist monastery in Funduqistan in Afghanistan which includes a faithful illustration of a perhaps sleeveless mail shirt. Similarly, the battles on 11th–12th century CE wall paintings in the cave temple at Ellora include several warriors almost certainly wearing mail armour.

Mail can also be found, though very rarely, in later medieval temple, and other, carvings from central and southern India from the 13th century CE onwards.

Things get considerably easier where later medieval Indian manuscripts are concerned, even though the dating of several late medieval or very early modern Indian manuscripts remains a matter of debate. What is obvious is a strengthening of both artistic and technological influence from the Islamic World. This is accompanied by increasingly clear illustrations of mail armour. Nevertheless, persistent differences in the style of such mail, mail-and-plate, and mail-lined soft armours also highlight the persistence of earlier Indian technological and military traditions.

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MAIL ARMOUR IN THE MARZOLI MUSEUM IN BRESCIA. PRESENTA- TION AND BRIEF INSIGHTS

Between 2024 and 2025, I conducted a systematic and entirely new study of the mail armour collection preserved at the Museo Marzoli in Brescia, with the authorization and valuable support of the curator, Dr. Merlo. This research resulted in the first comprehensive photographic

survey of the collection and in the identification of almost all the pieces, with only four or five items temporarily excluded, pending further analysis. The project included detailed photographs of each artefact, displayed on a mannequin to highlight structural features, precise measurements, and a preliminary examination of their main characteristics. This approach provided an unprecedented overview of the collection, revealing several items of significant typological interest, worthy of scholarly attention and intended for inclusion in the next official catalogue of the Museo Marzoli.

The work was carried out both on-site and off-site, requiring numerous full-time days of activity. Approximately forty mail pieces were examined, coming from the museum's storage and from the permanent exhibition, often concealed beneath plate armour that were dismantled and subsequently reassembled. The data collected was compared with iconographic documentation and digital records from public and private collections worldwide, in order to refine the identification of various artefacts. For each piece, a dedicated descriptive record was produced, the outcome of a process that further developed my specialist expertise in the field, with the aim of achieving a consistent and reliable classification.

The identification method applied required the full extent of my current knowledge and skills, while also raising new questions and encouraging the formulation of hypotheses and interpretative lines still under investigation. Although this presentation will not include a full description of the methodology – which will instead be detailed in the complete study catalogue currently in preparation – the process has provided a solid foundation for future scholarly discussion... I hope. No metallurgical analyses were performed on the pieces studied, at the moment.

The analysis made it possible to examine in their entirety several items of mail armour that had long remained hidden from view, originating from a variety of geographical

areas and chronological contexts. Notable examples include two bishop's mantles virtually identical to others preserved in major international institutions such as the Wallace Collection, the Saint Louis Art Museum, and the Burrell Collection, suggesting a form of serial production for a specific patron. Two shirts of mail can be plausibly attributed, on the basis of manufacturing characteristics, to the 14th century, along with other examples of exceptional workmanship, clearly indicating high production quality and significant manufacturing costs. Particularly noteworthy is a mail piece of probable Italian manufacture which, although requiring further confirmation, could represent a rare late-15th-century mail skirt (*gonnella*), and thus merits further study.

The historical catalogue records preserved in the museum archives, compiled several decades ago, offer only brief and nearly useless descriptions, with imprecise dating, and are therefore inadequate for rigorous scholarly analysis. The new survey, supported by updated photographic and descriptive documentation, seeks to fill this gap by providing a reliable tool for both the preservation and dissemination of the collection.

The presentation prepared for the National Museum of Slovenia symposium will offer a visual overview of the items studied at the Museo Marzoli, accompanied by brief in-depth analyses of the most significant items. The aim is to share the findings of this investigation, allowing the research community to have access to new museum references to compare and study.

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MAIL: EVALUATION OF TECHNIQUES OF MANUFACTURE VS. HISTORICAL EXAMPLES

For more than a thousand years mail was produced in volume across Europe, the Middle East and India, yet no documentation exists of the actual process steps involved. The only period woodcut illustrations are of the final assembly step yielding no clues to the precursor steps and few to the final assembly process. From these woodcuts it appears that a hammer, small anvil, and tongs were involved in the final garment assembly, but little else is shown. As an example, simple reverse engineering of the flattened mail links can identify necessary steps in the process; wire drawing, coiling the wire, cutting links free from the coil, flattening the links, overlapping, flattening the overlap, piercing and finally clenching the rivet/shaping the overlap area.

The key steps in the process that determine the final form are; the cutting of individual links from the coil, flattening or not flattening the link wire, the piercing of the overlap region and then the clenching and forming of the overlap region. A forensic examination of existing mail links in comparison to proposed manufacture techniques can yield confirmation or denial of proposed methods and tools used in the process. Tool marks present on the mail also provide clues to the tools involved and how much wear is present post-manufacture.

Proposed tools, manufactured via techniques appropriate to the 12th to 15th centuries will be presented. Concentration will be on wedge riveted mail. An evaluation of the mail links made with these tools will compare link to link consistency as well as the degree to which they duplicate the form and manufacturing artifacts of historical European mail. It should be noted that methods of reproduction are

extremely sensitive to wire size and require significant fine adjustment to produce the desired result. New insight into a possible more practical tool approach will also be presented.

Modern reproduction mail is typically made from mild steel wire. In this study, conclusion from the mild steel link manufacture are also checked against reproduction mail made from pre-17th century charcoal forged wrought iron hand drawn into wire to confirm that conclusions are not biased by the use of modern materials.

Each process step is examined to determine: 1) is it necessary? 2) is the tool used appropriate to the medieval period? 3) do resulting microcharacteristics that continue in to the finished link match existing historical mail? 4) if there are alternate tools that can do the job, was each used in period, and can we distinguish which was actually used?

Finally, the key step for the final shape of the overlap region is believed to be set by a die process involving the setting tongs used. Experiment has shown that the final result is extremely sensitive to wire size vs. the size of the wells in the clenching tongs. This sensitivity appears to be at the sub 0.2 mm level. The medieval craftsman could not afford to make multiple tongs until one turned out correct. Thus, methods of manufacture and adjustment are key factors in determining how this key tool was manufactured and fitted to a particular wire size link.

Finally, two resulting patches of reproduction mail will be compared: one fresh from manufacture and one that has been subjected to weeks of tumbling in a rock tumbler with grit to simulate wear. They will be compared to see what this can tell us about the blurring of initial manufacturer characteristics.

Construction and manufacture

INVESTIGATING SOLID MAIL LINKS

Traditional metallographic analysis of individual solid (as opposed to riveted) links of mail has been able to shed some light on the methods of their production. Modern 'non-invasive' techniques such as neutron diffraction are increasingly being used to augment this research, although the results may not necessarily be as useful as hoped. The creation of a broader database of analysed specimens, now in the process of assembly, should help to improve our knowledge of how solid links of mail were made.

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REPAIR AND RECYCLING ON THE ROMAN FRONTIER. INSIGHTS FROM THE BONN HOARD OF MAIL ARMOUR

The Bonn hoard, a remarkable find in Germany, offers valuable insights into the resource management practices of the Roman military along its northern frontier. This study explores the intersection of recycling, repair, and urban connections in the Roman military economy. The hoard, consisting of over 14 kg of mail armour, reveals how the Roman army's self-reliance in equipment production led to efficient recycling strategies. The paper investigates the motivations behind the deposition, shedding light on a likely stockpile of mail repair materials in a Roman *vicus*. This discovery underscores the complexity of resource management within the Roman military and its urban surroundings.

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COUNTING IN TENS. THE MAIL HAUBERK FROM BERANE

This explores arguably the only surviving example of a mail hauberk with an integrated coif, shedding light on its construction, origin, and historical context. The mail coat was discovered by locals in the 1930s near Berane, Montenegro. Its precise find location and its archaeological context are uncertain, yet its condition is remarkably well preserved, given the uniqueness of the object and the circumstances. Before this investigation, it was hypothesised that it may represent a European hauberk from the 11th to the 13th centuries. Examination of the coat, notably its design and adherence to the decimal system, suggests a non-European origin, likely Ottoman, dating back to the second half of the 15th century.

In order to understand and preserve the object, the missing rings were systematically filled in with look-alike, but distinguishable, replacement rings. The now-reconstructed shape gives hints to how its makers practically approached the making of the armour and who they were. This involves demonstrating new methods of using pattern transitions and orientation of the rings to backtrace the assembly of the garment, including the reconstruction of missing areas. There are so far unseen functional considerations in the garment's design, like the skewed placement of the coif for left-facing fighting styles, such as the Parthian shot manoeuvre. This study also introduces a novel perspective on the connection between numeral systems and mail garment construction, offering insights for broader applications in material culture research.

MAIL ARMOUR TERMINOLOGY

The topic of mail armour was long neglected by scholars – overall, yet especially regarding its manufacture and other practical aspects. With the recent renaissance of the lost craft of mail-making and shaping it becomes more and more obvious that a consistent and standardised terminology for mail armour is lacking. There are a handful of phenomena and points of interest unique to mail armour that no neighboring fields of research, such as textiles or plate armour, can cover. Hence, such terminology is required for further facilitating the exploration and highlighting the particularities of this craft. The mail armour symposium *Link by link* in Ljubljana is the first international convention of experts in the field of its kind and provides a perfect opportunity to establish and agree on such a vocabulary.

A collection of phenomena is presented including weave patterns, deviations from weave patterns as well as the orientation of the patterns in relation to other sections of weave and/or the garment. Furthermore, a variety of seams and the assembly of garments from sections is brought to public awareness. As far as the time-frame allows, the shape of individual rings is also covered. All is done with the intention to find common words useful for describing the nature of mail armour. To this end, a collection of photos is prepared for the symposium as well as a list of terms already in use. These terms, sometimes in conflict with each other, need to be evaluated regarding their practicability and current spread of usage. In many ways, new terms will be presented by the speaker or need to be found through interaction with the audience. The outcome of that will be documented in an article about the symposium by Sebastian Völk.

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THE ROLE OF CONSERVATION ETHICS AND DECISION MAKING IN THE CARE OF MAIL ARMOUR

Mail armour has been used and repaired both during its active lifetime and subsequent role in collections and displays. This presentation will look at conservation ethical frameworks and the decision-making process around the repair and conservation of mail armour. The use of careful study and object significance statements will be considered and their use in practice illustrated with case studies. There is no 'right way' of carrying out conservation on many objects and the use of an informed decision-making process and thorough documentation is essential for the preservation of armour without compromising future study and care.

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HISTORICAL APPROACHES TO CONSERVATION AND RESTORATION OF ARMOUR IN THE NATIONAL MUSEUM OF SLOVENIA

The conservation-restoration profession in Slovenia has its roots in the early days of the Provincial Museum of Carniola in the 19th century. This tradition has been an integral part of the activities of its successor institutions ever since. Today, the National Museum of Slovenia continues this legacy through its Department of Conservation and Restoration, which is the largest museum conservation-resto-

ration department in the country. The department employs eleven specialists, each focusing on specific areas that are generally divided into archaeological and cultural-historical materials.

The restoration of arms and armour in Slovenia is a relatively new field within conservation-restoration. According to departmental records, systematic work began in the 1962 when Ferdinand Tancik was hired as a conservator, then referred to as a preparator. This field first gained prominence when numerous historical weapons were restored for a new permanent exhibition at Bled castle in 1967 and later for the 1971 exhibition under Tancik's supervision titled *Arms and Armour from the Settlement of Slovenians to the End of the 17th Century*, which showcased the evolution of military technology. Following his graduation with degrees in history and art history, Tancik became the National Museum's first curator specializing in arms and armour. Unfortunately, his professional career was tragically cut short by his untimely death in 1973.

According to the sparse descriptions from the department's documentation in March 1963, we assume that the mail shirt currently on permanent display at Metelkova, along with three mail sleeves, had been restored during preparations for the exhibition of the National Museum at Bled Castle. During the 1960s, standard conservation-restoration methods included electrolytic cleaning, and the use of strong acids prevailed.

Due to inadequate working conditions, arms and armour restorers were frequently replaced. Until the 1990s, the museum lacked a specialist in this field. In 1994, a new restorer specializing in arms and armour was hired, trained as a mechanical engineer. Since the museum lacked experience in this area, the head of the department decided that the new restorer should gain practical knowledge through education abroad. As a result, the restorer completed a three-month training course at the Wallace Col-

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lection in 1995. This period marked a shift in conservation-restoration methods. Instead of relying on electrolysis, the focus shifted to the use of acids and mechanical cleaning techniques.

The symposium *Link by link: New insights into mail armour* now serves as an opportunity to analyse the state of past interventions, assess their suitability, and explore more effective procedures for the future conservation-restoration of arms and armour in the National Museum of Slovenia.

ANALYTICAL EVIDENCE OF MULTIPHASE CONSERVATION TREATMENTS ON MAIL ARMOUR FROM THE NATIONAL MUSEUM OF SLOVENIA

Mail armour, composed of interlinked iron rings, represents one of the most widespread forms of personal protection in Europe from antiquity to the early modern period. The subject of this study were three mail sleeves (inv. nos. N 35370, N 35372, N 4584) from the collection of the National Museum of Slovenia, which were preliminarily analysed by X-ray fluorescence spectrometry (XRF). XRF analyses revealed substantial amounts of phosphorus and zinc on the iron surface, indicative of zinc phosphate conversion coating. The objects were further investigated by means of Fourier-transform infrared (FTIR) and Raman spectroscopy. The analyses revealed a complex sequence of conservation treatments carried out during the 20th century, reflected in both inorganic and organic surface residues.

Detected components include wax coatings, hydrated zinc phosphate (hopeite, $\text{Zn}_3(\text{PO}_4)_2 \cdot 4\text{H}_2\text{O}$) indicative of chemical passivation, modern synthetic polymers (acrylic copolymers, epoxy resin), tannins forming iron-polyphenol com-

plexes, and proteinaceous residues from older adhesive applications. Iron oxides additionally record the corrosion history of the objects.

The combination of traditional protective materials with modern consolidants illustrates the development of conservation practice from the mid-20th century onwards. These findings provide new insight into the conservation history of mail armour and contribute to the understanding of the long-term stability and impact of different treatment strategies.

DOCUMENTATION AND CONSERVATION-RESTORATION CHALLENGES IN THE CASE OF MAIL DEFENCES IN THE NATIONAL MUSEUM OF SLOVENIA

The arms and armour collection of the National Museum of Slovenia contains several pieces of mail armour that have been subject to conservation-restoration treatment multiple times in the past, primarily for the needs of various exhibitions or catalogues. However, after occasional attention from curators and conservators, the individual pieces were returned to the depot, where they were stored in a disorganised and inappropriate manner in various boxes and improvised supports. Without consideration of the problem of storage and presentation, they once again waited for the next opportunity to see the light of day.

Such an opportunity presented itself in the spring of 2025, when we began preparations for the October symposium on mail armour. Upon arrival in the conservation workshop, the mail fragments were temporarily stored in a

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cardboard box, individually wrapped in bubble wrap and paper. Improper storage had worsened the already rather poor general condition of the fragments, and constant friction during transportation and handling caused damaged rings to fall off. The upcoming symposium presented an opportunity for a comprehensive and in-depth conservation-restoration treatment of the mail inventory; our goals were to produce clear graphic documentation, research the method of tailoring and construction of individual pieces, review and evaluate past conservation-restoration interventions, present the fragments to the professional audience at the symposium, and resolve the issue of damage repair and long-term storage.

