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1. Roman shipbuilding

1.1. Roman seafaring

When the Romans began to build ships on behalf of the state during the First Punic War, the states and peoples around the Mediterranean had long been building with the Mediterranean boat-building types that were still common in Roman imperial times.

When the Romans had previously gone to sea, according to Polybios, they made use of the ships of the confederates – for example when crossing the straits from Italy to Sicily.

The rise of Rome as a world power, though, is synonymous with the possibility of the rising power also assert itself on water. This was achieved in the First Punic War by copying the stranded Punic ships (but certainly also with purchased boat-building know-how). Here, in particular, the Carthaginian tongue and groove construction method was copied, which was certainly not invented by the Carthaginians (contrary to ancient statements).

It is characteristic, that the Roman as well as the Carthaginian boat-building tradition was completely in the lines of the Greek-Hellenistic seafare tradition. This had long since left behind the sole ramming purpose of the trireme and had moved on to the tetreres and penteres (etc.), in which several oarsmen operated one oar. Long-range weapons were mounted on these larger ships, so that the use of warships had greatly expanded. While the warships were not designed for high seas, but rather for shipping close to the coast (according to Polybios' report, the Carthaginian fleet – since nautically superior – already had alternatives that were superior to the Roman ship units), the civilian ships, especially those intended for trade and transport, were equipped with high seas for long-distance trade. As a rule, however, ancient shipping was coastal shipping, also because of the lack of nautical means (compass, telescope). By the beginning of the 2nd century BC, Roman shipping was increasingly superior to its Hellenistic competitors, so that by the middle of the 2nd century at the latest one could speak of Roman maritime supremacy, which could also outstrip maritime trading cities such as Rhodes. At the same time, the regulations, for example, on the setting back of Rhodes after 168 BC, were not always to the advantage of maritime safety, for with the disappearance of the local maritime power, which also fulfilled a police function, the control over the coastal stretches, that were difficult to survey, no longer existed. Since then, piracy has flourished, which Pompey was only able to eliminate a century later (B. Dreyer 2007).

Area-wide control was therefore also difficult for Roman naval supremacy to achieve in the long term unless the mainland was also clearly under Roman control. This only happened with the political-military control of all countries around the Mediterranean after Octavian's victory over his rival at Actium. This naval "decision" is symptomatic of the epoch-making clash of two different principles of naval warfare. The defeated party of the Egyptian-Roman alliance fleet offered the last achievements of the Hellenistic naval warfare tradition, which consisted of heavy units with ten rows of oars and more. Victorious was the fleet under the leadership of Agrippa, which relied on the smaller, more mobile units (Liburnians), which had rows of oars of 2-4, max. 6 rows. These also made the running afterwards, after the victory of Augustus, after the elimination of any competition and because of the subsequent period of peace. Since then, the fleets were concentrated in large ports, for the east with the supreme command in Ravenna,

for the western Mediterranean in Misenum near Naples. Other subordinate stations, also on the Rhine and the Danube, controlled the inland rivers and lakes. With the political-military control of the entire Mediterranean area, the development of naval warfare came to its end. The fleet guaranteed the security of maritime trade, the transport of men and material and controlled the "wet" borders (Bockius 2007).

1.2. Roman shipbuilding traditions

The Romans absorbed and carried on the shipbuilding traditions of the Mediterranean. With the expansion of the Roman Empire, local traditions of the Mediterranean were adopted, but also those of Mesopotamia and the regions north of the Alps (Bockius 2007; Bockius 2013).

A distinction must be made between these and the construction methods documented in the areas east of the Rhine, for example at the Danish Nydam Moor (Bockius 2013a). Here, the clinker construction method is found, which will later be successful in the Viking boats. In contrast, the Mediterranean construction method is kraveel. The outer skin is smooth and the planks are butt-jointed.

There is much evidence for this. We focus on two of the boat types that are best preserved in the region north of the Alps, in Manching and in Mainz (Bockius 2002 and Bockius 2006). The older version clearly belongs to the Mediterranean building tradition. The find from Oberstimm near Manching on an old tributary of the Danube (Breitlach) belongs, dendrochronologically dated, to a period around 100 A.D. The boats were abandoned for an unknown reason and used to fortify the fort mole. Excavation work in the 1980s revealed the wrecks of the two boats, which were lifted in the 1990s and conserved in Mainz. A museum for the Celtic finds of the oppidum and the two Roman boats was then built in Manching on the site of the Celtic oppidum. The excavator was Hüssen, Höckmann was initially responsible for the boats. The scientific documentation was presented by R. Bockius in 2002. Important for our context is the construction according to the Mediterranean tongue and groove method. As after the finding from Oberstimm, Wrack II, currently in the Celtic-Roman Museum Manching, the boat was reconstructed in 2017/8 (FAN). Grooves were cut out every 30 cm and oak springs inserted. It is locked in place by oak pins driven into the sides, about 6 cm long. The planking was done with pine and the robust side bracing (ribs) and longitudinal stiffening was done with oak.

The archaeological evidence for the later type of boat, which is also the best preserved in Germany, is found in Mainz. During the laying of the foundation stone for a sales building (Hilton) near the banks of the Rhine, several boat wrecks came to light in the 1980s, some of which, especially Wrecks I and V according to the later census (in the Mainz Museum of ancient seafare), can be assigned to the late antique boat type Lusoria. The excavation was led by Olav Höckmann, who also made the first interpretations regarding an assumed original length. R. Bockius (2006) then undertook a revision and ultimately the most reliable and last publication for all the finds from Mainz. These ships were part of a Celtic-Roman building tradition. In contrast to the ship types of the older Roman period (the first and second centuries) in Oberstimm, which are clearly indebted to the Mediterranean building tradition; perhaps of the Adriatic (Bockius), the younger, Late Antique finds belong to a local building tradition. Local means, that these finds can be traced back to traditions that were known in the Celtic area long

before the Romans arrived. Roman rule made use of these local traditions – as in other parts of the empire – and, through the new possibilities for communication, also opened up opportunities for knowledge transfer.

The topic of transfer is currently the subject of much discussion in research, since it can be verified that similar craft methods were used along the long-distance trade routes of antiquity (Bockius in an upcoming article on the F.A.N. building and testing; Bockius 2009). At first glance, this is astonishing, since craftsmanship is usually very conservative and exclusive, i.e. it tends to be constant and then also locally reduced through the transfer from father to son, if only to be able to profitably use recipes for success (e.g. Zimmer 1982).

Thus, Caesar (BG 3,16) already made acquaintance with the Celtic shipbuilding tradition on the Channel coast during his conquests in Gaul (but perhaps it was a matter of inland watercraft). Even though he may have had to contend with misunderstandings (for example, with regard to leather sails; however, linen sails are also red, dyed like leather, if treated appropriately, and tents can also be made of leather, thus also withstanding the weather. Often no clear distinction can be made between sails and tent fabrics), he characterises the enemy boats in brief strokes in the same way as they would have to be destinguished centuries later in Roman times and according to the finds from Mainz. In contrast to the Roman counterparts, Caesar emphasised the robust construction, the manufacture from oak and the connection with iron nails. While his own Mediterranean ships were lighter and more nautical, the Celtic Venetians were convincing with their robust vehicles, which the Roman commander attributed to the harsher weather conditions.

Such observations are important evidence of an attitude towards foreign achievements, which is a prerequisite for the transfer of technology. And clearly, elements of Roman craft know-how also flow into the late antique Lusoria – while preserving the typical elements (Bockius 2013). Whereas in the early and middle imperial period Roman military obviously still drew their boat-building know-how from the Mediterranean (for in the rarest of cases ships will have been transported from the Mediterranean via the river systems to areas north of the Alps; rather, as can also be proved in Oberstimm via the analysed timbers, the ships were built locally: Bockius 2002), the late Roman army fell back on local building traditions in the same boat category, because the reference to skills was "closer" and because the construction method was easier. These boats were mass-produced and had to be manufactured quickly for the range of uses. For long distances upriver, people will have weighed up anyway, whether these distances were covered with muscle power (main form of propulsion: oars) alone, or associatively with sails or by towing, if new boats were not built immediately further upriver.

In contrast to the Roman counterparts, we do not have any fully preserved wrecks available in the case of the Lusoriae from Mainz (Bockius 2006, p. 16-53; 160-187). While wreck 5 was almost completely preserved at the time of the discovery and before the lifting, this finding was lost up to 8 m from the bow. In the reconstruction, we now have to consider two wrecks (I and V), each preserved to 8 m and thus almost completely together, from the stern (wreck I) and from the bow (wreck V). Nevertheless, this is a methodological problem, because even if they are contemporary and similar in construction, they are two different ships. Thus, because of these uncertainties, there has also been a heated discussion regarding the total length to be estimated.

While Höckmann, after various attempts, finally arrived at a length of 21.5 m (initially he too had arrived at a length of about 18 m), Bockius settled on a length of the two wrecks of no more than 18 m (Bockius 2013, p. 52-53).

The different reconstructions have also led to different replicas. The first replica of Regensburg, under the constructional direction of Matthias Helterhoff and still under the supervision of Olav Höckmann, was still 21.5 m long (Ferkel/Konen/Schäfer 2004). The replica in the Mainz Museum of Ancient Shipping was built according to the same planning. The two other replicas, the one in Germersheim again under the supervision of the boatbuilder Matthias Helterhoff (Brechtel/Schäfer/Wagener 2016) and the one in Xanten, which is not yet finished, under the supervision of the boatbuilder Kees Sars were made according to the reconstructive line drawings by R. Bockius (2006).

While the longer version of almost 22 m poses ship geometrical problems, the line drawings from Bockius 2006 seem to be closer to reality. It must be taken into account that the lines plan there corresponds to the finds. The two thousand years of storage of the relics under the sediments have had an impact on the stock. Some ribs are dented (see record of discussion with Garleff and Bockius; and email exchange, end of November/beginning of December). With this shape, there would have been a large bend in the „Kimmung".

Therefore, we agreed with boat builder Andreas Gronau and Christian Garleff (head of the maritime department LBS for boat builders / LBS for sail makers; Berufsschule der Handwerkskammer Lübeck, Wiekstr. 5, 23570 Lübeck (Travemünde-Priwall)) and the editor of the Lusoria boats of Mainz to aim for the ideal-typical "middle" between a line outline that was drawn according to modern criteria and guaranteed the hydrostatic ideal position in the water, and the traditional found situation, in which individual frames were pushed down. The result is already the basis of this completely new reconstruction, which has already begun with the construction of the templates and has been prepared by felling the oaks (and spruces), see plans and development of the lines plan below.

1.3. River and maritime vessels

The purpose of the boats of the type Lusoria/Mainz, just like the predecessor type Oberstimm, can be determined reasonably well. For the areas of the river boundaries designated with "ripa" in the ancient sources, the rowing boats functioned as patrol boats. Produced en masse, as is recorded for the Lusoriae in the time of Apostata, for example, these boats served as fast means of transport to quickly move troops and quickly stab an enemy in the back downstream. In both cases of use, successful deployment is attested.

The construction of riverboats and, in principle, for inland waterway vessels, does not differ in principle from seagoing vessels. Those with muscle-powered locomotion, generally designed for coastal navigation and in the military ship type, are attested for Pisa, for example, and probably also for Herculaneum in exactly the same Mediterranean form as in the case of Oberstimm. Here the differences are basically in the height of the freeboard. For Pisa nave C, for example, the sheer passage is replaced by rudder passages that were additionally covered with leather to prevent gout (Bockius 2013, p. 43-45). Long-distance merchant ships, which necessarily had to rely on sails as their main source of propulsion (as in the case of Lauron's

2), had a different design, as they were dependent on stowing spacious merchandise as effectively as possible. All types of ships were part of a long Mediterranean shipping tradition that can be traced back to the 3rd millennium BC (Bockius 2007).

1.4. Focus on river vessels

1.4.1. Use

In the pre-modern era and for a long time afterwards, in some cases even until today, and in many parts of the world, rivers served unrivalled as the fastest means of communication. The term communication is meant in the broadest sense as a medium of all possible interactions, i.e. all possible forms of communication as well as the exchange of goods. In principle, river shipping had the same transport categories available for this as ocean shipping, only with a different focus, and with rafts and dugouts included.

Military ships also navigated on the great rivers, as can be proven archaeologically and on Trajan's Column (Pogorzelski 2008). The ship units were smaller (double-row rowing ships are attested). The normal patrol service was for the very small ships, the lusoria, along the border rivers (Vegetius' 4th book). This category was so common, that Vegetius explicitly did not consider it necessary to mention it in detail at the end of the 4th century.

Transport (of people, troops) was most effectively carried out via rivers such as the Rhine and the Danube. For military purposes, the aforementioned ships in particular could be used for this purpose, but transporters such as prahms also come into question. If the area was otherwise secured against attacks (possibly covered with lusoria), then the most effective way to supply people and material, even entire legions, was with prahms (2000 years of the Varus disaster) (Aßkamp/Schäfer 2008; Eger 2018).

Transport of goods either as part of military supplies and/or for trade along the river lines took place via prahme, which was far superior to transport over land. Several dozen tons could be transported on larger rivers such as the Rhine and the Danube, but large loads could also be transported over rivers such as the Lippe, the Main, as well as over the North Sea rivers, even far into enemy territory (as attested in Tacitus through the rivers Elbe/Albia, Weser/Visurgis, Ems/Amisia). Downstream, transport was reasonably quick and unproblematic, using rowing power, sails and stay poles. The towboat method was mainly used for upstream transport. On wider rivers, the use of the sail upstream was even possible against the wind. In antiquity, the Danube and Rhine were not only more meandering, but also much wider and flowed more slowly than today in their alternative courses, which can often still be seen on historical maps of the modern era. At narrow points, for example on the Danube (the Iron Gate or the Danube breakthrough at Weltenburg), the typical treatment of the rocks on the banks or entire towpaths carved into the steeply sloping rocks can be seen.

1.4.2. Different known types

Important for river navigation was the need to be fully operational even in low water. In contrast to ships on the high seas with a relatively high draught (for maximum utilisation of the loading capacity), river ships and ships on inland lakes had to be able to carry their loads far into the shallows to facilitate further distribution on land.

For military undertakings, troops had to be able to advance their offensives far into the country, for example into the source area of the Lippe or the Main (in documented offensives, e.g. 6 AD Caecina campaign), in order to be able to avoid a lack of infrastructure and enemy ambushes for as long as possible. Supplies and trade overland ran on the large rivers, were reloaded and transported subdivided on smaller barges (prahme) up smaller river courses until camps at the sources (like Anreppen) or further buyers unloaded these goods (Aßkamp/Schäfer 2008).

Consequently, it makes sense to categorise the inland boats in terms of their draught. While the boats of the Mediterranean type had a rounded hull, their 4 cm thick pine planks usually had to be bent under steam to fit. These had a draught of up to a maximum of 50 cm – as can be concluded by the replica from Erlangen, the F.A.N. The other ships used on the river systems north of the Alps were the one flatboats, the other without any bow, like rafts, but with side panels like prahms. While the Lusoria in the Gallo-Roman style were flatboats, whose planks of about 2.5 cm thickness could be bent around the hulls or frames without further aids due to the bending capacity inherent in oak, as they also required less bending around the stringers and frames compared to the Oberstimm type. The pure transport barges, which remained common as prahms almost timelessly until modern times, are completely flat on the ground.

1.4.3. Shipbuilding techniques – Mediterranean vs. Germanic/Gallic

As indicated, Caesar had already described the differences between the Mediterranean and Celtic boat designs when he conquered the Gaulish settlement area. According to Caesar, the robustness spoke in favour of the Celtic version, allegedly due to the harsh climatic conditions. The ships in this building tradition used the hardest wood of the region, oak. Oak in itself does not swim so well, but it is robust. But the planks also bend well thanks to the oak and because they are cut relatively thin (2.5 cm). The shape of the flat bottom is much chunkier compared to the shape of the Oberstimmer boat, which was built in the Mediterranean tradition. However, the robustness is also due to the fact that the planks and frames were all carpentered with iron nails, albeit butt-jointed, so the outer hull was smooth. This made the boat more than twice as heavy at almost similar length as its older counterpart of the Oberstimmer design, which was assembled with pine planks, oak in the core parts (keel and frames) and with wooden nails (except for bow and stern). All these boats had realised the Mediterranean type of smooth outer hull under direct or indirect influence, while boats of the Germanic building tradition practised the clinker construction method, like the Viking boats later on – this is proven by the ship finds from Nydam Moor in Denmark, all of which had been made with oak, with nails, but not with smooth outer hull.

2. Danube ships in Living Danube Limes

2.1. Danube ships

As both a border river and part of the Roman Empire, the Danube has been an important line of communication north of the Alps since the last two decades before the turn of time. It connected all provinces and played an important role in supplying the burgi, forts and legionary camps along this route, as well as the civilian settlements that established themselves at these locations. While civilian ships and transporters ensured trade and supplies, military

patrol boats of the Oberstimm type for the early and middle imperial period and the Lusoria ships in Late Antiquity provided guard services or ensured troop transports en masse. In the case of military offensives, larger ships (as in the Dacian campaigns of Domitian and Trajan) also sailed the Danube. While downstream journeys could be made quickly (at up to 100 km per day in exceptional cases), upstream a combination of propulsion methods had to be chosen. In the Danube delta, it was possible to profit from the seasonal easterly winds, to cruise further west on the wide, strongly meandering, slow-flowing river against the wind or to tow when the rowers were exhausted (Dreyer 2018/2019).

2.2. Research history

The history of research on the lusoriae as a type of ship has received a great boost from the finds in Mainz, much as in the case of the finds of the patrol boats from Oberstimm. In both cases, these finds are unparalleled even in the Mediterranean. In terms of construction and category, they represent several centuries of shipbuilding and, in addition, in the category of military rowing boats, at least 500 to 600 years of the time when Rome was also present on the Danube. They were built on site, with the wood that the Romans found in the surroundings.

Roman inland navigation in the Germanic region thus served in addition to civilian use (Eger 2018; see also: "Katalog Stadt - Land - Fluss. Römer am Bodensee", Thurgau 2017), above all as a means of military deployment and supply (see for the Germanicus campaigns Tac. Ann. I and II), and later for securing the borders, especially on the natural "wet" borders of the Rhine and Danube. The comments of the late antique author Vegetius on the ship "type" of scafae (4,37), which is the focus here, can serve as an explanation for this:

> *The larger Liburnians were accompanied by reconnaissance boats (scafae). They had about twenty oarsmen on each side. The Britanni speak of painted boats. They were used for sudden raids, sometimes intercepting the supplies of enemy warships, and by careful reconnaissance they were supposed to discover the arrival of the enemy and their intentions. But to prevent the reconnaissance boats from giving themselves away by bright colours, sails and ropes are dyed with "Venetian colour". This colour resembles the tide of the sea. Even the wax paint used to paint the ships is dyed accordingly. The sailors and marines wear "Venetian coloured" service clothing to better camouflage them as scouts by day and by night* (transl. according to Baatz-Bockius).
>
> Scafae tamen maioribus liburnis exploratoriae sociantur, quae vicenos prope remiges in singulis partibus habebant, quas Britanni pictas vocant. Per has et superventus fieri et commeatus adversarium navium aliquando intercipi adsolet, et speculando studio adventus earum vel consilium deprehendi. ne tamen exploratioriae naves candore prodantur, colore Veneto, qui marinis est fluctibus similis, vela tinguntur et funes; cera etiam, qua ungere solent naves inficitur. Nautaeque vel milites Venetam vestem induunt ut non solum per noctem sed etiam per diem ficilius lateant explorantes.

Knowledge about Roman inland navigation is based on literary and above all material finds. After the dubiously documented finds in Vechten at the end of the 19th century, the findings in Mainz and Oberstimm in particular have expanded our knowledge, representing a spectrum of previously known boats used for military purposes in Central Europe. The Mainz boats at the Hilton construction site belong to the Lusoria type, which is also known from literature

(mentioned by Vegetius in IV 46 and II 1; cf. Codex Theodosianus VII 17) and was built in Late Antiquity and used in the Germanic region. In addition, there are finds for this type of boat in Cologne "Alter Markt" and Rhine bank, Mainz "Kappelhof" and perhaps "Holzstraße" (Groove and tongue technique), Xanten-Wardt and -Lüttingen, Zwammerdam 4, Vleuten - De Maeern I, Woerden 1 and 7, Druten, Kapel-Avezaht, Zwammerdam 1,2,3,5,6.

They stand in the so-called Gallo-Roman building tradition, which – as said – Caesar already described (in the first century B.C.) in essential characteristics (de Bello Gallico 3,13,1-7). They were robust, built entirely of oak and held together by iron nails.

The other type of vessel was found in Oberstimm on a tributary of the Danube in the Breitlach, which has now dried up above ground. In addition to Vechten (see above), there are finds in Cologne "Alter Markt" for this type. In Mainz "Holzstraße", De Meern Kastell and Xanten Kiesgrube they are flat-bottomed vehicles partly in tongue-and-groove construction (in Xanten even only one dislocated tongue). The building tradition comes from the Mediterranean and is influenced by the tongue and groove construction, that has been documented in the Mediterranean world since the 3rd millennium BC. The construction tradition comes from the Mediterranean and is characterised by the tongue and groove construction with a smooth outer hull, which is documented in the Mediterranean world since the 3rd century BC. As a result, the boat, which weighs about 2.2 t. empty, has an almost optimal flow behaviour even under modern conditions, which has already been tested on 1:5 and 1:10 models as well as with the 1:1 reconstruction. In this context, the Oberstimm type, which had been in use in inland navigation since the time of Augustus, always proved superior to the Lusoria boats of late antiquity in terms of speed (see Caesar above). Thus, the Oberstimm boat is equal to the hydrostatic behaviour of the Attic warships (Rankov 2012) and also the Germanic clinker boats (Bockius, Nydam IV).

Our knowledge about the purpose of these boat finds comes mainly from historical texts, images and reliefs. However, these were rarely created with the aim of correctly recording technical details. A statement about the performance of the boats used, such as marching speeds, transport capacities or limits of use due to climate and weather, could at best be incompletely deduced from such sources. Questions about the transfer of technology (Bockius 2006a), which is important for the evaluation, are not (consistently) asked. Even if ancient texts – such as Caesar's – weigh the advantages and disadvantages of one's own shipbuilding tradition against those of others, ancient sources and material finds at best reveal the result of a transfer, but not the path and the motives in the case of paths in a glaring and random manner.

Since the end of the 20th century, replicas of historical ships, faithfully reproduced, have offered themselves as an additional, promising means of gaining knowledge. They are based on archaeological finds and supplemented by scientifically founded hypotheses (Coates/ McGrail/Brown/Gifford/Tipping/Wright 1995; Crumlin-Pedersen 1995). Such replicas can be justified by gaining knowledge about historical craft methods and by experimentally proving disputed design hypotheses. In addition, replicas make it possible to draw technical conclusions about sailing speed, sailing ability or manoeuvrability – and about technical transfers. Prominent examples of this are the aforementioned Greek trireme "Olympias" (Morrison/Coates/N.B. Rankov/B. Rankov 2000; B. Rankov 2012), whose replica was based

solely on hypothetical conclusions from historical documents, or the Viking ships of Skudelev (Nielsen 2016), which were based on an archaeological find near Roskilde, DK.

Our knowledge of the purpose of these vessels has also been investigated for the period of inland navigation of the ancient Roman Empire. The publication of the above-mentioned finds from Oberstimm and from Mainz by R. Bockius (2002 and 2006) provided the basis for the reconstructions, which were carried out in particular by Ch. Schäfer at various sites: in Regensburg (the Regina: Schäfer/Günther/Wawrzyn 2008), in Hamburg (the Victoria: Aßkamp/Schäfer 2008) and in Germersheim (the Rhenana: Brechtel/Schäfer/Wagener 2016), and currently also in Trier – supported for the first time with DFG funding – the Laurons II. The archaeological finds of these ship types document the construction of the hull up to the gunwale, as well as the position of the mast base (in the front third). Additional superstructures and attachments such as the rudder, oars, rigging and sails were hypothetically implemented on the basis of contemporary parallels (for the oars, for example: Valkenburg Excavations 1993).

The tests on these replicas have brought the conclusion that the sails can become a problem (Aßkamp/Schäfer 2008, p. 111-113; indicated by Bockius). In any case, the type of original sails is not clear. The square sail was the most common; however, square sails, for example with a spriet, are quite possible. Latin sails are only documented later, first in the East (Byzantium), although they are not ruled out for earlier times (two incidents are attested: see Weski in an upcoming article on the F.A.N.). Further problems arise due to the low lateral plan. Tests on replicas of the Lusoria – which is considerably heavier but has an even lower lateral plan because it has a flat bottom – and on replicas of the earlier type of boat showed, however, that under favourable conditions, sailing up to almost 90° on the wind is possible.

Conversely, the analysis of ancient boat types by Whitewright (2013) and Palmer (2009 and 2009a) virtually presupposes the need for a forward mast base for propulsion and manoeuvrability on courses close to the wind. In the case of the square-rigged sail, the centre of gravity is lower than that of the square-rigged sail, which has been extensively tested so far. Furthermore, propulsion (with the same sail area: 25 m2) is better ensured in crosswind conditions as well as on courses harder to the wind – as first tests in October 2018 on the Altmühlsee proved with the new reconstruction, which is truer to the original in terms of material and belt suspension and offers alternatives with regard to the unproven fundamentals (rudder, belt, take-off position, sails). On this new basis, new investigations are possible.

The FAU has built a ship of the type Oberstimm (wreck II) in 2017/8 under the direction of the Chair of Ancient History). Additionally, within the frame of the new EU Interreg DTP Project “Living Danube Limes”, the FAU will build a new boat, the late Antique Danuvina Alacris. At the end of June 2020, a team of FAU went to the Ancient Maritime Museum in Mainz to record the wrecks 1 and 5, which originate from different ships but are of the same design. The boats stand in gallo-roman ship building tradition. The 3-D reconstruction, based on these recordings, can be used as a basis for the reconstruction of the boat. The edition of the finds and discussion of the finds of wrecks 1 and 5 by Roland Bockius (2006) are the second basis for the reconstruction. The lines plan forms the basis of the reconstruction work of the boat builder Mr. Gronau. His preliminary construction plan (Gronau/Garleff) is the first starting

point (see below). With the two boats built, both vessels are tested to achieve optimal performance of the Roman boats.

Therefore, further investigations are necessary: on the one hand, further findings must be obtained to validate the assumed hypotheses (design of the sails, determination of the rudder depth, length of the hull, oar dimensions, length or geometry, etc.), and on the other hand, alternative hypotheses (spritsail, position of the masthead) must be tested. Even the late Latin sail must be evaluated as an alternative. All these examinations and further fluidic studies have direct consequences for the subsequent historical questions that must be pursued: Which (auxiliary) sails make the most sense, if any, for inland navigation in the river systems of Germania? Which combinations of oars and steers come into question in terms of the best possible manoeuvrability? How was a perfect "technical package" obtained by adapting the "foreign" boatbuilding traditions with the advantages of one's own boatbuilding techniques? What then follows for the usability of this type of boat in the phase of the Roman offensive and in the phase when these boats were used for border security? What were the verifiable functions of these boats: control, escort, transport of troops and/or material? How did the use of the legionaries as helmsmen affect their use in the offensive and defensive context? What stages were conceivable? Which performance spectra were possible for rapid troop deployment on the two main routes Danube/Rhine (and tributaries) downstream and upstream?

2.3. Archaeological evidence & literary evidence

2.3.1. The types of Oberstimm and Mainz

The evidence for the Mediterranean type of construction covers several millennia. It is attested in ancient Egypt alongside other types of construction (lashed and sewn) and spans the period of the empires in the Orient, Hellenism, but also in the western Mediterranean the Carthaginians perfected the method to such an extent that they were (wrongly) credited with inventing the method of construction. So, the Romans were on well-trodden paths, which they certainly designed in the sense of effectiveness – as in other military fields. This is well documented by finds (see above).

Celtic architecture is also well documented in literature (Caesar) and by finds for the Roman period (Mainz; see above). Due to the geographical proximity, it wins the race in Late Antiquity, also because the construction method was simpler.

These two ship types have covered in this military ship category – as far as we can see – in the region north of the Alps and especially on the Danube, also new archaeological finds seem to confirm this (Serbia).

2.4. The ship reconstruction in Living Danube Limes

Living Danube Limes aims to call back in mind the common Roman past and the common Roman heritage of all the countries along the Danube and to establish this memory at a high and sustainable level as permanently as possible. This includes, among other things, to foster a sustainable and eco-friendly tourism as well as the protection of the cultural sites in the

Danube Limes Region. The ship being replicated has been given the name Danuvina Alacris, after the Living Danube project: "winged Danube", "living Danube". The Latinised form of the name is philologically clean and at the same time ambiguous. With the component "alacris" we have the reference to possible partially mounted units that could do local service on the ship units.

Naming ships that even visually had the shape of a living creature (fish or similar) was common practice in antiquity. Perhaps the most famous ship gave its name to the mythical enterprise of the hero on the way to the Golden Fleece: Argo, which was later placed in the sky as a constellation. As in other times, the naming of the ship was subjected to a ceremony (the baptism) in Roman times, where a priest usually uttered a prayer to the god in charge (often Poseidon) after a sacrificial pour from a bowl.

3. Construction plan for Danuvina Alacris

3.1. Plans / parts of plans in size that details are recognizable

Fig. 1 shows the first version (© C. Garleff) of the lines plan (as total overview) before discussion between Bockius, Garleff, Dreyer on October 26th.

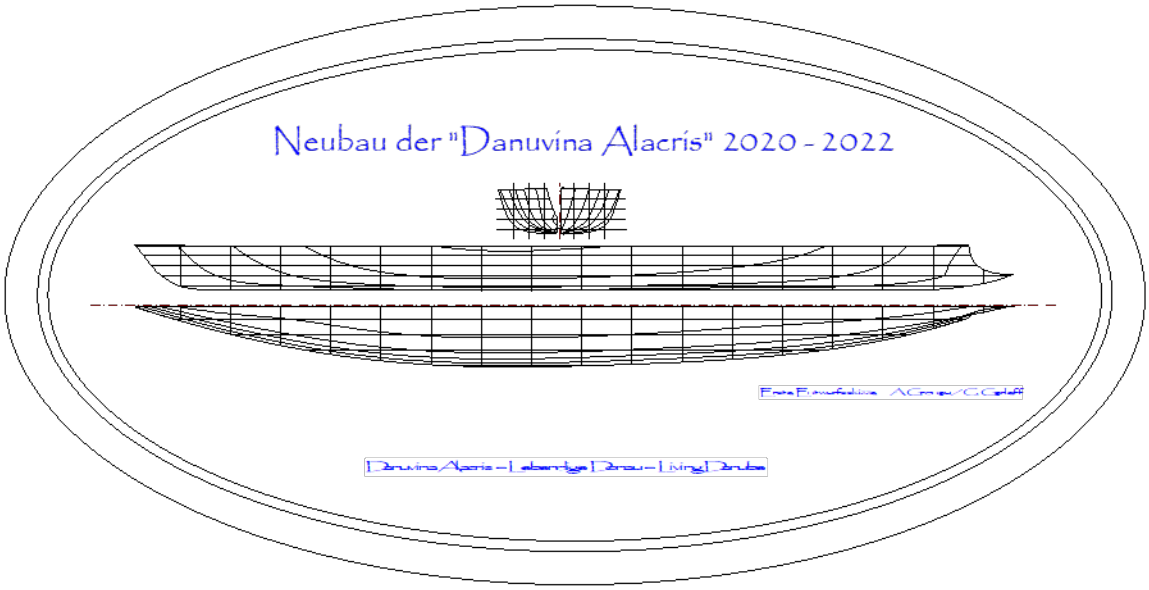

Fig. 1: total overview of the lines plans (© C. Garleff)

Fig. 2a and 2b show the lines plans (version 17.12.2020) more detailed.

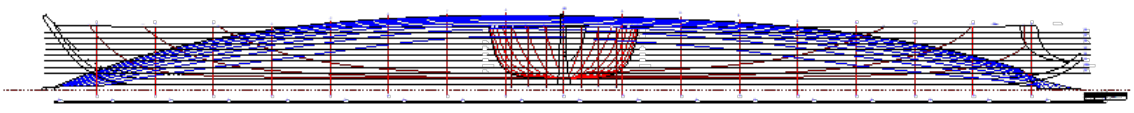

Fig. 2a: © C. Garleff

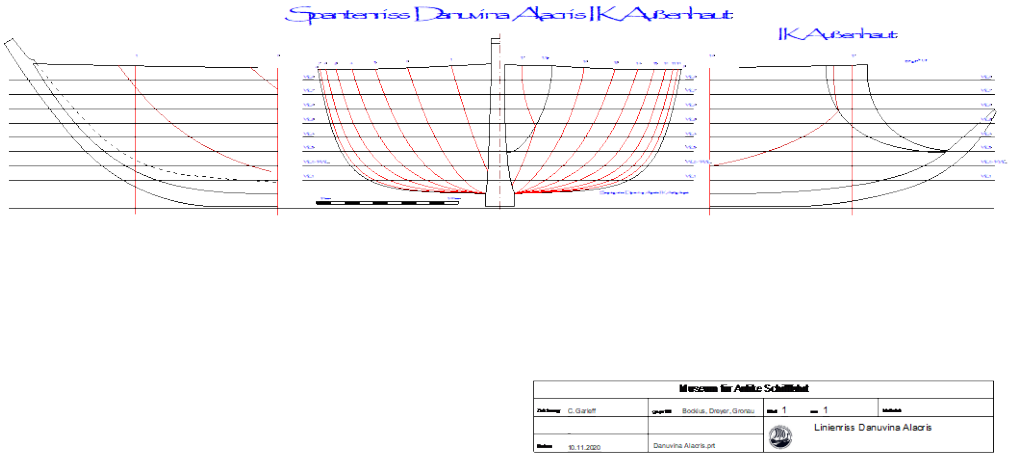

Fig. 2b: © C. Garleff

3.2. Descriptions in more detail

Lines plans (Linienrisse) represent the starting point for the design of the templates. The first drawing shows the frame plan / Spantenriss (construction frame plan / Konstruktionsspantenriss, i.e. the vertical cuts in transverse direction). The right side shows the view of the foreship, the left side the view of the stern (see above). The middle drawing and the lower drawing divide the boat horizontally. The middle drawing divides the boat into sections (Schnitte), right bow, left stern. The last drawing is a waterline plan / Wasserlinienriss. The aim is to determine the positions of the templates and later the frames and to position the planks so that they are streamlining. The lines plans are then the basis for the creation of the templates loft / Schnürboden, which determines the positioning of the templates/Schablonen to be created.

The drawings below (fig. 3) shows lines plans as a basis for the reconstruction of the Lusoria Danuvina Alacris in its development. The first line plan („alte Kurve 1") is that of the publication of Bockius 2006 and the second of C. Garleff sought an optimisation with regard to the hydrodynamic capabilities of the boat to be built („alte Kurve 2"), in intentional deviation from the findings of Wreck I and V (see picture). The discussion led to the final "design" („neue Kurve"), s. recorded discussion and final lines plans above (December 17th).

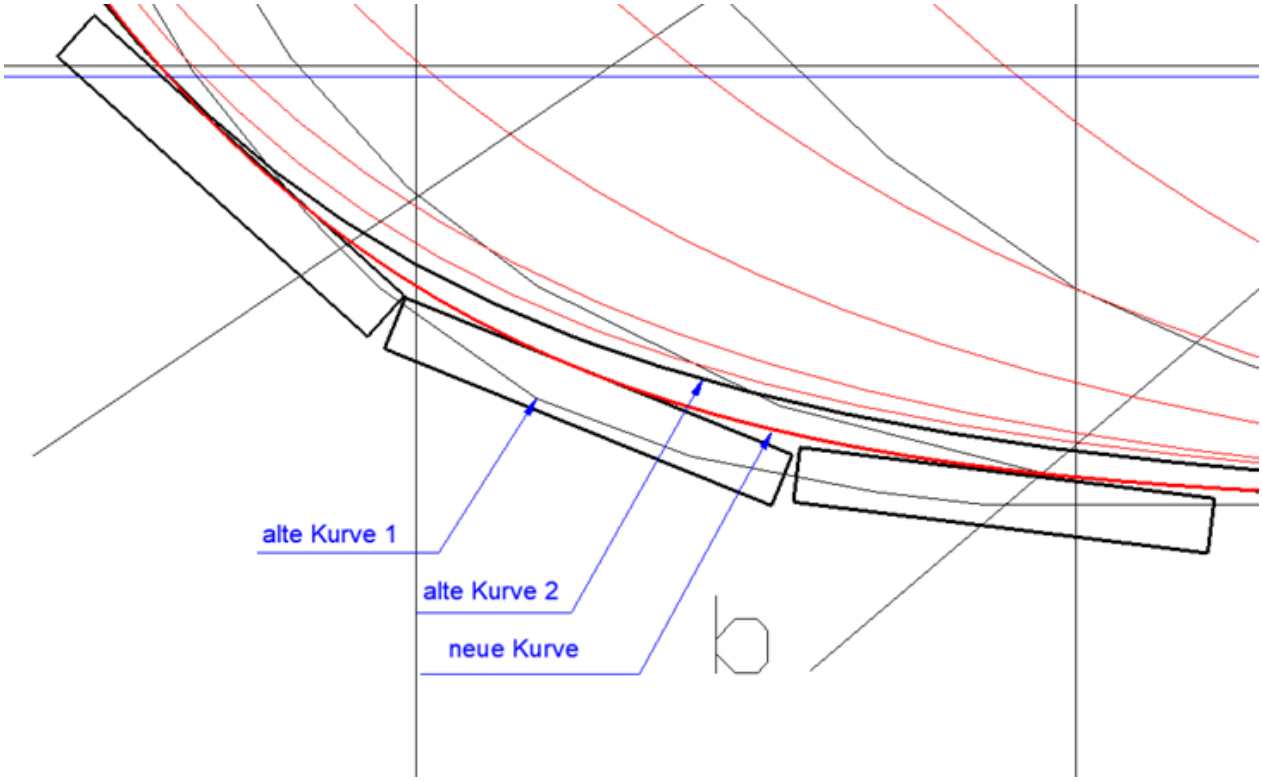

Fig. 3: © C. Garleff

The final outline from December represents a compromise between the calculable ideal line and the compressed findings.

3.3. Focus on techniques in 4th century

The boat-building techniques of the 4th century have been handed down over centuries, as the very notion of classification among the boat-building traditions attests (see also Deliverable I1.1.2). Ancient crafts, like modern ones, are conservative with regard to boatbuilding techniques. With regard to working with templates, one may say that especially in mass production, templates were reused in the sense of effective construction.

3.4. Research questions

The plan is based on the plans of the boat builder Mr. Gronau. The plans are preliminary and depend in detail on external factors that cannot be influenced. However, the relative processes are correct and the result is guaranteed. This schedule is part of the contract with the boat builder.

Work	**Time**	**Research questions**	**Activities linked to shipbuilding**
1. section: preliminary works for building of the Lusoria	start		

1.1 construction of the different lines plans	5.- 8. week (29.7.-25.08.2020)	s. above: discussion of the possible original lines plan; discussion of the length	Discussion B. Dreyer, R. Bockius, C. Garleff, A. Gronau Zoom-Meeting, additional corrections
1.2 building of the spiers (round wood)/ oars/ rudder)	9. -16. week (26.8.-20.10.2020)	Discussion of the optimal length for Spriet, yard, Lateen spar, in order to fit the various sails	Spruce trees selected in July, cutted in July; Additionally, 44 square shaped (10 cm) 5 m bars for oars ordered
1.3 Schnürboden (templates loft)	17. - 21. week (21.10.-24.11.2020)	Optimizing of lines plan and template plan	1:1 drawing of ship shape on building pavement
1.4 wood for building (cutting, preparation, conservation)	22. -25. week (25.11.-22.12.2020)	Discussion of width, length and shape of oak, in order to get the ideal number of truncs especially for the planks; number of Krummholz that will fit the crooked frames	Oak trees selected (already in July), cutted in November, 18 times 21 m oaks, with 50 cm diameter were transported to the final building place
Mile stone 1 (=end of section, evaluation)	To be fulfilled to the end of the 25th week		Slicing of oak could not be done, because mobile cutting machine was involved in an accident, postponed to Jan 18th
2. section: erection of shell in the boat hall/ planks			
2.1 new hall: preparation of the construction site; moving in boat hall	37. -39. week (10.3.-30.3.2021)	Architectural work; professional drawings and professional building company	Boat hall approved by authorities in December 20, will be built in beginning of new year
2.2 positioning of keel	40. -42. week (31.3.-20.4.2021)	Discussion on length of boat (see lines plan)	Fixation on pavement
2.3 positioning of backbone	43. - 46. week (21.4.-18.5.2021)		

2.4 Planing and fitting of planks, part 1	47. -52. week (19.5.-30.6.2021)	Discussion on width and length of each plank, s. lines plan	Cutting and planing of planks according to lines plan
Mile stone 2	To be fulfilled to the end 52. week		
2.5 Planing and fitting of lower and upper frames, part 1	53. - 55. week (1.7.-20.7.2021)	see Frame plan	Cutting and slicing of Krummholz
3. section: completion of shell			
3.1 Planing and fitting of planks, part 2	56. - 72. week (21.7.-16.11.2021)	Discussion of width of each plank, s. original finding and plan	7 or more planks star- and portside up to 18 m have to be planed
3.2 Planing and fitting of lower and upper frames, part 2	73. - 75. week (17.11.-7.12.2021)	Selecting the Krummholz according to frames plan; discussion, which Krummholz fits best to the varius frames of plan	Cutting, slicing of Krummholz; planning of frames
3.3 Finish of shell	76. - 78. week (8.12.-31.12.2021)		
Mile stone 3	To be fulfilled to the end of the 78. week		
4. section: fitting out and finish			
4.1 Planing and fitting of longitudinal connection (e.g. stringer)	79. - 81. week (1.1.-18.1.2022)	By lines- and framesplan position of stringers can be concluded	Cutting, slicing, planing of stringers, fitting the stringers
4.2 cutting, planing and fitting of gunwale	See above	Last part of each side according to the lines plan	Cutting, planing and fitting of gunwale
4.3 construction of pavement	82. - 83. week (19.1.-1.2.2022)	Measurements, discussion of the remains in Mainz,	Cutting, fitting of the wood
4.4 construction of front/prow	84. - 86. week	Measurement of wrack 5 in Mainz;	Cutting and planing of planks of prow part

	(2.2.-22.2.2022)	drawing of original shape of prow	
4.5 rowing seats and all inner connections / floor	87. - 89. week (23.2.-15.3.2022)	Measurements of the remains in the wrack I, sternpart. Drawings of the possible original shape	Cutting and fitting of seats asf.
4.6 all inner equipment/bottom of mast asf.	90. - 92. week (16.3.-05.4.2022)	Position of mast according to plans and remains of wrack V	Cutting of mast, fitting to bottom; spars of sails asf.
4.7 caulking and conservation	93. - 95. week (6.4.-26.4.2022)		Varnish for conservation
4.8 encaustic painting of antiquity		Discussion and tests of best receipt for painting according to encaustic method	Painting according to receipt of Dr. M. Speck
Mile stone 4	To be fulfilled to the end of the 95th week		
4.9 Rigging of boat		Best possible rigging for spriet, yard and lateen sail altogether	Establishment of rigging
4.10 Launching of boat	104. week (22.6.-28.6.2022)	Testing of tightness of boat; corrections; watering	Activities connected with this
Mile stone 5	To be fulfilled to the end of the 104th week		

4. Literature

4.1. Literature on boat reconstruction

R. Askamp, Ch. Schäfer, Projekt Römerschiff. Nachbau und Erprobung für die Ausstellung, Hamburg 2008.

D. Baatz, R. Bockius, Vegetius und die römische Flotte, Bonn 1997.

R. Bockius, Zur Rekonstruktion des römischen Plattbodenschiffes aus Woerden. Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz Vol. 43 (1996), S. 511-530.

R. Bockius, Die römerzeitlichen Schiffsfunde von Oberstimm in Bayern, Mainz 2002.

R. Bockius, Die spätrömischen Schiffswracks aus Mainz. Schiffsarchäologisch-technikgeschichtliche Untersuchung spätantiker Schiffsfunde vom nördlichen Oberrhein, Mainz 2006.

R. Bockius, Schiffbau und Schifffahrt in der Antike, Stuttgart 2007.

R. Bockius (ed.), Between the seas. Transfer and exchange in nautical technology, Mainz 2009.

R. Bockius, Ruder-„Sport“ im Altertum. Facetten von Wettkampf, Spiel und Spektakel, Mainz 2013.

R. Bockius, in: Nydam Mose, Aarhus, 2013, pp. 215–252 (=Bockius 2013a).

F. Brechtel, Ch. Schäfer, G. Wagener (Hgg.), Lusoria Rhenania. Ein Römisches Schiff am Rhein. Neue Forschungen zu einem spätantiken Schiffstyp, Hamburg 2016.

W. Brouwers, E. Jansma, M. Manders, Romeinse scheepsresten in Nederland. Archeobrief 2013-4, p. 13–27.

S. Bruni, The urban harbour of Pisae and the wrecks discovered at the Pisa – San Rossore railway station, in Le navi antiche di Pisa (ed. S. Bruni), p. 21-79, Firenze, 2000.

B. Dreyer, Die Fridericiana Alexandrina Navis (F.A.N.) - Nachbau sowie wissenschaftliche Erprobung und Einordnung der Replik von Oberstimm II - Stand des Baus (Anfang Februar 2018), Skyllis 17, Heft 1, S. 87-96

B. Dreyer, Oberstimm: römisches Schnellboot kehrt zurück, Archäologie in Deutschland, Heft 4, S. 64-65.

B. Dreyer, Experimentelle Archäologie und Wissenschaft - die Fridericiana Alexandrina Navis, Limes XII 1-2 (2018), S. 30-37.

B. Dreyer, Rebuilding the past, improving knowledge. The Fridericiana Alexandrina Navis, Ancient Warfare XII 4 (2018), p. 51-56.

B. Dreyer, A Scientific Adventure. Testing a F.A.N. Theory, Ancient Warfare XIII 2 (2019), p. 40-45.

I. Pekáry, Repertorium der hellenistischen und römischen Schiffsdarstellungen, Münster 1999.

R. Pogorzelski, Die Trajanssäule in Rom. Dokumentation eines Krieges in Farbe, Mainz 2012.

Ch. Schäfer, Lusoria – ein Römerschiff im Experiment, Hamburg 2008.

G. Ucelli, Le Navi di Nemi, Instituto Poligrafico e Zecca dello Stato, Roma, 1940.

S. Wolfmayr-Dobrowsky, Die Schiffe vom Lago di Nemi, Diplomarbeit, Graz, 2009.

4.2. Used bibliography on Ancient Seafare

R. Aßkamp, C. Schäfer, 2000 Jahre Varusschlacht, 1st ed., Koehlers Verlagsges., Hamburg, 2008.

R. Bockius, Die römerzeitlichen Schiffsfunde von Oberstimm in Bayern, Mainz 2002.

J. Bennett, Sailing into the Past: Learning from Replica Ships, Seaforth Publishing, 2009.

R. Bockius, Die spätrömischen Schiffswracks aus Mainz, 2006.

R. Bockius, in: Proc. Elev. Int. Symp. Boat Ship Archeol., Mainz, 2006. (=2006a)

R. Bockius, in: Nydam Mose, Aarhus, 2013, pp. 215–252.

F. Brechtel, C. Schäfer, G. Wagener, LUSORIA RHENANA , Koehlers V.-G., Hamburg, 2016.

J. Coates, S. McGrail, D. Brown, E. Gifford, C. Tipping, E. Wright, Int. J. Naut. Archaeol. 24 (1995), p. 293–301.

O. Crumlin-Pedersen, Int. J. Naut. Archaeol. 24 (1995), S. 303–306.

B. Dreyer, Tekmeria 7 (2004), S. 7–48.

B. Dreyer, Klio 87 (2005), S. 396–420.

B. Dreyer, Arminius und der Untergang des Varus, Klett-Cotta, Stuttgart, 2009.

B. Dreyer, Skyllis 17 (2018), S. 87–96.

B. Dreyer, Archäol. Dtschl. 4 (2018), S. 64–65.

B. Dreyer, Limes 12 (2018), S. 30–37.

B. Dreyer, Anc. Warf. XII 4 (2018), p. 51–56.

B. Dreyer, Anc. Warf. XIII 2 (2019), p. 40-45.

C. Eger, LVR-RömerMuseum Xanten, eds., Warenwege - Warenflüsse:, [1. Auflage], Nünnerich-Asmus, Mainz, 2018.

M. Junkelmann, Panis Militaris. Kulturgeschichte Der Antiken Welt 75, Mainz: Philipp von Zabern, 1997.

C.A. Marchaj, Sail Performance: Theory and Practice, London : Adlard Coles Nautical, 1996.

F. Mewis, Schiffbauforschung 28 (1989).

J. S. Morrison, J.F. Coates, N.B. Rankov, B. Rankov, Wiley Online Library, 2000.

S. Nielsen, Experimental Archaeology at the Viking Ship Museum in Roskilde, na, 2016.

C. Palmer, in: Sail. Past Proc. Int. Semin. Replicas Anc. Mediev. Vessels, 1986, p. 178–193.

C. Palmer, Wooden Boat Mag. 92 (1990).

C. Palmer, Int. J. Naut. Archaeol. 38 (2009), S. 90–96.

C. Palmer, Int. J. Naut. Archaeol. 38 (2009), S. 314–330. (=2009a)

B. Rankov, Trireme Olympias. The Final Report, 2012.

C. Schäfer, Imperium (2009), S. 203–209.

C. Schäfer, H. M. Günther, A.C. Wawrzyn, Lusoria: Ein Römerschiff Im Experiment, Koehler, 2008.

J. Whitewright, Int. J. Naut. Archaeol. 40 (2011), S. 2–17.

S. Wilkinson, Partially Separated Flow around Masts and Sails., PhD Thesis, University of Southampton, 1984.

R. Wolters, Die Römer in Germanien., Beck, München, 2000.

5. Appendix

Photo of the lines plans (scale 1:1 and 1:4) of C. Garleff:

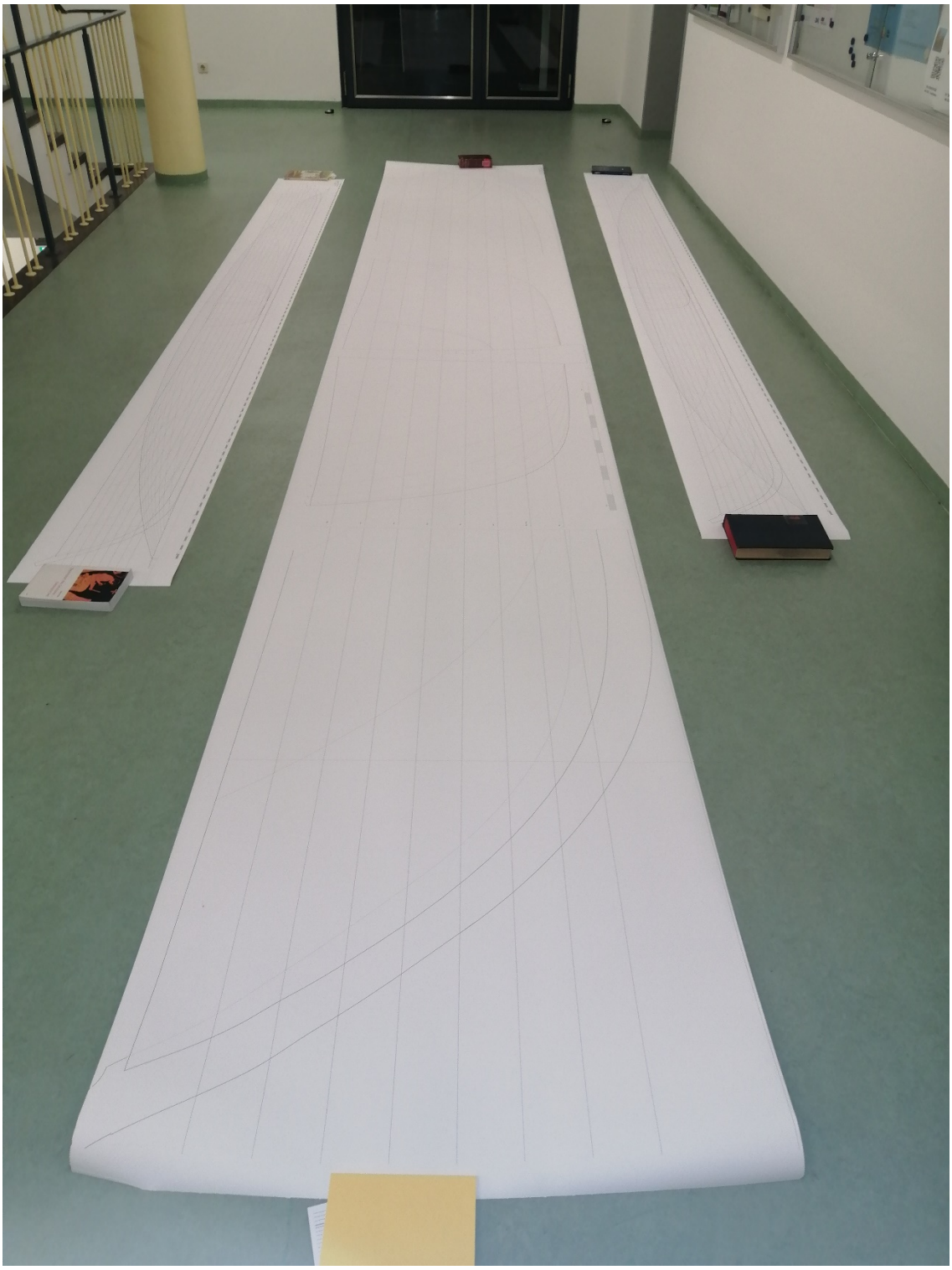

Photo of the lines plans in scale 1:1 (middle plan) and 1:4 (right and left plan) (© Ch. Sponsel-Schaffner)

Three short video files (© Ch. Sponsel-Schaffner) are attached to this deliverable, showing the single lines plans in their full measure:

D.I1.1.1_appendix_video 1_lines_plan_scale 1_to_1_middle plan_Sponsel-Schaffner.mp4

D.I1.1.1_appendix_video 2_lines_plan_scale_1_to_4_left_plan_Sponsel-Schaffner.mp4

D.I1.1.1_appendix_video 3_lines_plan_scale_1_to_4_right_plan_Sponsel-Schaffner.mp4