‘…incorrupti imbribus, ventis, ignibus omnique caemento firmiores?' Earthen building materials in the Roman West

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Earthen Building Materials in the Roman West

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In Book 35 of his Natural History, immediately after his discussion of *pozzolana*, Pliny the Elder dedicates a short section of his account to reminding his readers of the varied uses of earth in building. It is worth quoting in full, given its succinctness (35.48):

> *quid? non in Africa Hispaniaque e terra parietes, quos appellant formaceos, quoniam in forma circumdatis II utrimque tabulis inferciuntur verius quam struuntur, aevis durant, incorrupti imbribus, ventis, ignibus omnique caemento firmiores? spectat etiam nunc speculas Hannibalis Hispania terrenasque turres iugis montium inpositas. hinc et caespitum natura castrorum vallis accommodata contraque fluminum impetus aggeribus. inlini quidem crates parietum luto et lateribus crudis exstrui quis ignorat?*
>
> Are there not in Africa and Spain walls made of earth that are called framed, because they are made by packing earth in a frame enclosed between two boards, one on each side, and so are stuffed rather than built; and do they not last for ages, undamaged by rain, wind and fire, and stronger than any rubble stone? Spain still sees the watchtowers of Hannibal and towers of earth placed on the mountain ridges. From the same source is also obtained the substantial turf suitable for the fortifications of our camps and for embankments against the violent flooding of rivers. At all events, who does not know that partition walls can be made of hurdles coated with clay and built with mudbricks?

In this short passage Pliny mentions four building materials that were staples of Roman construction but which have been substantially overlooked in architectural history: rammed earth, turf, daub, and mudbrick. Although Pliny specifically references Africa and Spain, the remains of structures built in these earthen materials have long been known from all across the Roman world, both at rural and urban sites, in modest and utilitarian structures, as well as elite residences.

Despite their widespread use, few analytical studies of the use of earthen building materials in the Roman world exist, especially compared to the range of work on other, more canonically *Roman* building materials, such as brick, concrete, and marble. This stands in marked contrast to recent work on the global histories of earthen materials, including their use in areas once part of the Roman empire, such as the Medieval Maghreb and Spain (Houben and Guillard 1994; Jaquin *et al.* 2008). While the great masterpieces of Roman architecture were not created in earthen materials, a very considerable portion of the population of the Roman world lived in buildings constructed in timber and earthen materials. Analysis of these materials, and the various techniques that made use of them, therefore, can provide key insights into the discrepant architectural realities of populations within the Roman world, and the development of vernacular traditions that often adapted pre-Roman practices and sometimes outlasted Roman rule. Geoarchaeological methods can shed particular light on themes of interest to anyone working on Roman architecture: the sourcing, processing and use of materials; the adaptation and refinement of construction techniques; the dissemination and transferral of knowledge and skills.

This contribution will focus on two categories of earthen structures: walls in either rammed earth or cob that were built using timber formwork; and turf walls. While the former have received some attention in previous scholarship on Roman architecture, turf walls have largely been ignored from an architectural perspective. Drawing on new analysis from sites in the north-western provinces, and existing research on regions bordering the Mediterranean, this paper will consider how and where these materials were used, the distribution of know-how relating to them, and the evidence for experimentation with, and adaptation of, them.

… *quos appellant formaceos*: building in rammed earth

The walls that so attracted Pliny's attention in Spain and Africa were made 'by packing earth in a frame enclosed between two boards, one on each side, and so are stuffed rather than built.' An earlier reference in the Latin tradition to walls that are probably of the same type is made by Varro, in his *De Re Rustica*, who describes field walls in both Spain and the area around Tarentum, in Apulia, as being made of earth and gravel/pebbles in forms — *ex terra et lapillis compositis in formis* (Varro, *De Re Rustica*, I.14.4; on these sources, and later ones which add little, see de Chazelles 2016, 12–13). For both Varro and Pliny the defining feature of this method of construction was the use of formwork. In modern scholarship such walls are called 'mass' earth walls; they are not built up of individual elements in the way that mudbrick or turf walls were constructed from individual mudbricks and turf blocks. The ancient authors say little about the make-up of the earthen mix used for these walls other than Varro's observation that it is often gravelly. The fact that both authors connect this technique with Spain, as well as individually with Africa and Apulia, also implies that they regard it as a technique best suited to warm and relatively dry climates.

The building technique Varro and Pliny describe has plausibly been identified as what in English is typically called rammed earth or in French (and internationally) *pisé* (in Spanish- and Portuguese-speaking countries this material is called *tapial* and *taipa* respectively, both derived from the Arab term *tabiya*. See Houben and Guillard 1994, 6–7; de Chazelles 2010, 312). This technique has a long history, especially in Medieval and Early Modern North Africa, Europe, and China, and is still widely used around the world (Houben and Guillard 1994, 6–7); indeed it has recently received considerable attention from engineers and architects as a sustainable construction method for contemporary projects (Maniatidis and Walker 2003; Jaquin *et al.* 2008; 2009; Beckett *et al.* 2020; Abhilash *et al.* 2021).

The earth used in rammed earth requires minimal processing. Soil from the building site or nearby is excavated, broken up, large inclusions taken out and is then ready for use. Fibres are not added as standard as excessive shrinkage on drying is not expected. The best soil type for optimising the mechanical strength of rammed earth is one with a high sand content, up to around 75%, and a low silty-clay component, ideally not more than 25-30%, though different guides to the technique offer a range of suggested 'mixes' (Williams-Ellis *et al.* 1947, 45–7; Maniatidis and Walker 2003, 8–9; Rael 2009, 17). Once dug and prepared, the earth is packed between formwork and compacted in layers. Rammed earth acquires its mechanical strength though compaction densification as well as suction—a phenomenon wherein microscopic bodies of water, trapped between soil particles, act to hold those particles together (Hamard *et al.* 2016b). To achieve the highest density possible, the soil for rammed earth is placed between formwork at its "optimum water content" for compaction, which can appear reasonably dry (damp) (Maniatidis and Walker 2003). This is different from the soil mix used for mudbrick production, for instance, which is packed into moulds in a wet state, since the mechanical strength of mudbricks is provided through drying shrinkage densification, internal suction, and, to varying but small degrees, mineral cementation (Jaquin *et al.,* 2009; Hamard *et al.* 2016b).

From a technological perspective what is especially interesting about rammed earth is the use of formwork. Since it is the compaction—the ramming—that gives rammed earth its mechanical strength, the formwork that holds the soil in place is key; without this the soil cannot be constrained and compacted. The formwork used for rammed earth construction needs to resist the expansive forces but also be moveable. Different types of formwork have been documented around the world and are typically made of wood, though nowadays metal is often used (Houben and Guillard 1994, 204–9). A basic division can be drawn between fixed and mobile formwork. Fixed formwork consists of upright panels framing the line of the wall that can be attached to posts secured to the ground or the foundations of the wall (Fig. 1) (Houben and Guillard 1994, 204). If these posts are inside the panels then vertical 'ghosts' of them will be left in the wall (de Chazelles 1990, 106–7, fig. 15); if they are placed on the outside of the panels then the only remaining trace of them might be a line of postholes along the face of the wall. While such fixed formwork can be assembled and used relatively easily, it requires considerable quantities of panels and posts. For this reason, most rammed earth today and in the documented past uses mobile formwork (Fig. 2). In its most basic form this comprises a pair of panels, or shutters, arranged upright parallel to each other to form the sides of a box to which ends—end stops or endboards—can be added as required. These shutters, which run parallel to the faces of the wall, are held together by horizontal ties, struts or battens, sometimes ropes, which run perpendicular to the faces the wall and leave behind characteristic putlog holes; these can be filled in later but are often left behind whatever surface coating or render is added. In more elaborate versions of mobile formwork, different types of braces are incorporated to ensure that it does not lose its shape, while wedges and spacers can be employed to make sure it is correctly adjusted (Maniatidis and Walker 2003, 49). This type of formwork is constructed over the foundations or wall footing and the earth rammed inside of it. It is then moved along the line of the wall and once a full course, or 'lift', of layers has been completed, it can be moved upwards to start the next course.

The formwork used for rammed earth construction, especially the fixed variety, is comparable to that employed in certain types of concrete construction in the Roman world (on this point, Russell and Fentress 2016, 140–1; de Chazelles 2016, 15). The major difference, however, is that rammed earth formwork, at least the mobile variety, can be disassembled and moved immediately after the earth within it is compacted, whereas formwork for concrete presumably had to remain in place until it had set, and in vaults it may have been required until the material had fully dried (Maniatidis and Walker 2003, 48). In comparison, since the earth that is rammed in rammed earth is not overly wet, it does not need to be left to dry: the strength it derives from compaction and friction between its particles is present immediately. Rammed earth formwork is also endlessly re-usable, since it does not get wet and so should not warp. Fourteenth-century Spanish sources show that formwork was highly valued and was commonly rented for specific jobs from specialist builders (Hamilton 1936, 214; Glick 1976, 149-150).

Like other walls built in earthen methods, rammed earth walls have to be protected from the elements. They tend to be raised above the ground on stone or brick socles or footings to prevent damp or frost damage, covered by projecting roofing, and rendered or plastered (Beckett *et al.* 2020). The thickness of rammed earth walls vary but Williams-Ellis suggests that exterior walls of a single storey building should be 0.35 m wide, those of a two storey building 0.45–0.60 m, while 0.23–0.30 m is sufficient for internal dividing walls (Williams-Ellis *et al.* 1947, 17, 24–5, 40). If properly constructed and protected the walls can be both dense and durable; indeed the towers that Pliny mentions in Spain were over 200 years old by the time he was writing.

Roman rammed earth

Identifying rammed earth walls in archaeological contexts is not straightforward. Collapsed or degraded rammed earth walls have a tendency to 'melt' back into deposits resembling those from which their primary materials were originally sourced. In the absence of the walls themselves, stone or brick footings and remains of plaster or other render can be used as proxies, but they rarely indicate the construction method employed. Rammed earth walls do occasionally survive to a height sufficient to allow their construction method to be identified, however. Some of the finest examples of still-standing Roman rammed earth walls, some up to 1.48 m high, can be found in House 2b at Ampurias, north-east Spain (Fig. 3) (de Chazelles 1990, 101–9). This elite *domus* was first constructed in the late first century BCE and it makes use of rammed earth throughout (rammed earth is used in the neighbouring house and elsewhere at the site too; see de Chazelles 2016, 20–21). Most of these walls were constructed on low stone footings, or dwarf walls, typically 0.3-0.4 m high, sometimes up to 0.5 m; one thin interior wall was built on a base of tiles just two courses high (personal observations of authors on site). The majority varied in thickness, to judge from their footings, between 0.50 and 0.52 m, though some are only 0.35–0.45 m thick, with the narrowest dividing wall surviving at just 0.23 m. The layers in which the earth was compacted in the walls are discernible by eye in most cases and range in height between 0.04 and 0.14 m, with most between 0.10 and 0.14 m deep (Fig. 4). Claire-Anne de Chazelles was able to identify a pair of putlog holes in one of the walls of this house, indicating the use of mobile formwork and suggesting that the walls were constructed in lifts of 0.53–0.63 m depth, though in some cases they could have been deeper (de Chazelles 1990, 104, fig. 7–8; 1997, 101–3; 2016, 21, fig. 14). Macroscopically the material used in the walls can be identified as comprising a significant amount of red-orange sand, with much smaller quantities of silt and clay, as well as small stones, gravel and even fragments of ceramics, bone, charcoal and metal-working debris, usually 10–20 mm in diameter, sometimes 20–50 mm (de Chazelles 1990, 102; 1997, 100; confirmed by personal observations of author). These macroscopic observations have been confirmed by microscopic analysis by Cécile Cammas (2018, 174 table 6). Micromorphology by Cammas analysed the voids and fissures, distribution of coarse fraction within the groundmass and the inclusions, and demonstrated that the earthen mixes used for the walls had been coarsely mixed, were relatively dry when applied, and were very strongly and homogenously compacted (Cammas 2018, 163 table 2, 174 table 6, 176 fig. 11a-d). Lateral grooves visible on the top of at least one wall in House 2b, as well as another wall in the area of the forum, show that mobile formwork was in use at Ampurias, though it is possible that fixed formwork was also sometimes employed (de Chazelles 1997, 101, 104–5, fig. 107). Considering what has already been said about the similarities between rammed earth methods and Roman use of coffering for concrete construction, it is worth noting that the Roman city walls of Ampurias have superstructures of concrete set within formwork on top of a stone base, an unusual form of construction for structures of this sort (de Chazelles 1997, 111 fig. 121–2; 2016, 21, fig. 15). These date to the first century BCE and are only slightly earlier than the rammed earth walls discussed above.

Cammas has used micromorphology to identify the same diagnostic features of rammed earth construction in other Roman walls, at Mouriès in south France and Rirha in Morroco (on Mouriès, Cammas 2018, 174 table 6, 176 fig. 11e-g). At Rirha, samples were taken from two walls of a second-century CE Roman *domus*; these were both constructed with masonry bases, c. 1 m high, and had rammed earth preserved to a height of 0.35 and 0.40 m on top of these. Micromorphology confirmed that these walls were composed of silty sand and sandy silt aggregates, with various anthropogenic inclusions such as ceramics and charcoal (but also pieces of earlier mudbricks and mortar) indicating they were sourced from close to the surface and probably near the building site (Cammas 2018, 171–3, Fig. 9; on earth construction at the site more generally, Roux and Cammas 2016a). The arrangement of the aggregates and fissures visible indicated that the earth had been applied moderately moist—though not very wet—and vertically compacted, strongly though not as much as at Ampurias and Mouriès (Cammas 2018, 173, Fig. 10). Importantly, careful cleaning one these walls at Rirha also identified a row of three putlog holes close to the base of the mass earth wall, which provide clear evidence for the use of mobile formwork (Cammas and Roux 2015; Roux and Cammas 2016b; de Chazelles 2016, 18–19, fig. 11).

Walls similar to those at Ampurias and Rirha but identified as rammed earth only macroscopically have been found at a range of sites in North Africa: Kerkouane (Fantar 1984, 309–14), Utica (Russell and Fentress, 134–6), Thysdrus (Slim 1985: 38; de Chazelles 2016, 16, fig. 7) and Acholla in Tunisia (Slim 1985, 38; de Chazelles 2016, 16), Tajurah in Libya (di Vita 1966, 15; de Chazelles 1997, 97; 2016, 16), and Volubilis (Lenoir 1985; also Russell and Fentress, 136) and Thamusida in Morocco (Cavari 2008, 259–60; Camporeale 2008, 85–6, Akerraz, El Khayari and Papi 2009, 162). Of these, the site to have produced the earliest convincing evidence of rammed earth, in this case constructed with fixed formwork, is Kerkouane. There, vertical grooves (0.04–0.06 m deep, 0.12 m wide) were found in the stone socles of the walls of a house at the corner of the Rue du Temple and Rue des Artisans, which were presumably for upright posts, to which a fixed formwork was attached (Fantar 1984, 313, pl. 11–12; de Chazelles 1990, 106, fig. 15; 1997, 95–6). This structure is dated to the third century BCE. The earth used for the superstructure contained rubble and degraded and broken up mudbrick, which the excavator identified as re-used from a previous building.

Aside from this early example at Kerkouane, the bulk of the walls that have been plausibly identified as rammed earth in North Africa date to the Roman period, the majority of these to between the first century BCE and second century CE. Like the structures already discussed at Ampurias and Rirha, the houses in which many of these walls are preserved are far from humble. At Acholla and Volubilis rammed earth walls have been found in high-end *domus*, the Maison de Neptune and Maison des Fauves respectively, where they were then faced in painted wall plaster (Slim 1985, 38; Lenoir 1985). At Tajurah, the walls in question come from the Villa of the Nereids (di Vita 1966, 15). At Thysdrus, the Maison de Lucius Verus, one of the largest known in the city, has rammed earth walls (Slim 1985, 38). At Thamusida, the rammed earth walls described by Cavari come from a first-century CE building of uncertain function but which had painted wall plaster and was obviously of relatively high status (Cavari 2008, 259–60). At Utica, some of the finest rammed earth walls uncovered to date from the first-century CE Maison de Grand Oecus, located just to the east of the city's forum. Here two-storey rammed earth walls, some with projecting piers in the same materials were found (Fig. 5 & 6). These were internal walls, faced with painted wall plaster, which enclosed rooms with floors of *opus sectile* and supported mosaic floors on the second storey (Russell and Fentress 2016, 134–6, fig. 6). This was opulent domestic architecture—some of the finest in the city—for which rammed earth was considered a perfectly suitable material.

The micromorphology carried out on the Ampurias, Mouriès and Rirha samples confirmed that all of these walls were built in rammed earth. But the same analyses also show that there were slight variations possible within the technique, notably when it comes to the make-up of the earth mix, its moistness, and the intensity of compaction (Cammas 2018, 173, Fig. 10). Similar variation in the exact materials used in the walling has been noted at other sites. The Kerkouane walls contained degraded mudbrick, for instance. At Acholla, the walls of the Maison de Neptune comprised beach sand mixed with shells (Slim 1985, 38). At Utica, relatively few large inclusions were found in the walls of the Maison de Grand Oecus and analysis identified the presence of very abundant beach sand, which also contained fish bones. To this tally of variation we can add the use of different formwork types, fixed at Kerkouane (and perhaps also Thysdrus (de Chazelles 1997, 97–8), mobile at Rirha and Ampurias, and uncertain elsewhere. At each of these sites the builders responsible for these walls were adapting a largely standard technique to their own conditions, making use of slightly different soil mixes and combining them with different sorts of inclusions and quantities of water. What connects these walls is that they were made of largely dry earth, compacted in layers between formwork and on these grounds they can reasonably be labelled as rammed earth walls.

Evidence from around the western Mediterranean and even as far north as Britain, however, reveals that rammed earth was not the only form of earth construction to make use of formwork. Indeed if we are prepared to move away from later (mostly modern) categorisations of construction techniques, we can identify a spectrum of approaches to earth building in the Roman period that often yielded impressive results.

Variations on a theme: shuttered cob

In her survey of the known rammed earth walls of Punic and (mostly) Roman North Africa, de Chazelles spends some time considering the walls of a particular house at Lambaesis, in Algeria. The structure in question, 'une grande domus somptueusement décorée de mosaïques et de peintures', like the houses at Thysdrus and Utica, is an elite residence (de Chazelles 2016, 17–18). At the site generally, earth was used as infill in *opus africanum* walls, in both the form of mudbricks but also mass earth. In this *domus* the mass earth wall made use of a coarse, heterogeneous earthen mix, which contained vegetal material and was seemingly applied in a relatively wet state in layers 0.2-0.5 m deep. It was not possible to demonstrate that the earth had been compacted. Based on this evidence, de Chazelles is reluctant to identify this material as rammed earth specifically, preferring instead to label it simply 'terre coffrée' (de Chazelles 2016, 17–18). The builders of this structure were using shuttering, therefore, but they appear to have been handling the soil they packed between this formwork differently from the builders at Rirha, Utica or elsewhere.

Sites across the western Mediterranean have produced evidence for earth walls, like those at Lambaesis, that were probably constructed with the aid of formwork but the technique of which, in the absence of micromorphology, remains uncertain. Various sites in Spain have produced early evidence for earth walls which could have been constructed in rammed earth or using a wetter mix of soil and fibres (on the late third-century BCE evidence from the Iberian site at Calafell, see Pou Vallès et al. 2001, 101; Belarte 2001, 33; de Chazelles 2016, 19–20. More generally on the Spanish evidence, see de Chazelles 1990, 117; 2003; Russell and Fentress 2016, 137). Similar walls are relatively common at sites across Italy from the fourth century BCE onwards and have often been identified macroscopically as rammed earth (for relevant references, see Russell and Fentress 2016, 137–9). Recently a stretch of such walling has even been identified in the late antique baths at Gerace on Sicily (Wilson 2020, 482–3). Further east, the walls of at least one house on Delos seem to have been constructed in earth packed between shuttering, perhaps rammed earth (Zarmakoupi 2015, 10–11; Russell and Fentress 2016, 139). And similar walls have been found in Cyrenaica (at Ptolemais, for example: Żelazowski et al. 2011, 26, Fig. 20). In Gaul, first- and second-century CE structures with mass earth walls probably constructed with the assistance of shuttering have been identified macroscopically at Cravant, Bram, Cavaillon, and Orléans (de Chazelles and Guyonnet 2007, 109; Coulon and Joly 1985, 93–4). Even as far north as Britain, mass earth walls that seemingly made use of formwork have been identified in first- and second-century CE contexts at Verulamium, London, Colchester, Canterbury, the villas at Farningham and Lullingstone in Kent, and the military site of Castell Collen (For references and further details, see Russell and Fentress 2016, 139–40).

It has been argued that some of these walls, especially in Spain and Italy, were probably constructed in rammed earth (Russell and Fentress 2016, 139). However, to prove this definitively would require sampling and detailed micromorphology. At the same time, the walls of the Lambaesis *domus* and some of these other structures were certainly *not* built in rammed earth; the earthen mix employed seems to have contained vegetation or other fibres and to have been applied wet. In many of these cases, the technique employed was closer to that of cob, or *bauge* in French. Cob walls are constructed out of a mix of earth and fibres (typically straw) applied in clods in a plastic, that is reasonably wet, state (Houben and Guillard 1994; Keefe 2005; Watson and McCabe 2011; Hamard et al. 2016a). The earth is packed in place by hand or treading and not compacted to the same degree as rammed earth; it acquires its mechanical strength (which is usually less than that of rammed earth) through drying shrinkage densification and suction (Jaquin et al. 2009; Hamard et al. 2016a). As cob contains more water than rammed earth, it shrinks to a greater extent when drying; the vegetal fibres contained within the mix act to reinforce the material against cracking when shrinking. Cob walls are usually built up on a base by hand, their faces patted back to ensure they are vertical and then trimmed when they are dry; they tend to be raised in lifts, one on top of the other, with each left to dry before the next is added (Hamard et al. 2016a, 112).

Formwork is not required in traditional cob construction because the earth is not compacted to the same degree as in rammed earth and is not applied dry. However, detailed geoarchaeological analysis at the important Iron Age site of Lattes in southern France has shown that a largely unappreciated tradition of shuttered cob or *bauge coffrée* certainly existed in antiquity. At Lattes, the key evidence comes from a fourth-century BCE wall that struck the excavators as particularly homogenous: in other words, it seemed to lack the visible layers of earth seen in other cob walls at the site (Roux and Cammas 2007, 88; Roux and Cammas 2010). The wall flanked the east side of an open courtyard and was 0.78–0.90 m wide (Roux and Cammas 2007, 89–90). The silty earth mix also included occasional small stones (40–50 mm wide) and fragments of mudbrick (sometimes burnt), charcoal and wood. Three lifts could be noted in the wall, the two fully preserved ones 0.30–0.40 and 0.38–0.48 m deep respectively. Micromorphology confirmed that the earthen mix had been applied in a moist state. Vegetal remains and other inclusions were probably a result of extraction of earth on or close to the building site, and close to the surface, rather than deliberate additions. Crucially, evidence for compaction at the edge of the wall, in the form of oblique elongated voids revealing deformation of the earth, shows that this material was pressed against a formwork that was then removed (Cammas 2018, 170). The fact that this wall was among the densest and most homogenous excavated at the site implies that this use of formwork brought with it real benefits: it enabled the earthen mix to be packed into place more forcefully and offered additional support as it dried, preventing slumping. Modern work on cob construction indicates that the use of shuttering enhances the builders’ control of wall dimensions, results in neater faces, and allows the soil mix to be applied in a more plastic state than in normal cob walls, which improves its workability within the formwork (Klein 2003, 125-128; Keefe 2005; Watson and McCabe 2011, 65).

Until recently the wall from Lattes was the only example of shuttered cob to have been identified by geoarchaeological analysis. Recent study of a pair of Roman walls in London by the current team, however, shows that this technique continued and was probably used right the way through the Roman period in the north-western provinces. The full analysis of these walls, from a site at Moorgate, will be published elsewhere (the site in question is MOQ10 and excavated by MOLA; we are grateful to Louise Fowler for providing us with access to this material and collaborating with us on its analysis). But what this reveals is that much more work needs to be done on earth construction in the Roman northern provinces to understand the spread of building techniques and related know-how. London provides some of the richest evidence anywhere in the empire for the largely overlooked Roman tradition of earth (here called ‘brickearth’) construction (for an overview of the range of construction types identified in the city, see Perring and Roskams 1991, 71–84; Perring 2002, 92–5). But we also know of large numbers of buildings built using earth at, for example, Colchester (e.g. Crummy 1984, 20–4), Lyon (e.g. Desbat 1985; Clément 2016; de Chazelles et al. 1985), and a range of sites in Germany (e.g. Precht 1971, 53-62; 2002, 183, 189, 193-194; Kraus 1999, 19, 20, 48), and Switzerland (see Rentzel 2013a; 2013b).

Building in turf

Whereas the materials used in cob walls were extracted, mixed and then applied in handfuls, the turf (*caespites*) that Pliny described next, in the passage with which this contribution opened, required considerably less processing. 'Turf', in a literal sense, is the upper layer of a vegetated ground surface and comprises the topsoil and subsoil held together by the root mat of the vegetation. In turf construction, the 'turf blocks' or 'turves' are simply cut sections of this vegetated surface (Fig. 7) (a note on terminology: in German 'turf blocks' are called *Grassoden*, *Rasensoden* or *Plaggen*, *Graszoden* or *Zoden* in Dutch; turf is distinct from peat, slabs of which are called (confusingly) *Torfsoden* in German and *Turfzoden* in Dutch. The French term for turf blocks is *mottes de gazon*; peat blocks are *mottes de tourbe*).

Turf has a long history as a building material, especially in the North Atlantic region (notably Iceland and Scotland), but also in the marshy areas of the Netherlands, northern Germany, Scandinavia and North America (e.g. Walker 2006; Sigurðardóttir 2008; Stefánsson 2019; Nicolay 2018; Uerkvitz 1997; Siegmüller 2010; and on the 'soddies', turf-built houses, of Nebraska, see Welsch 1969). In the Roman period, as Pliny notes, turf was commonly used in infrastructure and, in particular, military projects. All of the other ancient writers who refer to turf construction, in fact, do so with regard to military contexts (see Livy 25.36.5; Suetonius, *Aug.* 24.2). The most detailed of these sources is Vegetius (*De Re Militari* 3.8), in his directions for the building of a camp:

> *… cum sublati caespites ordinantur et aggerem faciunt, supra quem ualli, hoc est tribuli lignei, per ordinem digeruntur. Caespes autem circumciditur ferramentis, qui herbarum radicibus continet terram, fit altus semissem, latus pedem, longus pedum semis*.
>
> '… the raised turf blocks (*caespites*) are laid out in line, forming a rampart. Above it, *valli*, that is stakes or wooden spars, are ranged along its length. The turf is cut around with iron tools, retaining the earth in the grass roots, 0.5 ft. high, 1 ft. wide and 1.5 ft. long.'

Camp and fort rampart walls constructed fully or partially in turf have been identified across the northern provinces (Jones 1975, 78–81). This material was also used for one of the largest military construction projects in the Roman empire, the Antonine Wall in Scotland, while much of the western end of Hadrian's Wall was also originally built in turf (on the Antonine Wall, Keppie 1974; Hanson and Maxwell 1983; Romankiewicz et al. 2020, 2022; Hodgson 2020; on the 'Turf Wall' of Hadrian, see Breeze 2019). The Antonine Wall, in fact, is the only Roman structure that is specifically noted as having been built in turf by an ancient source: it is described in the *Historia Augusta* (*Ant. Pius* 5.4) as a *murus caespiticius*, a turf wall (though the complexity of the structure will be discussed more below).

Archaeologically, turf blocks can often be identified by their stripy appearance, with the stripes being the layers of vegetation, topsoil and subsoil of the original surface from which the block was cut; in soil science these are referred to as the O, A and B horizons respectively (on the micromorphology of turf, Huisman and Milek 2017). The distinct appearance of turf blocks has led to their identification elsewhere than Britain, including further south: turf was used in the ramparts of the Flavian legionary fortress at Strasbourg in France (Kuhnle 2018, 147-158), for instance, as well as in the Julio-Claudian fort at León in Spain (Morillo and García 2009, 392-393). Although the phenomenon has received little attention in scholarship it is likely other structures, especially in the Roman north, made use of turf for the superstructures of walls (on a building in turf constructed against the south side of the Antonine Wall, see Romankiewicz et al. 2022).

In many ways turf is the most straightforward of all earthen materials to use in construction. It requires cutting, trimming and placing, but no other processing. Nevertheless, the cutting method, the size of the blocks, the depth they were cut from, how they were arranged in place, and the way in which this material was combined with others—especially stone and timber—in the complete structure are all revealing of the decision-making of those responsible, their training and the spread of know-how. In what follows we highlight two sites at which close analysis of Roman turf structures has provided detailed insights into turf use.

Ramparts—and their builders—at Vindolanda

Due to its preservation conditions, the material culture from Vindolanda, and especially the famous writing tablets, provides remarkable insight into the lives of Roman soldiers on the frontier (A. Birley 2002; Bowman 2004; R. Birley 2009). Although the site is rarely examined in architectural studies, these same preservation conditions make Vindolanda a crucial site for reconstructing the often overlooked turf and timber building practices of the Roman army. Of the nine forts constructed at Vindolanda, one on top of the other, the first six were all built in turf, earth and timber. These range in date from the Flavian to Antonine periods (Periods I-VI, with the last of these having two phases), while the later forts at the site were built in stone. Where these early ramparts have been exposed during excavation they are often in good condition, with individual turf blocks clearly visible and organic material still preserved (and identifiable).

In 2019, three stretches of superimposed rampart were uncovered, datable to the Flavian (I and III) and Antonine (VI) periods of occupation of the site. These were documented and then sampled for micromorphological analysis (Fig. 8). The results—both macroscopic and microscopic—were combined with observations made on site during earlier campaigns of excavation to build up a picture of turf building developments at the site over time. A detailed explanation of the approaches taken to these three ramparts has been published elsewhere (Russell et al. 2021); here, we summarise some of the key findings.

The first noticeable variation between the ramparts of the different periods of fort at Vindolanda can be discerned at their base. At Vindolanda, the Period I and II ramparts are laid on timber corduroy rafts of alder, birch and oak branches or logs, mostly 0.08-0.15 m in diameter, split longitudinally. These were laid perpendicular to the long axis of the rampart, though a line of branches was sometimes also laid parallel to this axis along the face and rear of the rampart (for this arrangement at Strasbourg, see Kuhnle 2018, 148-149). In Period VI the first-phase rampart was laid on a similar raft but this was then expanded outwards in a second phase, with this extension laid on a raft of oak planks, some certainly re-used from other structures (Fig. 9) (A. Birley 2007, 18–20). The rafts with laid in an earth mix with off-cuts of turf packed between them. Excavations in 2018 of a stretch of the Period I raft identified fragments of tent leather in this layer as well (Russell et al. 2021). These rafts were presumably intended to provide a solid and level base at the commencement of construction. The builders of the Period III ramparts did not consider whatever benefits a raft offered worth the investment in timber and labour, however—the turf blocks of this rampart were laid directly on the ground surface.

These rafts are not the only timber elements used in the Vindolanda ramparts. At semi-regular heights up the superstructure of the ramparts further courses of timbers were laid across their widths. These lacing courses generally used thinner branches than the rafts, with alder and silver birch favoured. Where sampling was possible—in the Period III and VI ramparts—it was noted that these branches were laid in a mix of sub-soil material, probably sourced on site, perhaps from the ditch in front of the rampart, since at least one sample contained anthropic inclusions in the form of rubified clay fragments. These lacing courses are inserted roughly every 0.30–0.50 m up the rampart and they have been confirmed for the Period I, III and both Period VI ramparts, while the Period II rampart is nowhere preserved to a sufficient height to judge whether its builders used them. Again, these features are found at other forts in Britain and elsewhere, sometimes more closely spaced (0.20–0.30 m at London, for example), sometimes further apart (0.60–0.70 m at Strasbourg) (see, for examples, Dunwoodie, Harward and Pitt 2015, 45–47; Frere and Wilkes 1989, 15–27; Jones 1975, 89, pl. Va; Kuhnle 2018, 148–149, pl. 179, 180, 182). They were possibly laid to prevent sagging or deformation.

The presence of these rafts and lacing courses shows that turf construction was not simply a matter of stacking blocks. This can also be noted within the turf elements of the superstructure. On top of the raft (or ground surface, in the case of the Period III rampart), as well as between the lacing courses, the turf blocks were laid in more or less neat courses. However, to ensure these courses were broadly level, a certain amount of trimming and adjustment had to take place, with off-cuts wedged in gaps between blocks and uneven areas levelled out with earth infill (Russell et al. 2021, 204–5). These efforts—and we can included the lacing courses here—were all intended to ensure the ramparts went up in regular stages and distributed the weight of the superstructure evenly. Without this attention the ramparts could easily have slumped or acquired irregular upper profiles that would have comprised their defensive efficacy. Turf was used in all the ramparts through their whole profile, except in the Period III ramparts, which seem to have been built with turf cheeks (or faces) and an earth core. This is another difference between this rampart and the others on the site.

Both macroscopic and microscopic analysis shows that the military builders at Vindolanda sourced turf from the area around the fort and placed the turf blocks in their ramparts grass-side down. Sometimes they even double-cut the turf, meaning that they managed to extract two blocks from one on top of the other, so deep was the root penetration; but even in these cases the blocks were inverted during construction. Across periods we can also see that blocks of broadly the same size were used, measuring on average 0.40 × 0.30 × 0.08 m. If we accept that these blocks have been compacted by the weight of the rampart and subsequent building and post-depositional factors, these dimensions are not dissimilar to those quoted by Vegetius, which translate as broadly 0.45 × 0.30 × 0.15 m (*De Re Militari* 3.8). Blocks of this size would have weighed somewhere between 20 and 30 kg on average, a manageable weight for a solder to lift and position, which perhaps explains their standard size across periods (Romankiewicz et al. 2022, 131). This standardization does not apply to the shape of the turf blocks, however. While the blocks used in the Period III and the second phase of the Period VI ramparts are parallelogram-shaped, with slightly angled ends, the Period I and first-phase Period VI blocks are lozenge-shaped. This morphological difference is most clear along the joint between the two phases of the Period VI rampart.

Period	**Start date**	**Superstructure**	**Corduroy raft**	**Lacing course**	**Turf form**	**Unit**
I	c. AD 85	Solid turf	Y	Y	Lozenge	*cohors I Tungrorum*
II	c. AD 90	Solid turf	Y	?	?	*cohors I Tungrorum*
III	c. AD 100	Turf cheeks and earth core	N	Y	Parallelogram	*cohors VIIII Batavorum*
VI (1)	AD 140s-160s	Solid turf	Y	Y	Lozenge	*cohors II Nerviorum*
VI (2)		Solid turf	Y	Y	Parallelogram	?

Table 1: Details associated with the different periods of rampart.

Careful comparison of these small details between ramparts reveals certain differences in practices within a generally fairly standard framework of how to build a turf and timber rampart. We can see that the builders of the Period I and first-phase Period VI ramparts cut their turf blocks in a different way from the builders of the other ramparts; this may well result from the use of different tools (Russell et al. 2021, 34-35). The Period III builders, unlike all the others, decided not to put down a raft at the base of their rampart; and the second-phase Period VI rampart builders opted for oak timbers rather than alder or birch branches in their raft. Different units, in other words, took slightly different approaches to rampart building and might well even have had different equipment. The units stationed at the site were all auxiliaries and the unique documentary evidence from Vindolanda allows us to identify most of these units. We know, therefore, that the *cohors I Tungrorum* built the Period I and II forts (as well as the Period IV fort, of which little survives), the *cohors VIIII Batavorum* the Period III fort; and the *cohors II Nerviorum* the first phase of the Period VI fort. The original troop mustering grounds for these units were in *Gallia Belgica* and *Germania Inferior*. While by the late first century and mid second century CE few of the troops in these units would have come from these territories, the evidence from Vindolanda indicates that these units might still have had their own institutional practices and perhaps equipment—ways of doing things and kit—that caused the differences now discernible on the ground.

The apex of Roman turf construction: the Antonine Wall

The evidence from Vindolanda shows the potential complexities of Roman military structures in turf. Combining turf, the exact composition of which would have varied across terrains, timber and other earthen mixes effectively and rapidly required a specific skillset and level of experience. However, since Roman military units on the march built camps on a daily basis, and every new unit arriving at a site like Vindolanda constructed their own new fort, the men responsible would soon have become experts in turf building. With every construction project new lessons would have been learned and it is arguably in the building of the Antonine Wall—probably the largest turf structure built in the Roman empire, and perhaps anywhere (Fig. 10)—that we can see some of the results of these.

Archaeological investigations along the length of the Antonine Wall have largely confirmed the statement in the *Historia Augusta* that it was a turf wall, a *murus caespiticius*. Some variation in the composition of its superstructure has been proposed for parts of its eastern section: areas where the Wall seems to have had an earth core bound by turf cheeks have been noted and others where 'clay' cheeks have been suggested (Macdonald 1925, 283–5; Steer 1961a, 94; 1961b, 322; Keppie 1976, 71–2, 77–8; Bailey 1995, 580). However, the western and central sectors of the Wall seem to have been built entirely in turf, and it is also very likely that in the eastern sector it was the nature of the turf that was different rather than necessarily the mode of construction (on this point, Keppie 1976, 77). A new section across the Wall at Laurieston, near Falkirk, excavated in 2020, certainly indicates this, though how representative it is remains uncertain. Based on this new work, and previous observations, certain insights into the relative sophistication of the structure compared to earlier turf ramparts can be noted.

Perhaps the most novel constructional feature of the Antonine Wall is its base. This is constructed in stone for the entire length of the monument and comprises two rows of dressed kerb stones between which is arranged a rubble raft (on the arrangement of the base, see Keppie 1974, 155–6; Breeze 2006, 71–2). Culverts, covered by large slabs, were built through this base at frequent intervals to ensure drainage from one side of the structure to the other, and it has also been argued that the porous base facilitated drainage of moisture from within the rampart itself (Fig. 11) (Romankiewicz et al. 2020, 126–7). At Laurieston it was noted that this base was itself laid into a bedding layer of mixed earth and turf off-cuts spread across the original ground surface, which had been stripped of its turf and levelled (Romankiewicz et al. 2022). On top of the stone base a levelling layer, again of mixed earth and turf off-cuts was laid to even out any irregularities in the stone base. Comparable features have been noted elsewhere along the Wall (Romankiewicz et al. 2022, Table 2), though not everywhere, and they imply that considerable efforts were put into providing a solid and level base that would also facilitate moisture management. All of this work required more investment of materials and labour than a typical fort rampart.

The Laurieston excavations also revealed that the builders of the Wall took particular efforts when it came to sourcing the turf used in the construction and arranging it in place. The Wall here comprised distinct cheeks (or faces) and a core (Fig. 12). Although the core was immediately identifiable as turf during excavation, and has a distinct multi-coloured appearance, the cheeks comprised a pale grey material that lacked any of the characteristically striped appearance of turf noted elsewhere—indeed, on first inspection, the cheek material appeared to be a series of clay blocks. Only following micromorphology was it possible to show that both cheeks and core was built in turf blocks, but that these came from different sources. The turf of the core seems to have been sourced on site and in the immediate vicinity of the Wall's corridor; they were cut from grassland on glacial till. The turf used in the cheeks, in contrast, developed on a clay and sand-rich soil, probably from a water meadow in an alluvial zone. This turf must have been brought from further afield, though the exact source cannot be pinpointed (Romankiewicz et al. 2022, 122–3, 128–30). Why the builders decided to use turf from two different sources is not clear but it is possible they found that the clay- and sand-rich variety was easier to cut and stack neatly than the siltier turf of the core. An alternative reason may be that the cheek material was selected for moisture management. Depending on their relative hydraulic properties, the cheeks may have acted to wick moisture away from the core of the wall, thus maintaining its integrity, or could have accelerated evaporation, again supressing moisture levels overall. Further testing is required to understand the exact hydraulic role, if any, of the cheeks but, whatever the reasoning here, this pattern of sourcing shows the level of thought the builders were putting into their materials.

The builders of the Antonine Wall at Laurieston carried this care for constructional details through to the laying of the turf blocks. Unlike at Vindolanda, where the turf blocks appear to have been laid either parallel or perpendicular to the axis of the rampart, at Laurieston the blocks of the core were laid at an angle of approximately 45 degrees, with this orientation alternating course by course (Fig. 13). The blocks of the cheeks, on the other hand, were laid perpendicular to the long axis of the rampart, with their rear surfaces cut to receive the angled blocks of the core. This arrangement between core and cheeks shows these features were built up together, course by course, and so carefully keyed together. This arrangement avoids a sharp, straight juncture between cheeks and core, which could have been a potential weak point. This diagonal arrangement of turf blocks has not been described elsewhere in any detail but can be noted on at least one plan of an earlier trench across the Wall (opened just to the west of Laurieston) (Bailey 1995, fig. 3). We have noted a comparable arrangement of turf blocks in the fort ramparts at High Rochester in Northumberland and there is apparently similar evidence from Carlisle (analysis of the High Rochester turf is forthcoming; for the Carlisle observation, which has not been published, we are grateful to William Hanson).

To date, no lacing courses have been identified at any point along the line of the Antonine Wall. It is possible that they were only used high in the structure and so have not survived but it is more likely that they were not used at all, since timber was also not used in the base. At the same time, other features noted at Vindolanda and in other forts are not apparent here: the turf blocks were not all laid grass-down, but both grass-up and grass-down, potentially in an alternating pattern, though the section at Laurieston was not wide enough confirm this; and double-cutting of turf did not take place—all of the blocks analysed have O horizons. What these constructional features suggests is that the builders of the Antonine Wall had learnt from the roughly 100 years of experience that the Roman army had acquired of turf construction in Britain. Turf structures can survive for 20–50 years without major maintenance (Romankiewicz et al. 2020, 133–8). This was a structure built to last. In its stone base, careful sourcing of materials and their intricate arrangement we can see systematic planning and execution at work.

Conclusions

There were no ancient how-to-guides, no books of instructions, for building in earth (that we know of; it is possible that other military manuals, like Vegetius', contained more detail).

Information about effective techniques was presumably disseminated by practitioners, either through migration or the movement of itinerant builders, and modified in response to local conditions. Certain techniques worked in certain locations, not others. Experimentation and adaptation within the broad parameters of particular techniques would have been incessant. In frontier zones, a major stimulus for these processes would have been the movement of military units, which were always heavily involved in construction and had their own ways of doing things. For these reasons we should be careful not to assume that the divisions between building techniques that are today applied by architects, engineers and other researchers would have meant much in antiquity.

This is particularly clear in the case of the various Roman earth construction techniques employing formwork. While modern analyses tend to draw a clear line between rammed earth and cob, the evidence outlined above shows that in the ancient world the reality was more fluid. At certain sites builders were using dry, sandy and gravelly (sometimes shelly) mixes, which could then be intensely compacted. At other sites the earth they packed between their formwork was more clayey or silty, was used in a plastic state, and needed to be combined with fibres to stop it cracking when it dried. From a geotechnical perspective, these two techniques worked in quite different ways; the densification of the walls resulted from different mechanisms. From the perspective of an ancient builder, however, these two techniques would probably have been considered largely identical. They both involved the packing of earth mixes between formwork; they are both, from this application point of view, 'shuttered earth' and could also be described in the terms used by Pliny and Varro.

At these different sites we can see builders adapting accepted modes of construction for their own needs and according to what was available on site. These walls, therefore, are documents of on-site, ad hoc decision-making; and they reveal the importance of local savoir-faire in this process. Utica is an instructive example of this. Here it is striking that mudbrick is widely used in Punic (sometimes early Roman) structures but that this is gradually replaced in construction by rammed earth from the first century BCE onwards (Russell and Fentress 2016, 135–6). We can assume this was due in part to the properties of the earth on site, which is indeed extremely sandy and low in clay. External support for this is provided by, of all people, Vitruvius, who tells us that the Utican magistrates demanded that mudbricks used in the city were dried for an extra-long period of time, presumably due to concerns over their quality (Vitruvius II.3.2. Vitruvius says that at Utica mudbricks had to be left to dry for 5 years, while he recommends 2 years as the standard; these seem like very long times and it is possible that months rather than years are meant here). If the local materials were poorly suited for mudbrick production they would also have been unsuitable for cob. At London, in contrast, the opposite was basically true. In the Moorgate walls, we can see builders who were probably quite familiar with mudbrick construction in the city, adapting the available materials to a shuttered mass earth walling technique. Across the city, in fact, we can identify a wide array of earth building techniques, sometimes within the same structure, which are perhaps reflective of the extremely cosmopolitan make-up of the city, especially in the first century CE, and the interaction between locals and immigrants (on this point, Wallace 2016, 81–2).

Turf construction is no less varied and provides a picture of varied practices within an accepted broader framework. Perhaps more than with any other earthen materials, builders in turf were limited by the properties of their locally available materials: you cannot add anything to a turf block to make it either less clayey or less likely to crumble when dry. In the timber rafts and lacing courses, the levelling layers and patches at Vindolanda and elsewhere we can see the actions of different units responding to the material that was itself a reflection of the local landscape. In the form of the Antonine Wall, we can see how lessons learnt at sites like Vindolanda were put into practice and refined.

Occasionally the results of these on-site adaptation and experimentation processes can be baffling. The absence of a wooden raft beneath the turf of the Period III ramparts at Vindolanda is not easily explained, for example. Sometimes hybrid techniques emerge that cannot be easily explained: at the Villa Dar Buc Ammera, near Lepcis Magna, at least one wall of Flavian date has a hybrid technique combining rammed earth and concrete, for instance. The wall is divided between these materials longitudinally, with one face constructed in concrete for its entire height and the other in lifts of rammed earth between which are layers of concrete 0.08–0.10 m thick (Aurigemma 1962, 31; de Chazelles 1997, 97–8, fig. 102). The builders must have added these materials to the formwork at the same time and built them up in layers. This curious approach is a perfect illustration of the technical overlap between Roman rammed earth and concrete construction, but it appears not to have taken on elsewhere.

A final point is worth stressing. Although earth building materials have rarely been integrated into mainstream studies of Roman architectural history, the evidence for the distribution of these materials and their adaptation stands out more clearly in the Roman period than almost any other. In Britain, therefore, although turf construction is attested in the pre-Roman Iron Age and early Medieval and later periods, we have nowhere near the wealth of archaeological evidence for turf use from these periods as we do from the Roman period. All of the largest original turf structures known from Europe date to the Roman period. And while later turf construction is associated with the North Atlantic, the turf walls from Léon (Julio-Claudian), from the newly-discovered fort at Valkenburg (probably Julio-Claudian) (the material from this site is being studied by the current authors), and Strasbourg (Flavian) pre-date many of the well-studied examples from Britain, which are largely Flavian and later. In the case of rammed earth, although much scholarship has focused on the origins of this technique, our best evidence for its use comes from the Roman period. In North Africa, beyond Kerkouane, all of the rammed earth walls that have been studied to date come from Roman structures, often elite *domus* of the Imperial period. In Spain and southern France a similar picture emerges. The earliest walls that de Chazelles is prepared to identify confidently as rammed earth in this region come from first-century BCE Roman houses at Ampurias. Shuttered earth construction broadly defined and using moveable formwork also only seems to have been introduced further north, in the Rhineland and then in Britain in the Roman period, from the first century CE onwards.

All of this hints at a degree of knowledge transfer and experimentation in the field of earth building in the Roman empire that has yet to be fully appreciated. At Moorgate we see a technique imported into Britain in the Roman period, with roots in the Mediterranean but perhaps more directly inspired by practices in the Roman Rhineland, which at the same time overlaps in its basic principle with aspects of concrete construction; and it produced remarkably durable walls.

What detailed studies of structures built in even these apparently 'humble' materials reveal are the decisions made by their maker(s) and how these changed over space and time. Relatively few Roman earth structures have been intensively investigated using the techniques outlined above and those remaining constitute a largely untapped dataset that can fill important gaps in our understanding of everyday Roman architecture.

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Figure captions

Fig. 1. A form of fixed formwork for rammed earth in use in early twentieth-century Britain (after Williams-Ellis 1920, 99).

Fig. 2. A rammed earth wall under construction using mobile formwork in northern Vietnam (image: Alfred Boc).

Fig. 3. House 2b, Ampurias (image: Ben Russell).

Fig. 4. Detail of rammed earth wall in House 2b, Ampurias, showing lifts (image: Ben Russell).

Fig. 5. Collapsed rammed earth walls and piers with mosaic from an upper floor, Maison du Grand Oecus, Utica (image: Elizabeth Fentress).

Fig. 6. Collapsed rammed earth wall with plaster facing, Maison du Grand Oecus, Utica (image: Elizabeth Fentress).

Fig. 7. Turf blocks stacked grass-down, ready for use as part of a structural testing experiment (image: B. Russell).

Fig. 8. Section showing three phases of rampart at Vindolanda, with individual turf blocks and other features outlined and the divisions between ramparts marked (image: T. Romankiewicz).

Fig. 9. Plan of the Period VI rampart, phases 1 and 2, corduroy bases excavated in 2005-2006 (image: © Vindolanda Trust).

Fig. 10. The Antonine Wall rampart (right), its berm and ditch (centre) and upcast mound (left) just to the west of Roughcastle (image: Ben Russell).

Fig. 11. Stone base of the Antonine Wall, with line of culvert marked, at New Kilpatrick (image: T. Romankiewicz).

Fig. 12. Excavations of the Antonine Wall at Laurieston: excavation of the south cheek (top left), the kerb beneath the south cheek with the stone base beyond (top right), and the south cheek, to the right, and core, to the left, of the rampart in section (bottom) (images: Ben Russell).

Fig. 13. Plans of two layers of turf blocks in the core of the rampart of the Antonine Wall at Laurieston (A and B), a comparison of the arrangement of the turf blocks at Callendar Park (after Bailey 1995, illus. 3), and a sketch plan showing the reconstructed construction layout (image: T Romankiewicz).