Layer by Layer: A Mortar with Charcoal from the Costeşti-Blidaru Cistern

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Abstract: The aim of this article is to present the characteristics of a mortar layer from the floor of the cistern discovered by C. Daicoviciu and his team underneath Costeşti-Blidaru fortress. This investigation is based on the published information, on data from the excavation records and on the results of a recent mineralogic analysis of a sample from the layer in question. I compared the layer and the cistern with water related features and structures from the Mediterranean area, in an effort to identify the origins of the techniques that were used during the cistern's construction. Additionally, the recourse to ancient literary sources allowed me to discuss the practices of hydraulic engineers in classical times, in order to assess the validity of C. Daicoviciu's appreciation, according to which the cistern was built by following "Vitruvian recipes". The final part of the paper contains some observations regarding the chronology of the cistern, based on the techniques that were used and on the chronology of the fortress and its related structures.

Keywords: mortar, charcoal, undercoat, cistern, Vitruvius

Rezumat: Scopul acestui articol este prezentarea caracteristicilor unui strat de mortar din podeaua cisternei de sub cetatea de la Costeşti-Blidaru, descoperită de C. Daicoviciu şi de echipa sa. Această investigaţie se bazează pe informaţiile publicate, pe datele extrase din rapoartele de săpătură şi pe rezultatele unei analize mineralogice recente a unei probe prelevate din stratul

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respectiv. Am comparat stratul şi cisterna cu alte elemente şi structuri legate de apă din zona mediteraneeană, pentru a încerca să identific originile tehnicilor folosite la construcția cisternei. Pe lângă aceasta, recursul la sursele literare antice mi-a permis să discut despre practicile hidraulicienilor din perioada clasică, pentru a determina validitatea părerii lui C. Daicoviciu, conform căreia cisterna a fost construită prin respectarea "rețetelor vitruviene". Ultima parte a articolului conține observații privind cronologia cisternei, pornind de la tehnicile folosite şi de la cronologia cetății şi a structurilor asociate.

Cuvinte-cheie: mortar, cărbune, substrat, cisternă, Vitruvius

The location

The many examples of water-related structures found in the Orăştie Mountains stand out from those found in other regions of Dacia, this specificity being caused mainly by the local geographical features[1]. Besides this, other structures from this micro-region indicate the employment of classical techniques of construction[2], which were evidently "imported" long before the Roman conquest. This is the case of the cistern at Costeşti-Blidaru as well.

The cistern in question was found underneath the plateau of the Costeşti-Blidaru fortress (690 m height), namely on its north-western side (Fig. 1, 12)[3]. On one hand, its horizontal position could be related to the orientation of the main access way towards the fortress. The terrain was modified in order to restrict the access to a narrow saddle on the southern side of the fortress (Fig. 1). As such, the fortress could be seen as protecting the cistern from possible threats coming from the south. This side of the fortress was the most exposed, as it faced the higher ground of the Târsa plateau to the south. On the opposite side of the Blidaru hillock, where the cistern was placed, the slope is steep and it descends towards the Grădişte valley.

On the other hand, the vertical position of the cistern outside the walls of the fortress, and at a lower level, was related to the possible tapping of a spring, which is to be found underneath the same southern saddle. This was based on the fact that, if the spring was tapped, a certain

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[1] For the geographical description of the area in relation to water-management systems see Vasilache 2021a.

[2] For a discussion regarding classical influences and water management structures in the same area see Vasilache 2021b.

[3] Pescaru et al. 2014, 4–5.

difference of level was needed between the source and the cistern in order for the water to flow (Fig. 1) [4]. However, direct evidence, such as a tapping installation of the spring or a conduit that should have been found between them were not identified. The only direct proof as to how the cistern was supplied is represented by a terracotta tube fragment that was found on the western side of the cistern, facing the direction of the spring[5]. Unfortunately, this alone cannot precisely indicate the source of the water, since both runoff and spring water could have been transported through the aforementioned terracotta pipe. This detail is important, because if the cistern was supplied directly from the spring, it could have served as a redistribution basin, given the expected surplus of water that could have been transported to locations further down. An indirect argument for the use of spring water could be that, in the case runoff water was the source, then why not construct the cistern inside the walls and supply it through the roofs and platforms of the fortress itself? The exact location of the spring elludes us today, as it is probably clogged, while the area is still swampy. Only the identification of *in situ* remains would indicate the ancient position of the spring, which could have changed since then.

Therefore, it appears that there was a certain reasoning behind the placement of the cistern *vis-a-vis* the defensive elements around this protruded hillock. Its position indicates that it was set up in order to supply the fortress, especially if the latter was threatened from the south. Although it may seem that this spot is too exposed (as it lays outside the walls), this vulnerability is ameliorated by the fact that the fortress on the Blidaru hillock is at the center of a much larger network of defensive elements. Many isolated towers were identified in strategic positions, covering the main ridges that descend from the Târsa plateau to the Grădişte valley, thus blocking the access ways towards the fortress from both the lower and the upper level (Fig. 2)[6]. The fact that the cistern was placed "behind" the fortress makes sense, because the slopes that descend towards the Grădişte valley from this side of the hill (Muchia Chiştoarei and Muchia lui Todirici) were steep and dominated by towers, the last of them reaching the first terrace of the valley itself (Fig. 2). Another bigger tower was placed closer to the cistern, at Poiana Perții, and it is oriented towards the Chiştoarei valley, which starts from underneath the same saddle of the Blidaru fortress.

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[4] Glodariu 1983, 37.

[5] Daicoviciu et al. 1954, 141-142.

[6] Pescaru et al. 2014, 5–8.

To resume, setting up the cistern outside the walls of the fortress does not seem to be necessarily problematic, since the defensive system around Blidaru was based on a "vertical", in-depth setup of its composing elements. From this perspective the cistern is clearly related to the fortress, as it is the first large structure that appears underneath it, on the side of the hill that was naturally protected by steep slopes and additional towers. At the same time, the "horizontal" setup of the defensive structures around the Blidaru hillock, denotes that the main threat was expected to come from the south. If the spring underneath the southern saddle was, indeed, the source tapped for the cistern, this would mean that, if the fortress was besieged and the water supply was cut off by the enemy from the south, the cistern would have remained accessible from the fortress.

As such, it is most probable that this cistern was built for a strategic purpose – to serve the fortress during a possible siege. Besides the arguments expressed above, another argument can be provided by comparing the cistern underneath Blidaru with a similar discovery from the same area. At the base of the above-mentioned ridges that reach the Grădişte valley, a wooden cistern was identified on a small terrace near the Chiştoarei stream, close to one of the towers that reached the valley (Fig. 2). Besides the fact that it was located at a lower level, this structure is different from the first as other materials and techniques of construction were employed. It can be described as a quadrilateral structure made out of wooden posts, beams and planks, with a shingle roof and fencing[7] (its dimensions were 2,95 x 3,05 x 2 m, indicating a capacity of around 18 m^3). Supplied through a terracotta pipe from the close stream, it worked as a kind of a fountain-basin, which is typical in this mountainous area for spring tapping[8]. Its open structure might suggest that it could have supplied a greater number of people, and that it was not necessarily under a direct military control (although its closeness to the tower might not exclude a direct relation with this sphere as well). No (preserved) watertight measures were documented for this structure. As such, this structure is different from the cistern underneath the fortress, since the latter had many types of hydraulic mortars, which denotes a different approach towards water conservation.

Although both cisterns described above are more or less related to the defensive system around Blidaru fortress, they differ through their location, nature and possible function. The low-lying wooden cistern tapped the rich water resources available in this area, facilitating the collection and access to a constant amount of water. The upper cistern was

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[7] Daicoviciu, Ferenczi 1951, 24.

[8] Vasilache 2021a, 24.

larger but the resources of water present in this area were scarcer. The use of hydraulic mortars in order to waterproof this structure is a clear indicator of its main function – to conserve water as long as possible. The complexity of the latter structure is indicative for its relation with the fortress, and it shows that much more effort and interest was put into its construction. Such aspects indicate that the two cisterns were located and built in different ways because they served partly different purposes, that can be related to the intended use of the collected water. For the upper cistern, it is quite probable that the access was restricted, especially if only low levels of water were available, while the low-lying installation was probably much easier to access, as water availability was less of a problem in this area.

The role of both cisterns can also be related to the access roads used in the area. These access ways were usually presumed based on the distribution of the towers that were placed in strategic points, their aim being to watch over and possibly block these paths. A few segments of these roads were identified near some of the towers[9]. The main road identified in the area climbed the Faeragului ridge and passed near the fortress (its saddle) on its way to the upper Târsa plateau[10]. C. Daicoviciu supposed that another path could have started from the lower ridges (Todirici and Chiştoarei), somewhere around the intersection with the valley, where the lowest-lying towers were identified. He preferred the Chiştoarei ridge, as it was more accessible[11]. On the opposite slope of the Chiştoarei valley, underneath the Faeragului ridge, a number of anthropogenic terraces were identified, where no stone towers were found. Although no specific structures were identified, the archaeologists found spread ceramic fragments, a charcoal hearth and shards of small vessels[12]. On one of these terraces, four limestone blocks were identified. It was presumed that they may represent the foundation of a house or of a wooden watchtower[13]. This might indicate that the basin of the Chiştoarei valley was more diversely inhabited, at least in its lower part, while a possible access way followed the Chiştoarei basin upstream. Further up this valley, closer to the fortress, the bigger terrace and the tower at Poiana Perții blocked any possible access from this valley towards the terrace with the cistern and further up to the fortress[14]. This tower also blocked a

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[9] Pescaru et al. 2014, 6.

[10] Daicoviciu, Ferenczi, Glodariu 1989, 184.

[11] Daicoviciu et al. 1955, 227-228; Daicoviciu, Ferenczi, Glodariu 1989, 185; Pescaru et al. 2014, 6.

[12] Daicoviciu, Ferenczi, Glodariu 1989, 186 (nos. 20, 27.5-27.7).

[13] Daicoviciu et al. 1966, 83.

[14] Daicoviciu et al. 1955, 227.

possible access way over the Chiştoarei valley that splits from the upper main road that followed the Faeragului ridge[15]. From Poiana Perții, a quite steep slope of 30-40 m separates it from another terrace, located underneath the one with the cistern[16]. D. Teodorescu mentioned, at the beginning of the 20th c., that a steep road dug in the slope of the hill was connecting the first terrace underneath the fortress with the cistern. Two rows of stones holding the slope were still visible on some of its part[17].

In conclusion, it seems that the roads in this area have a circular symmetry, with defensive structures controlling the roads and the essential choke points at their intersections. While both cisterns are integrated in this well-organized system, they fulfill different functions. In the lower part of the Chiştoarei valley it is possible that the wooden cistern was placed intentionally near a pathway to facilitate an easy access. On the other hand, in the upper area of the same water basin, near the fortress, much more emphasis was put on the conservation of a larger amount of water while the access ways were evidently better controlled.

The cistern underneath the fortress

The recorded measurements of the cistern's interior are 8 x 6,2 m (Fig. 3/b). It was constructed inside a cavity dug in the hill slope for about 5 m depth from the modern level recorded during the excavation[18]. However, it functioned as a basin up to 4 m, a fact indicated by the height of the secondary walls (Walls B and C – Fig. 4/a), which were attached to the interior of wall A (so it had a 198,4 m^3 capacity – Fig. 3)[19]. The first of these walls (Wall B), composed of local stones bound with mortar, had the role of sustaining the barrel-vault made with limestone blocks of local origin. As such, it was constructed only on the longer sides of the structure (Fig. 3). Wall B was covered in different plasters of *opus signinum*, similarly to the other two visible faces of wall A (on the short sides of the structure), indicating a first functional phase of the cistern. A second wall (C) was added later on all four sides of the cistern's interior. It had a wider stone base and *opus signinum* mortar as binder, while its exterior was also plastered[20].

In order for the cistern to be constructed, the terrain was levelled, and this can be seen in the structure of the cistern itself (Fig. 3/a-b). Its first, exterior wall, was made out of local stones and mortar, and encompassed

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[15] Daicoviciu et al. 1954, 145.

[16] Daicoviciu et al. 1954, 144.

[17] Teodorescu 1923, 11.

[18] Daicoviciu et al. 1954, 141.

[19] And on the fact that the latest wall, C, was 30 cm lower that wall B, the interstice being filled with a fine hydraulic plaster.

[20] Daicoviciu et al. 1954, 140-142.

the structure on all four sides. The southern side is much wider than the others (approx. 2 m), as it was also meant to hold the slope[21]. This wall extended towards west as well, where the above-mentioned pipe fragment was found, a fact explained by the same structural necessity. This is one of the reasons why this wall was preserved (in height) to a greater extent than the others. It is also obvious that its height was greater than the probable maximum height of the vault (Fig. 3/a).

On the other three sides, wall A was not preserved to a similar height, and it is possible that it was shorter on these sides. Nonetheless, according to the plan, it can be observed that, on the longer sides of the structure, this wall reached at least the level of the vault's spring (Fig. 3/a). Thus, it is probable that the cistern had a partly elevated structure, and at least the vault and the southern side of wall A were above the ground. The extension of the southern wall towards west could indicate, besides the need to retain the slope, a possible access way towards the cistern from the upper area of the fortification.

The structure was archaeologically documented in the early 1950's, but it was identified some time before that. Initially, C. Daicoviciu considered it to be of Roman origin, based on the presence of *opus caementicium*, which was not documented in other Dacian structures from the area[22]. After starting the excavation, he soon realized that it represented a cistern which functioned in the Dacian period, and that it was constructed by using classical techniques that were "following Vitruvian recipes". However, he was unsure whether it was constructed by a Greek engineer (because he related the charcoal-mortar in the floor to the so-called Greek technique mentioned by Vitruvius – *infra* n. 85), or by a Roman one[23]. I. Glodariu argued without hesitation in favor of a Roman engineer[24]. The interval during which the cistern was in use could not be clearly delimited, because few artifacts were found inside the structure (a couple of Dacian ceramic fragments). One explanation for this may be that it was looted by treasure hunters, which is also indicated by the big hole they left in wall A of the structure (that was documented by the archaeologists – Fig. 3/a.d)[25].

Therefore, the chronology of the cistern could not be established by itself, but only by correlation with the phases of the fortress. Both C. Daicoviciu and I. Glodariu related the structure with the second phase of the fortress' development, thus dating it in the 1st c. AD, or maybe only in

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[21] Daicoviciu et al. 1954, 140-142.

[22] Daicoviciu, Ferenczi 1951, 26.

[23] Daicoviciu et al. 1954, 140-142.

[24] Glodariu 1983, 38.

[25] Daicoviciu et al. 1954, 140-142.

its second half[26]. This was based on the proximity of the cistern to the north-western tower (tower no. V – Fig. 12) and to the walls, which belong to the second (phase and) enceinte of the fortress, the latter presenting certain particularities. On the inner side of these walls, there are rooms of different sizes, which probably served as storage spaces, and it is believed that their roof was used as a platform (Fig. 12)[27]. In many of these rooms, remains of *dolia* vessels were found in corners, while a number of 8 large *dolia*, arranged in rows, were discovered in the interior of tower V. Most of the *dolia* from the tower had small openings (which were cut before burning) at the base, that were sealed with stoppers made out of an unburnt, waterproof clay plaster. These storage vessels were linked by the authors of the research with the storage of water coming from the nearby cistern[28], although this can't be certain. Even so, it is quite probable that the cistern was used during this second phase of the fortress, but it is much harder to pinpoint the exact moment of its construction, as the chronology of tower V is itself open for debate.

The mortars

In the initial archaeological report, the mortars and plasters identified on the walls and on the floor of the cistern were not described in detail. C. Daicoviciu preferred to use the terms *opus signinum* or *cocciopesto* when describing only some of the layers[29], even though other ones also contained crushed ceramic in one way or another. To resume a longer discussion, it can be safely assumed that the exterior, structural walls (A and B – Fig. 3/a-b) of the cistern were made in an *opus caementicium* technique, while the interior wall (C) was made in an *opus signinum* technique (Fig. 3/a-b). The faces of walls A and B, respectively C, were covered with different types of plasters, ranging from coarser or finer types of *opus signinum* to pure lime interfaces. It is possible that some of these plasters were also polished or had special additives added to the mix. The ordering of these layers is not accidental, since the finer plasters were used at the exterior while the coarser, but still thin layers, acted as support for the first. In wall C, an even coarser *opus signinum* mortar was used[30].

The types of mortars used for the structure, as well as their order, are similar to Vitruvius' precepts, who recommended using a *signine* technique when building cisterns[31]. Although he mentions, in the same note, that a

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[26] Daicoviciu et al. 1954, 145; Glodariu 1983, 38.

[27] Glodariu 1983, 92.

[28] Daicoviciu et al. 1957, 264-270.

[29] Daicoviciu et al. 1954, 142.

[30] For a complete discussion see Vasilache 2022, 62-71.

[31] Vitruvius, VII, 6.14.

mortar made with flint aggregate should be employed, the common aggregate used in Roman hydraulic mortars were volcanic ones. Their presence in the mix determined a so-called *pozzolanic* reaction. This material and the reaction are described by Vitruvius in the chapter with the same name[32]. Regarding the re-use of ceramics as aggregate, in his chapter about lime mortars he mentions the possibility of adding burnt brick in mortars, in order to strengthen them[33], and he discusses their use in coating layers in the chapter regarding the application of *stucco* in damp areas[34], while data about the succession of plasters and mortars can be found in the two chapters about *stucco*[35]. Recent studies have shown that crushed ceramics has a similar *pozzolanic* effect in mortars, strengthening the bind, and the Romans applied this method very often, especially when creating coatings for water related structures, although sometimes such mortars were also used in structural walls, or in foundations, floors, or to protect inner wall surfaces from external humidity[36]. In conclusion, mortars with volcanic compounds are true *pozzolanic* hydraulic binders, while the ones that contain ceramic aggregates, commonly referred to as *opus signinum*, generate a milder *pozzolanic* reaction of the mix[37]. This difference is evidenced by the fact that true *pozzolanic* mortars were not commonly used by the Romans for small-scale, terrestrial structures[38], but more commonly in special structures, such as port embankments, to quote an example provided by Vitruvius[39]. In contrast, *opus signinum* was employed on a larger scale, both for hydraulic and structural reasons, especially in areas where volcanic compounds were hard to obtain[40]. Lastly, *cocciopesto* is a term used since the Renaissance to describe a similar mortar containing ceramic aggregate[41].

The floor of the structure was succinctly described in the initial report. According to the authors, the cistern's floor was built, like the walls, during two phases. The overlying stratum was described as a thick layer made out of a mortar with broken tiles (*opus signinum*), while the one beneath it was composed of stones, mortar and tile fragments. The second floor (from the first phase) was described as being composed of mortar, ash and charcoal, and that it was particularly hard, since it could be chipped only in its upper part[42].

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[32] Vitruvius, II, 6.
[33] Vitruvius, II,7.5, 8.15.
[34] Vitruvius, VII, 4.
[35] Vitruvius, VII, 3.
[36] Siddall 2011, 153-154.
[37] Siddall 2011, 153.
[38] Siddall 2011, 153.
[39] Vitruvius, VI, 12.2.
[40] Nikolić et al. 2015, 80.
[41] Siddall 2011, 153.
[42] Daicoviciu et al. 1954, 142.

The plan attached to the report contained a more detailed stratigraphy and description of the layers, that I have represented separately (Fig. 3/c). The following description and the observations about the layers are based on the corroboration of the information from the plan with the data from the documentation (the layers are described in reversed order, *i.e.* from top to bottom):

1. Floor with lime and sand – A first, thin layer (5-6 cm), made out of a mortar which had a lot of sand and little lime in its composition; it had a fine, reddish surface, that was degraded by the time it was discovered.

- The reddish surface indicates that brick powder was either added to the mortar or, more probably, that it was used to plaster the layer's surface.

2. Lime, sand and small rock fragments – A second layer (6-10 cm) made of tightly arranged stones of local origin, bound with little mortar.

- The mortar that binds this layer seems to be similar to the one described above, since both contained much sand. I believe that we are dealing with one and the same mortar, that was poured over a base of tightly arranged stones. As such, it appears that the second floor of the cistern was constructed on a bedrock of stones, that was covered with a sandish mortar, which was then was finished with an *opus signinum* plaster. In the published report, it is said that both layers contain tile fragments, but that does not seem to be reinforced by the description from the plan or the documentation. Nevertheless, at least the interpretation of the plaster as an *opus signinum* remains valid.

3. Lime mixed with small fragments of tiles – A second floor with a fine, red surface, similar to the first one, but better conserved and with a more intense color. The layer (6-7 cm) was composed of a mortar rich in lime and tile fragments (1-3 cm). It is described as an *opus signinum* with a "good strength".

- This seems to be a hydraulic mortar used for coating, the surface of which was finished with a finer plaster of *opus signinum*. This can be related to the situation of the first layer, that certainly had an *opus signinum* plaster, while the mortar used was sandier and did not (?) contain ceramic aggregate.

4. Lime mixed with charcoal fragments – A base for the third layer, to which it was organically bound. It was 6-7 cm wide, its color was brown, and it appears to have been composed of a mortar (called "cement", because it was harder than the previous one) that contained charcoal fragments, ashes and white stones (?).

5. Very hard flooring – A white-greyish layer, with a fine surface. Its width is unknown since it was impossible to section. Samples were not taken for the same reason and its composition could not be determined.

As we can see, the first floor of the cistern had a much more complex stratigraphy then initially described (Fig. 3/c). While the undercoat layer (2) of the second phase was built using simpler techniques, the base of the first floor was carefully set by adding at least two layers (4 and 5), described as particularly strong mortars, and which did not contain ceramic fragments, but other aggregates, such as charcoal. A third layer (3) of *opus signinum* mortar was added on top of this base, being plastered afterwards with another, finer layer of *opus signinum*. In consequence, different types of *opus signinum* were used to plaster the exterior of the floors from both phases, while coarser *opus signinum* mortar (3) was definitely used as a support for these plasters in the first phase of the floor. None of the plasters that were applied on the exterior of the floors in both phases were recorded separately in the plans (Fig. 3/c). As such, both layers 1 and 3 should have an extra subdivision, 1A and 3A, representing the *opus signinum* plasters and the interfaces of the two main phases of the entire floor (Fig. 3/c).

The charcoal mortar

The focus of this study is on the fourth layer, that was described in the initial publication as the first "floor" of the structure. As shown above, it is evident that this layer with charcoal was positioned in between the recorded layers of the first floor (Fig. 3/c). At the same time, it is clear that the two undercoat mortars at the base of the first floor were different from the others used in the structure, and that they were working in tandem. This was suggested in the initial publication, where this "floor" was interpreted as a single layer made out of two parts[43].

The general characteristics of the mortar in layer 4 were described in a more recent analysis (Fig. 4-5)[44]. The study shows that it was constituted by a mineral aggregate of sand type, together with charred vegetal remains, that were bound in a fine cristalized mass that resulted after the recristalization of a mineral binder. The ratios are: 10% sand, 10% charred vegetal remains and 80% finely crystallized, fissured and porous

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[43] Daicoviciu et al. 1954, 142.

[44] A sample of this mortar was included in a bulletin made by the Department of Geology of the Babeş-Bolyai University (no. 14 in the Buletin de Analiză Mineralogică şi Petrografică nr. 9/2018) for the National Museum of Transylvanian History in Cluj-Napoca. The analysis had the purpose of describing the mineral and petrographic characteristics of the samples, through polarized light microscopy and X-ray diffraction.

mineral mass. The sand is constituted by lithic fragments of crystalline schists (gneiss) and quartzites, together with minerals of quartz, muscovite, and biotite. The vegetal inclusions are about 1 cm, and they represent charred fragments from deciduous trees, since annual growth rings were identified (Fig. 4/d-e). The mass of the mortar contained agglomerations of calcium carbonate (calcite), sometimes mixed with chlorites and/or portlandite (calcium hydroxide), together with crystallized compounds like para-aluminohydrocalcite, calcium hydrated oxide, aluminium and/or gypsum (Fig. 5). Sometimes, calcium was associated with lamellar chlorites or depositions of neoformation calcium enveloped muscovite minerals (Fig. 4/f), that represented the support for the recrystallization of these neoformation minerals during the hydration and strengthening of the mineral bind. This composition could suggest the use of natural materials like volcanic ash or tuff, mixed with natural gypsum and lime[45].

The sample is of a greyish colour when finely crushed (Fig. 4/a-b). The apparent strength of the mortar was determined by its highly reactive compounds, with few and carefully selected aggregrates (sand and charcoal), mixed in an 80% lime-based matrix. The presence of gypsum as trace element (Fig. 5) indicates that the mortar functioned as an undercoat, because of its water solubility. Usually, after being burnt, gypsum was used as plaster for interiors, or to facilitate setting in floor undercoats – this was attested in the Roman cisterns of Carthage, where gypsum was included in base coats, while the older Phoenician cisterns were using ash-mortar as undercoats[46]. Apart from charcoal, it was suggested in the archaeological documentation and in the report that this mortar also contained organic ash, but the latter was not mentioned in the analysis. Smaller fragments of wooden charcoal can be observed in some of the microscopic images (Fig. 4/e). Even smaller ashes could have been added to the mix, but these are hard to identify because the calcium carbonate mass of the binder is very similar to the fine ash component, which is mostly calcium carbonate[47]. These smaller charcoal fragments and possible ashes most likely resulted from the same process of wood burning. This can be asserted because when charcoal is found in mortars, it is usually associated with ashes[48], and also because no other types of organic remains were identified in this mortar.

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[45] Buletin de Analiză Mineralogică şi Petrografică nr. 9/2018.

[46] Goodman 1998, 14, n. 27.

[47] Goodman 1998, 34.

[48] Lancaster 2019, 35.

The use of volcanic compounds, although suggested in the analysis bulletin, was not documented directly (obvious volcanic tuff fragments were not identified), even though it is mentioned that some of the minerals contained in the sand aggregate could have had volcanic origins. But these minerals could have been of local origin as well, as sand aggregate with similar constituents is used in the local ceramic material (quartz, muscovite, biotite etc.)[49]. As such, if volcanic compounds were used, they had to be smaller ash-sized volcanic particles. Such grains are altered during the *pozzolanic* reaction, which makes them harder to identify[50]. Recent investigations on Roman revetment works in Italy have demonstrated that this special mortar used a calcium, silicium and aluminium hydrated fundamental binder[51]. The *pozzolanic* reaction in these mortars was determined by the use of silica rich volcanic ash (*pulvis*), while tuff was used as aggregate (*caementa*)[52]. In general, a hydraulic mortar is defined by its calcium silicate hydrate phases (determined by the use of *pozzolana* or other similar substances, such as burnt clay)[53]. Similar elements appear in the diffraction pattern of the sample from Blidaru (Fig. 5), thus possibly indicating a hydraulic property of the mortar. Burnt clay determines a hydraulic reaction as well, because it contains very high levels of silica[54]. The mortar sample from Blidaru contained no tuff *caementa*, but a silica rich sand, which could have conferred some hydraulic properties to this mortar, although they represent only 10% of the mass.

The proper identification of possible traces of volcanic ash in this mix needs to be investigated through specific analysis. As such, for the moment it is safer to assume that the mortar was based on a mass rich in lime and other binding substances, that, when mixed with sand aggregate, had a low or non-hydraulic character. This would not be uncommon, as even Vitruvius recommended, in his discussion related to revetment works, the use of a concrete made of lime and silica sand when *pozzolanic* mortar was not available[55].

The other aggregate used in this mortar was not discussed until now, namely the charcoal fragments. However, as will be shown bellow, these do not contribute to a possible *pozzolanic* reaction, as they are not silica-, but carbon-based[56] (the calcium carbonate trace in the diffraction

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[49] Vasilache 2022, 184.
[50] Jackson et al. 2013, 1677.
[51] Jackson et al. 2014, 141.
[52] Oleson, Jackson 2014, 4.
[53] Lancaster 2012, 146.
[54] Lancaster 2012, 146.
[55] Oleson 2014, 22.
[56] Goodman 1998, 40.

could have come from ash and charcoal, besides lime). The presence of wood charcoal, as larger aggregate, and the probable use of wood ash as well, determined other qualities in this mortar.

A more recent study focused on the different types of inclusion present in mortars from Greece, based on 1302 samples ranging from the Hellenistic to the early modern period. Charcoal was present in samples from all eras, mostly in structural mortars (more than 20% of the samples – many of which are dated in the Ottoman period), but in low quantities (0,5-1%), with random shapes, and with sizes varying between 0,5-2 cm[57]. In the Hellenistic period, charcoal was present in less than 1% of the samples and these were of a round shape. Charcoal was present in 0,5-1% of the samples of Roman mortars; these fragments were sensibly larger (1-1,5 cm) and in good adhesion with the binder[58]. The proportions were similar in samples taken from mortars from other periods. This sporadic presence of charcoal was explained through its accidental inclusion in the composition following the burning of lime[59].

When analyzing pozzolans, L. Lancaster observed that a difference should be made between plant ashes and wooden charcoal. The first ones can contain a high level of silica that reacted with lime and were converted into calcium sylica hydrate (the fact that this specific element was not identified in the diffraction of the sample from Blidaru could suggest that this mortar did not contain plant ashes). On the other hand, since wood charcoal is carbon-based, it does not react with lime as some plant-based ashes do[60]. The author observed that most ash mortars were found in Levant, North Africa, southern Spain and on the Mediterranean islands such as Pantelleria and Sardinia, all being regions that were connected in one way or another to a Phoenician/Punic presence at some point (Fig. 7). She relates this to a late 4th c. BC mention belonging to Theophrastus (On Stones, 69), which says that in Phoenicia and Syria, *gypsos* was made by regularly burning the ordinary kinds of stones, while the harder stones, like marble, had to be combined with cow manure to burn better and more quickly[61]. Based on this, Lancaster supposes that this practice led to the understanding that some ashes can, indeed, help to create a hydraulic binder[62]. This was further emphasized by the fact that most examples of plant ash-based mortars (Fig. 7) were used as linings of baths and basins, while only a few

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[57] Stefanidou et al. 2012, 747.

[58] Stefanidou et al. 2012, 747.

[59] Stefanidou et al. 2012, 747; Lancaster 2019, 35.

[60] Lancaster 2019, 35.

[61] Lancaster 2019, 37.

[62] Lancaster 2019, 37.

were found in structural mortars[63]. Some examples are the cistern underneath the "House of the Greek Charioteers" in Carthage, where a coating with 5-10% burnt organic material (undetermined) was used in a first phase, being covered afterwards by a coating layer that contained no ashes, but 30-40% volcanic material. Other similar cisterns from Byrsa in Carthage were using small amounts of ash. In the same "House of the Charioteers", another mortar used in a structural wall contained many types of charred plant remains (olive pits are the most common, but other plant remains like wheat, barley, rye, canary grass and figs were also found, all indicating a high-silica type of ash)[64]. In a study that compared cistern linings from the Phoenician to the Roman period in Carthage, it is shown that the Phoenician plasters contained at least 3-5% burnt organical material, 30-40% shell fragments and sand, in a 50% lime matrix, with one particularly hard mortar that contained 10-15 % organic ash[65].

The use of ash mortar in this area is interesting, since the Romans usually employed *opus signinum* mortar for waterproofing. Particular archaeological contexts from this area attest the use of *opus signinum* coatings that are overlapping older ash-based coatings. However, the use of such mortars in the area persisted in the Roman time as well, and the aqueducts and cisterns at Meninx in the 2nd and 3rd c. AD show that it was used together with *opus signinum*[66]. As such, the mortars that contained ashes, especially of burnt plants, were purposefully used as hydraulic coatings in North Africa, especially when their proportions are higher than what can be considered accidental.

Other similar ash mortars have been documented in the Levant and have been connected to a similar, although older, Phoenician tradition. Well-dated hydraulic ash mortars were documented starting with the 1st c. BC, and they were usually employed as undercoats in water-related structures (Fig. 8)[67]. A specific kind of these mortars was found in the channel C of Caesarea's Roman aqueduct, which was built sometime in the late 4th c. AD and functioned until the 10th or 11th c.[68]. Here, the channel of the aqueduct was coated starting with a porous ash layer that contained relatively few, coarse aggregates (sand, shells and ceramic fragments – the fact that no finer aggregate was found was related to the complementary use of ash) and charred remains of both plant ash (from animal dung) and

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[63] Lancaster 2019, 37.
[64] Lancaster 2019, 37.
[65] Goodman 1998, 10.
[66] Lancaster 2012, 149.
[67] Goodman 1998, 11.
[68] Goodman 1998, 17.

wood charcoal for approximately 10-20% of the mix (Fig. 9/c-d)[69]. This layer was covered by a reddish, hydraulic mortar (of *opus signinum* type), that was coated with a reddish plaster on top (Fig. 9/a-b). The grey undercoat was applied directly on the masonry (it was suggested that the ash and the few coarse aggregates contained in this mortar may have had the role of increasing adhesion of the mortar to the masonry base)[70], providing the appropriate gradient for the channel. The next, hydraulic layer was placed upon the undercoat when the latter was only stiffening so the two had a diffuse interface. In contrast, the finishing plaster on top of the hydraulic support was applied on the latter after it had already stiffened[71].

The latter observations from Caesarea can be related to the apparent "organic" bound observed between the charcoal undercoat (4) and *opus siginum* uppercoat (3) in the Blidaru cistern, indicating a similar manner of setting for these layers.

The three-layered coating of the channel at Caesarea was, soon after building, covered by another similar set of layers (the only difference is that smaller aggregate was used in the base layer for a smoother application), probably because this segment of the aqueduct was prone to water stagnation and needed to have its gradient remodeled[72].

Although the situation from Caesarea is similar to the one from Blidaru (because of the similar succession of strata and their characteristics), there are some differences. Firstly, the organic fraction in the mortar at Caesarea was of both plant and wood origin, which gave the mortar a somewhat hydraulic property, while the one from Blidaru was represented only by non-reactive charcoal and ash. Secondly, the aggregates included in the Caesarean mortar were more diverse than the ones from the Blidaru cistern, although in both cases they represented a relatively small fraction of the whole composition. Thirdly, it is evident that the wooden charcoal was used at Blidaru as aggregate because of its proportion, while at Caesarea the charcoal fragments were fewer in number, and a part of a more diverse range of inclusions.

The results of Goodman's analysis of the effects of adding ash in mortars might be helpful for our case study. He experimented with some mortar samples which had a lime and sand aggregate, and he added to this mix a quantity (0%, 10%, 20%, and 30% respectively) of sieved, non-reactive wooden ash. He observed that the ideal quantity of ash in mortars

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[69] Goodman 1998, 34.

[70] Goodman 1998, 34.

[71] Goodman 1998, 29.

[72] Goodman 1998, 29.

is 10-20%, as it enhances the workability, adhesion, flexural strength, porosity and brute density, speed of setting and contraction, crack resistance, water retention, absorption and vapor transmission increase (Fig. 10). One major problem was identified: wood ash lowers the resistance of lime plasters to crystallization stresses determined by soluble salts and ice formation during freeze/thaw cycles[73]. The author considered that this susceptibility to frost would limit its use in colder climates like that of North America and Europe[74].

The latter aspect is evident in the conserved state of the sample from Blidaru, as its mass is fissured. This does not necessarily indicate that the ash could not have had a positive contribution to this binder, at least for a time, because the layer in question has deteriorated especially after the cistern went out of use. However, there is a big difference between these mortars, as the samples studied by Goodman were based mainly on ash-sized particles of wood charcoal, while the Blidaru sample contains mostly charcoal fragments, while ashes may have also been included. With regard to the external soluble salts that could affect ash mortars, it has to be noted that this problem is most likely to arise in the Mediterranean coastal regions, and that the mortars will not necessarily degrade if they are covered/protected by an additional layer[75]. Such a solution may have been considered by those who constructed the Blidaru cistern, since the layer with charcoal and ash from the first floor was applied between an undercoat and an upper, hydraulic layer, but for a different reason.

Fine ash determines the creation of small pores and microcracks that are more susceptible to freezing, although in normal circumstances these increase the flexural strength or the adhesion of the mortar[76]. Both charcoal and fine ash components absorb water during the process of mixing of the mortar, and release highly soluble potassium salts that could have a similarly negative effect on mortars affected by frost[77]. Although this was not the purpose of his analysis, Goodman observed that larger charcoal fragments could have a significant role in improving the performance of lime plasters for base coats. This was exemplified through the increased water retention capacity of charcoal in comparison to that of the finer ashes, that reduced cracking due to rapid shrinkage and improved workability and adhesion to porous substrates[78]. He also considered that

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[73] Goodman 1998, 119.

[74] Goodman 1998, 131.

[75] Goodman 1998, 131, n. 118.

[76] Goodman 1998, 133.

[77] Goodman 1998, 40-43, 62, 113, 132.

[78] Goodman 1998, 131.

the increase in flexural strength and adhesion of the mortar could be attributed to the effects of the charcoal, that was acting as a flexible aggregate, intended to accommodate shrinkage[79]. In samples from both Caesarea and Blidaru good binding between the wooden charcoal fragments and the mass can be observed, as the fragments present microcrystalline calcite that is interspersed in their structure (Fig. 5/d-e; Fig. 7/d). As such, the apparent preference for charcoal instead of finer ash in the mortar from Blidaru could have been intentional, in an effort to minimise the cracking of the mortar affected by frost, as this was especially determined by the ash fraction. In any case, if the proportion of charcoal fragments in the mix from Blidaru was estimated at 10%, the unknown proportion of ash probably did not exceed, together with the charcoal, the maximum 20% proportion of organic additives suggested to be used in ash-mortars by Goodman. Nevertheless, the use of mortars with ash in this climate seems to have been problematic, and this may explain the predominance of the charcoal fraction in the mortar from Blidaru, together with the fact that it was employed as an intermediate layer.

Specific studies on this mortar would prove useful for the assessment of its particularities and, more importantly, for determining the effects of charcoal as aggregate in mortars. More data about the role of this layer could come from the analysis of the other complementary and even harder undercoat (layer 5 – Fig. 3/c). This mortar without any apparent aggregate had a lighter color than that of the overlying layer. It could be possible that this colour was determined by an ash component, as charcoal is definitely absent in layer 5. The fact that this layer is mentioned to have had a fine surface could be related to its apparent lack of aggregate (perhaps the latter was concentrated only in its lower side), but also to the probability that the mortar was levelled (which would imply a faster stiffening rate, as in the case of the overlying layer). It is also unclear if another layer followed this one and in what way was the contact with the soil managed.

The floor of the first phase of the cistern can be thus described as being composed of at least two complementary undercoat layers (the upper one containing charcoal), that were covered by a hydraulic *opus signinum* layer, which was in turn plastered with a finer *opus signinum*. The use of charcoal in the middle layer cannot be related to the need for imprinting a hydraulic property to this mortar (which was achieved, eventually, through the use of other compounds). Therefore, the use of charcoal as aggregate probably enhanced other properties, such as

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[79] Goodman 1998, 134.

porosity, water absorption, flexibility, reduced cracking due to shrinkage, adhesion etc., that were more important in undercoats. The ash mortars from Caesarea, even if they were somewhat hydraulic (thanks to the inclusion of plant ash and other aggregates), they were also more porous and permeable than their upper hydraulic linings[80]. As such, it seems that during the Roman times, in Levant and North Africa, the ash mortar became a typical undercoat for *opus signinum* hydraulic uppercoats.

The use of non-reactive charcoal was employed in revetment works from the classical world[81], and its benefits were known by ancient authors. While describing the casting of concrete blocks for port embankments, Vitruvius mentions (V/12.6) that if the soil was soft, it had to be treated with charred alder or olive wood pillings filled with charcoal, which is similar to the method he recommended for preparing the foundations of theathres and city walls[82]. This brings to mind Plinius the Elder's remarks on the architect Chersiphron, who treated the marshy soil underneath the foundations of Diana's temple in Ephesos by applying layers of trodden charcoal that were covered by wool[83]. Additionally, some of the *pozzolanic* mortars that were used in embankments contained charcoal, as shown by a sample from Portus, which contained numerous fragments of charcoal, besides pieces of basketry, rope and lumps of relict lime[84].

More information regarding the use of charcoal and ash in the mortar can be found, once again, in Vitruvius' *De Architectura*, namely in the passage about the simple, yet effective Greek technique of paving floors in winter rooms [85]. According to him, the first step would be to excavate the ground until a depth of about two feet is reached. Then, a mass of broken stones or burnt brick has to be arranged in such a way, that its inclination would allow the formation of vents in the drain. This first layer had to be covered with compact, trodden charcoal. Afterwards, a mortar made of gravel, lime and ashes had to be poured over to a depth of half a foot. The last step was the levelling the surface of the mortar layer. In this way, a meritorious pavement was obtained: ′hence, at their dinner parties, whatever is poured out of the cups, or spirted from the mouth, no sooner falls than it dries up, and the servants who wait there do not catch cold from that kind of floor, although they may go barefoot′[86].

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[80] Goodman 1998, 18.
[81] Lancaster 2019, 35.
[82] Oleson 2014, 22.
[83] Pliny, XXXVI, 21.
[84] Hohlfelder, Branson 2014, 58.
[85] Vitruvius, VII, 4.5.
[86] Vitruvius, VII, 4.5.

As such, it appears that in the classical world, the non-reactive charcoal could have been used as a specific layer when preparing different foundations. Sometimes, it was included in *pozzolanic* mortars of revetment works. The Greek technique described by Vitruvius is different, since in this case ash mortars were applied at the surface of floors and not as undercoats, while charcoal was basically used as in the foundation preparations. In the Phoenician environment, non-reactive charcoal was always associated with plant ash in undercoats of cistern linings. Additionally, mixes that contained charcoal and other aggregates (*e.g.* ceramic fragments) are attested in cistern linings such as those from Pentelleria island[87] or Petra[88]. Until now, I was able to find only one case where charcoal was used as a main aggregate, namely in a cistern render from the Roman town of La Rioja in Spain. There, the mortar was used as a base coat in a large pool belonging to a thermal complex, that is loosely dated from the 1st to the 4th c. AD[89]. Although other samples of mortar from the same town contained sporadic charcoal, only in the case of the coat from the pool base is the inclusion of charcoal fragments considered to be deliberate, because they were abundant and evenly distributed[90].

To conclude, non-reactive charcoal seems to have been used in the classical world for preparing foundations on wet ground. Such a tradition could have determined the use of charcoal in undercoat mortars of water-related structures. One might think, when dealing with large structures, of structural matters as well. The cistern from Blidaru was erected on a rough terrain and in an area with heavy precipitations, which may suggest that it required a strong and adhesive undercoat that could also combat moisture.

Conclusion

The aforementioned archaeological discoveries show that cistern linings made with ash and charcoal had a long tradition in the Phoenician-influenced southern and eastern mediterranean areas. After these regions were integrated in the Roman Empire, ash mortars remained in use, but as undercoats and in association with *opus signinum* hydraulic uppercoats (*e.g.* at Carthage, Caesarea, Pentelleria etc.). A similar association is seen in the layers of the first floor from the Blidaru cistern. In this case, however, the situation is slightly different, because the wood charcoal was used as main aggregate in the mortar of the first undercoat, an aspect that was not common in the southern and eastern Mediterranean ash-based mortars.

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[87] Schön 2014, 105.

[88] Bonazza et al. 2013, 466.

[89] Pavia, Caro 2008, 1810.

[90] Pavia, Caro 2008, 1810.

Additionally, in the classical world, charcoal was included in mortars used for the foundations and structures that were built on soft and marshy ground for a very long time. As such, it is unclear if the Roman practice of including charcoal fragments in *pozzolanic* revetment mortars or as aggregate in undercoat mortars of water related structures can be only related to a Punic influence. The use of charcoal as an aggregate in undercoat mortars (that was documented only at Blidaru and La Rioja) seems to represent a partly different "recipe" from the Phoenician ash-based one, in the sense that the latter was given a hydraulic property through the inclusion of plant ashes in the mix. For example, older ash-based mortars were sometimes used as single-layer linings in cisterns, so their hydraulic property was important (at "The House of the Charioteer in Carthage", or in the Levant during the Herodian period – Fig. 7). This is further demonstrated by the replastering of these initial coatings with *opus signinum* during the later Roman period (the cisterns from "The House of the Charioteer" in Carthage and El Maklouba)[91]. On the other hand, during the Roman period, new linings of cisterns employed ash mortars as undercoats in junction with *opus signininum* hydraulic uppercoats (at Meninx, Caesarea or at various Levantine sites – Fig. 7), indicating that this older technique was used now in a somewhat different purpose, for which the mortar did not had to be necessarily hydraulic. The fact that a similar association of mortars was employed in first floor of the cistern at Blidaru indicates that both types of organic mixed mortars (with plant ash/wooden charcoal) were used in a similar manner as undercoats, even though they had somewhat different properties. This could suggest that the Romans developed the model of organic mortar as undercoat/*opus signinum* as uppercoat in the southern and eastern Mediterranean areas, afterwards transferring it to other areas. Thus, the use of charcoal instead of ash in base coat mortars may be related to the actual adaptation of this type of mortar to colder conditions, while the ash-based mortar was used in parallel and for similar purposes in the areas where it had a long tradition and where the climate permitted. This does not exclude that the similarly old tradition of using charcoal at the base of foundations attested in the classical world did not contribute to the use of charcoal in undercoat mortars. However, given the arguments presented above, it it most likely that the association of organic mortar undercoats and *opus signinum* uppercoats appeared in the southern and eastern Mediterranean areas during the Roman period.

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[91] Lancaster 2012, 149.

As such, the model could have reached Blidaru only after its establishment in the above-mentioned areas and could have been transferred in Dacia mainly through the Romans. This must have happened (at least) before the end of the 1st c. AD, as the chronology of the cistern from Blidaru suggests.

The cistern from Costeşti-Blidaru presents other probable Roman technical influences. To the use of *opus signinum* hydraulic mortar (associated with a charcoal mortar undercoating), we could add the barrel-vault made out of *voussoir* limestone blocks and the *opus caementicium* exterior wall that were elevated above ground. The construction of barrel-vaulted cisterns partially or entirely elevated above ground was made possible once the mortared rubble building techniques appeared in the Roman period[92]. As such, the cistern from Blidaru was probably built by a Roman engineer or at least by someone who was familiar with Roman building techniques. Such characteristics of the structure and the materials that were used indicate that it could not have been built earlier, under a Hellenistic technical influence, as is the case of the fortress that it supplied. The building of the cistern would not have been possible if the people who designed it did not possess specific knowledge. The architectural features of the cistern and the use (of the correct proportion) of charcoal in the composition of the undercoat are direct proof of the constructors' know-how. Once this has been established, one other question remains: does the employment of Roman techniques indicate when was the cistern built?

As shown in the beginning, both C. Daicoviciu and I. Glodariu proposed a rather late date (given the general chronology of the fortress) for the construction of the cistern. According to the authors, the cistern was in use only during the second phase of the fortress in the 1st c. AD. Recent archaeological investigations showed that two towers which dominate Faeragului ridge and are part of the defensive system around Blidaru fortress (Fig. 2), had *opus signinum* floorings (Fig. 13). Their chronology suggests that the floors were set up during a later phase, when the towers were partly dismantled[93]. These are the only two cases when *opus signinum* mortar was used in Dacian related structures in the Orăştie Mountains. This particularity is further evidenced by the fact that the Hellenistic construction techniques traditionally employed in the area did not use binders, as they relied heavily on ashlar masonry. As such, the *opus signinum* mortars attested in the structure of the cistern at Blidaru and in the second phase of the towers from Faeragului ridge seem to indicate

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[92] Wilson 2008, 289.

[93] Pescaru et al. 2014, 10.

another type of classical construction technique in the architecture of the Orăştie Mountains area, but this time of a Roman origin and quite possibly of a later date than that of its Hellenistic counterpart. The fact that in both cases the mortars were employed in the later phases of the structures they served (with the cistern related to the fortress) could suggest that they were used in temporal proximity. At the same time, this cannot be used as evidence for a singular constructive effort, as the refurbishment of the second phase of the cistern with *opus signinum* confirms that the technique could have been used at any time in the area after its initial employment.

Such observations seem to be in line with the chronology proposed for the cistern's construction by the archaeologists, namely sometime during the 1st c. AD and most likely in its second half. Literary sources also hint towards such a possible moment, as we know from Cassius Dio that Domitian '[…] had given large sums of money to Decebalus on the spot as well as artisans of every trade pertaining to both peace and war […]', as part of their 89 AD truce[94]. As such, it could be possible that the cistern was built by a Roman architect after 89 AD, as a result of this treaty. The construction of the cistern could not have been delayed much longer than this, since the structure was refurbished before the conquest of the area by the same Romans in 106 AD. However, even if this represents a possibility, one might not exclude other moments when this technique could have been imported, as the contact with the Romans is well attested in the area through other material evidence. I. Glodariu spoke about the gradual re-orientation of the Dacian trade from the Hellenistic towards the Roman world between the end of the 2nd c. BC and the 1st c. AD (in the latter century the Roman coin became dominant in the local environment)[95]. Such a process could be paralleled by the apparition of new construction techniques in the Orăştie Mountains, this time of Roman origin. The fate of the cistern is suggestive for the relationship between the Dacian Kingdom and the Roman Empire during this period: it was built to enhance the defenses of the fortress at Blidaru, but symbolized at the same time the growing influence of the Romans in the area.

This cistern was, indeed, built using classical techniques, following many of Vitruvius' recommendations (such as the use of signine mortars for coating) and following certain recipes (like that of the charcoal mortar). The structure's technique of construction is out of the ordinary for the local environment, as no other mortar structures from the Dacian period are attested with certainty (with the exception of the above mentioned tower

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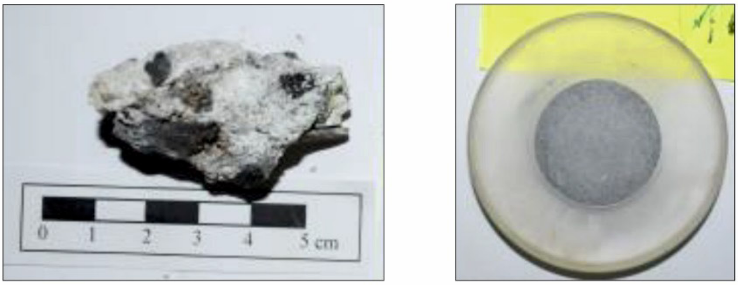
[94] Glodariu 1983, 125; Cassius Dio, LXVII, 7.

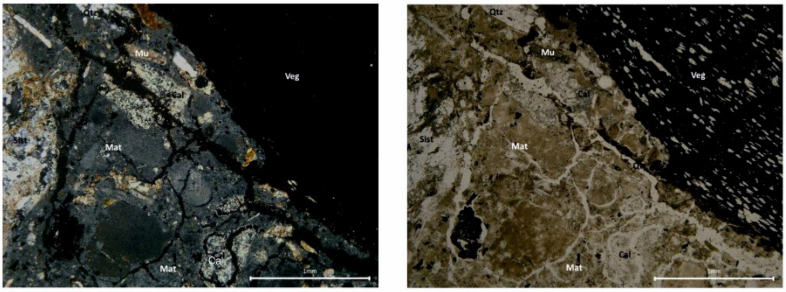
[95] Glodariu 1974, 174-178.

floorings), neither in the Orăştie Mountains area, nor in the rest of Dacia. This attests that the employed techniques were imported in the area, being at the same time different from other classical influenced techniques and structures attested well before this moment in time. From a macro-regional point of view, the presence of this type of structure in the humid and mountainous area of south-western Transylvania, together with special materials, like the charcoal mortar, is an exception to the general distribution of such materials and structures that are usually found around the Mediterranean basin (Fig. 7).



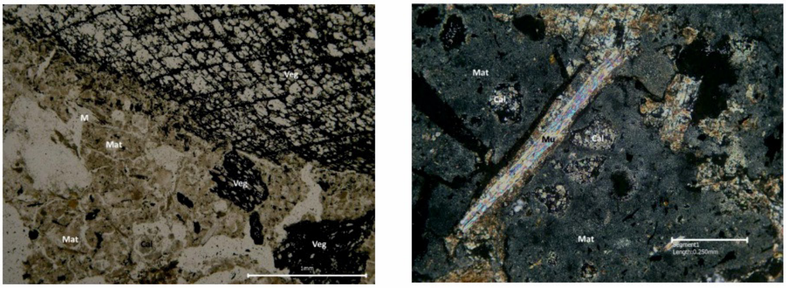
a. Macroscopic aspect of the sample

b. Finely crushed aspect of the sample.



c. Structural-textural microscopic image (N+) of the sample, with lithoclasts (schists) and carbonized vegetal remains (Veg), bound in the matrix (Mat) with visible calcite granules (Cal).

d. Structural-textural microscopic image (1N) of the sample, with lithoclasts (schists) and carbonized vegetal remains (Veg), bound in the matrix (Mat), with visible calcite granules (Cal).



e. Structural-textural microscopic image (1+) of the sample, with carbonized vegetal remains (Veg), calcite (Cal), bound in the matrix (Mat).

f. Structural-textural microscopic image (N+) of the sample, with mineral (muscovite) with neoformation rim, pores with calcite in the matrix (Mat).

Fig. 4. Photos (**a**-**b**) and microscopic images (**c**-**f**), of the sample of mortar with charcoal from Costești-Blidaru cistern, after 'Buletin de analiză', Fig. 60-63.

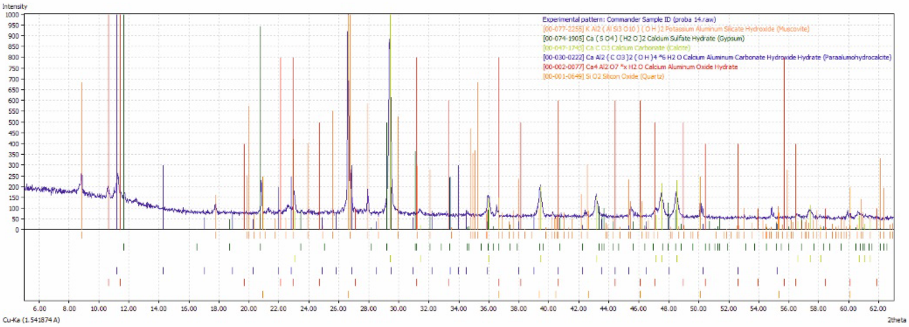


Fig. 5. X-ray diffraction pattern of the sample with lines characteristic to quartz, calcite, muscovite, para-aluminohydrocalcite, gypsum and calcium aluminium hydrated oxide, after 'Buletin de analiză', Fig. 64.

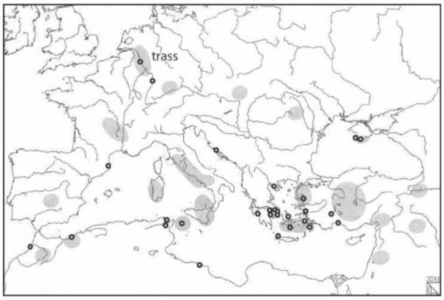


Fig. 6. Map showing locations of mortars containing volcanic ash (grey areas denote volcanic zones), after Lancaster 2019, Fig. 2.

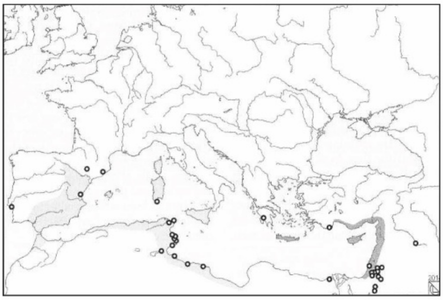
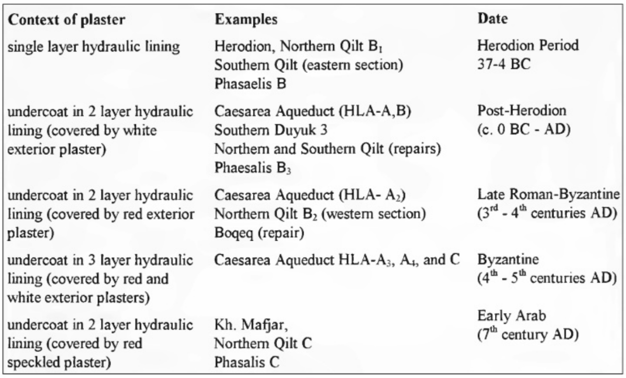
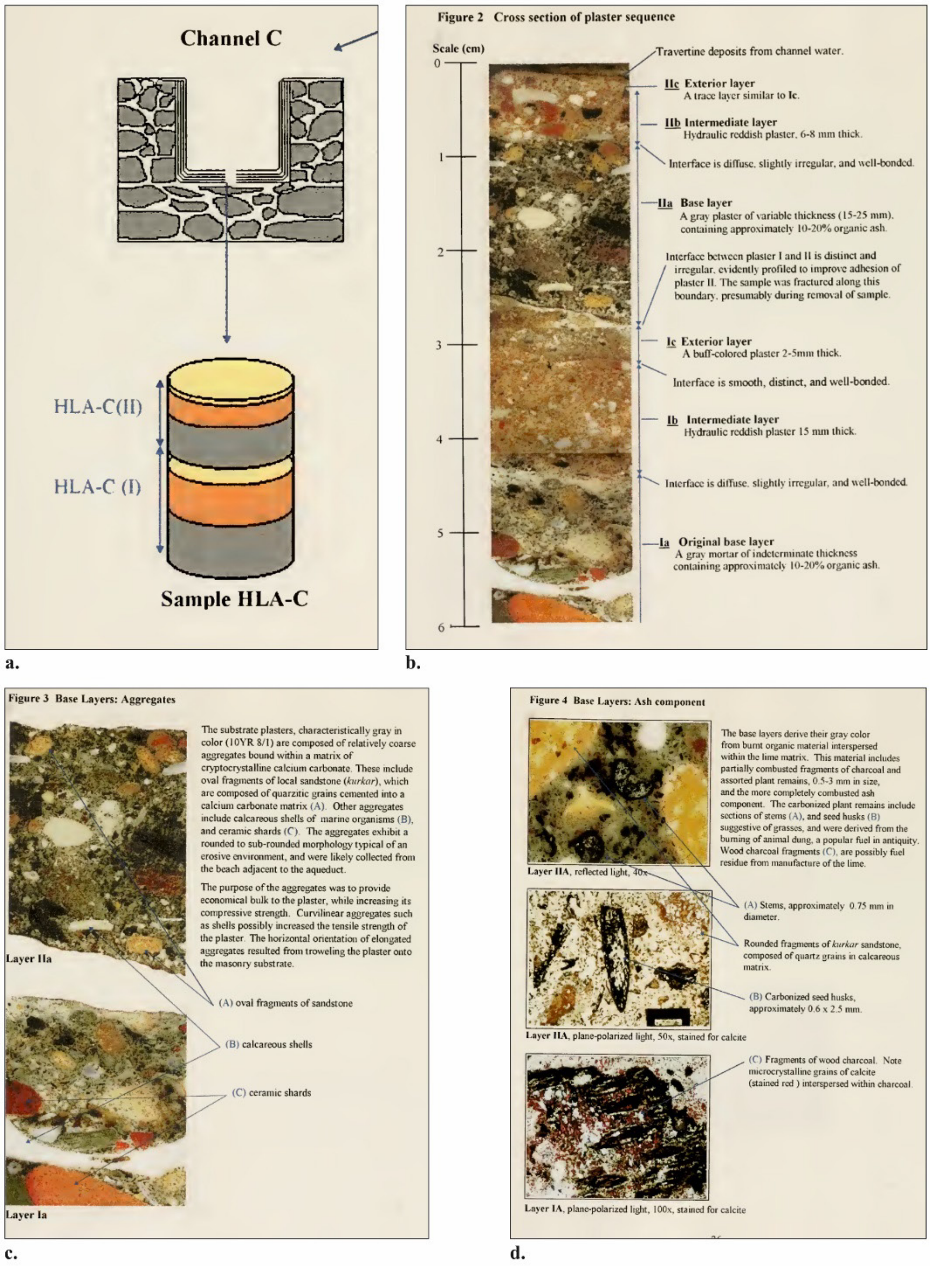


Fig. 7. Map showing locations of mortars containing ash (dark grey areas denote Phoenician influence and light gray areas of Punic influence), after Lancaster 2019, Fig. 6.



Context of plaster	Examples	Date
single layer hydraulic lining	Herodion, Northern Qilt B_1 Southern Qilt (eastern section) Phasaelis B	Herodion Period 37-4 BC
undercoat in 2 layer hydraulic lining (covered by white exterior plaster)	Caesarea Aqueduct (HLA-A,B) Southern Duyuk 3 Northern and Southern Qilt (repairs) Phaesalis B_3	Post-Herodion (c. 0 BC - AD)
undercoat in 2 layer hydraulic lining (covered by red exterior plaster)	Caesarea Aqueduct (HLA- A_2) Northern Qilt B_2 (western section) Boqeq (repair)	Late Roman-Byzantine (3rd - 4th centuries AD)
undercoat in 3 layer hydraulic lining (covered by red and white exterior plasters)	Caesarea Aqueduct HLA-A_3, A_4, and C	Byzantine (4th - 5th centuries AD)
undercoat in 2 layer hydraulic lining (covered by red speckled plaster)	Kh. Mafjar, Northern Qilt C Phasalis C	Early Arab (7th century AD)

Fig. 8. Chronology of ash rich plasters found in Israel, dating from the 1st c. BC to the 7th c. AD, after Y. Porat, quoted in Goodman 1998, Table 1.



Travertine deposits from channel water.

IIc Exterior layer
A trace layer similar to **Ic**.

IIb Intermediate layer
Hydraulic reddish plaster, 6-8 mm thick.

Interface is diffuse, slightly irregular, and well-bonded.

IIa Base layer
A gray plaster of variable thickness (15-25 mm), containing approximately 10-20% organic ash.

Interface between plaster I and II is distinct and irregular, evidently profiled to improve adhesion of plaster II. The sample was fractured along this boundary, presumably during removal of sample.

Ic Exterior layer
A buff-colored plaster 2-5mm thick.

Interface is smooth, distinct, and well-bonded.

Ib Intermediate layer
Hydraulic reddish plaster 15 mm thick.

Interface is diffuse, slightly irregular, and well-bonded.

Ia Original base layer
A gray mortar of indeterminate thickness containing approximately 10-20% organic ash.

The substrate plasters, characteristically gray in color (10YR 8/1) are composed of relatively coarse aggregates bound within a matrix of cryptocrystalline calcium carbonate. These include oval fragments of local sandstone (*kurkar*), which are composed of quarzitic grains cemented into a calcium carbonate matrix (A). Other aggregates include calcareous shells of marine organisms (B), and ceramic shards (C). The aggregates exhibit a rounded to sub-rounded morphology typical of an erosive environment, and were likely collected from the beach adjacent to the aqueduct.

The purpose of the aggregates was to provide economical bulk to the plaster, while increasing its compressive strength. Curvilinear aggregates such as shells possibly increased the tensile strength of the plaster. The horizontal orientation of elongated aggregates resulted from troweling the plaster onto the masonry substrate.

The base layers derive their gray color from burnt organic material interspersed within the lime matrix. This material includes partially combusted fragments of charcoal and assorted plant remains, 0.5-3 mm in size, and the more completely combusted ash component. The carbonized plant remains include sections of stems (A), and seed husks (B) suggestive of grasses, and were derived from the burning of animal dung, a popular fuel in antiquity. Wood charcoal fragments (C), are possibly fuel residue from manufacture of the lime.

Layer IIA, reflected light, 40x

(A) Stems, approximately 0.75 mm in diameter.

Rounded fragments of *kurkar* sandstone, composed of quartz grains in calcareous matrix.

(B) Carbonized seed husks, approximately 0.6 x 2.5 mm.

Layer IIA, plane-polarized light, 50x, stained for calcite

(C) Fragments of wood charcoal. Note microcrystalline grains of calcite (stained red) interspersed within charcoal.

Layer IA, plane-polarized light, 100x, stained for calcite

Fig. 9. The multilayered coatings of channel C of the Roman aqueduct at Caesarea Maritima, after Goodman 1998, Fig.1-4.

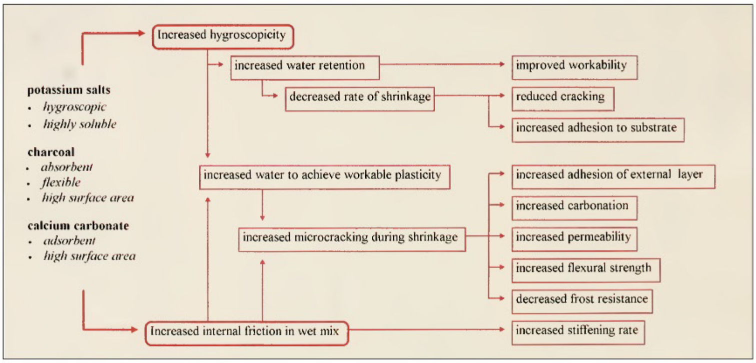


Fig. 10. The proposed mechanism by which wood ash improves lime plaster for base coat application, after Goodman 1998, Fig. 73.

Fig. 11. *Opus signinum* flooring in tower no. 1 on the Faeragului plateau, after Pescaru et al. 2014, Fig. 8.

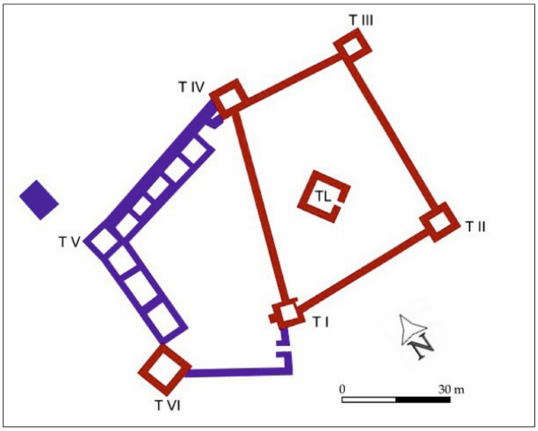


Fig. 12. Plan of the Costești-Blidaru fortress with main construction phases highlighted, after Pescaru et al. 2014, Fig. 2.

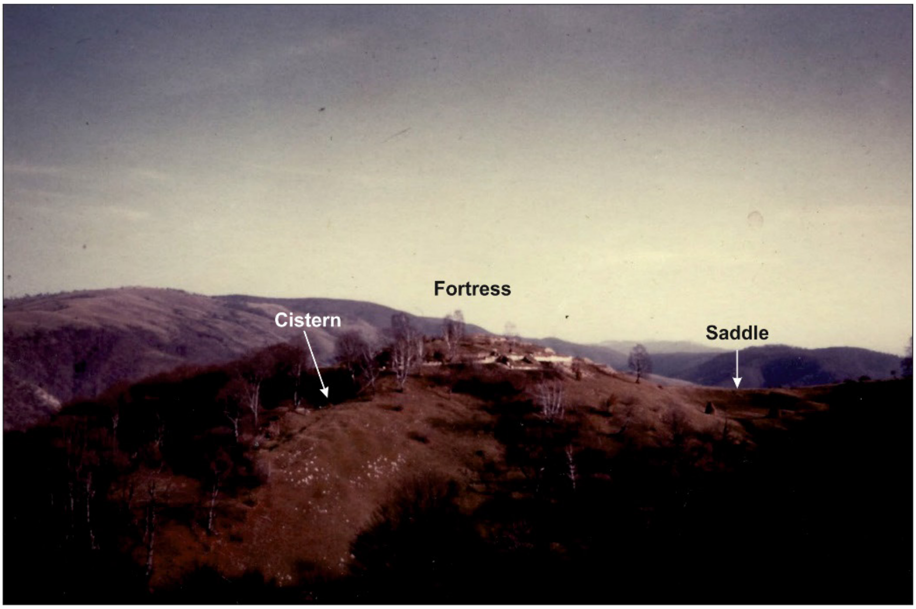


Fig. 1. The Blidaru hillock viewed from the East, after Pescaru et al. 2014, Fig.1.

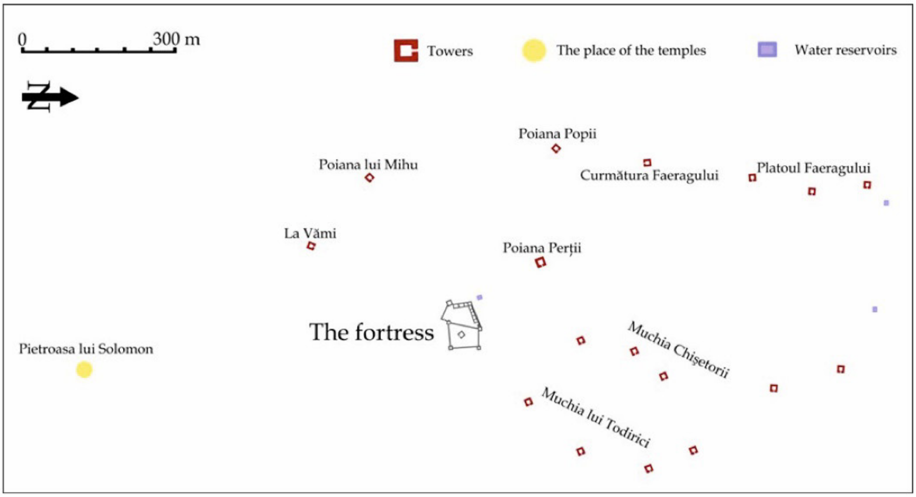


Fig. 2. The defensive network around Blidaru fortress, after Pescaru et al. 2014, Fig.4.

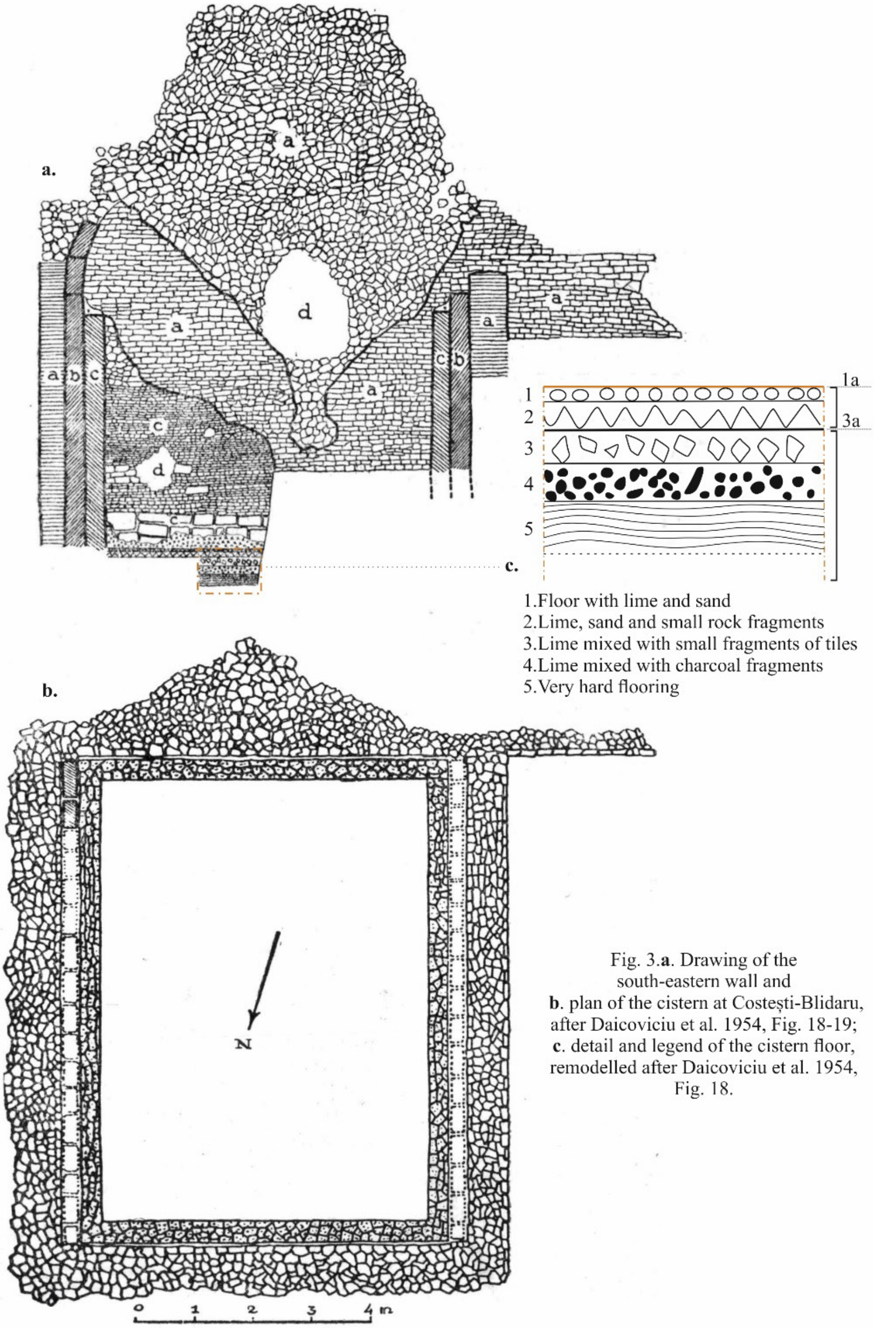


Fig. 3.**a**. Drawing of the south-eastern wall and **b**. plan of the cistern at Costești-Blidaru, after Daicoviciu et al. 1954, Fig. 18-19; **c**. detail and legend of the cistern floor, remodelled after Daicoviciu et al. 1954, Fig. 18.

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