Britannia 50 (2019), 185–202
doi:10.1017/S0068113X19000035

The Vindolanda Calendrical Clepsydra: Time-Keeping and Healing Waters

By ALEXANDER MEYER

ABSTRACT

An unusual copper-alloy fragment was recovered during excavations at Vindolanda in 2008. It has been identified as part of a calendar or water clock. A very similar fragment was found near Hambledon in Hampshire in 2017. Further investigation of the Vindolanda and Hambledon fragments and of similar objects from Frankfurt, Salzburg and Grand reveals that the Vindolanda and Hambledon fragments were once attached to clepsydrae to form time-keeping devices that are unattested in ancient sources, but that might be called 'calendrical clepsydrae'.[1] *The links between similar artefacts and deities associated with water and healing are explored and evidence for a shrine located near sulphur springs in the Allen Valley is also discussed. The Vindolanda calendrical clepsydra is placed within this social and religious context.*

Keywords: Vindolanda; calendars; time-keeping; clocks; clepsydrae; baths; shrines; water; healing

INTRODUCTION

In 2008, archaeologists discovered a fragment of an unusual copper-alloy artefact during excavation of an unstratified context between the east granary and the headquarters building of the third-century stone fort at Vindolanda.[2] Although the object cannot be dated contextually, it has received considerable attention from scholars interested in time and time-reckoning in the years since its discovery.[3] Until recently, however, it has been impossible to determine the original form and function of the complete artefact from which this small piece is derived.

[1] Clepsydrae are simple water clocks that measure time by the outflow or influx of water. In their simplest form they measure the fixed amount of time it takes to empty or fill a vessel with a regulated flow of water. More sophisticated clepsydrae may include marks on their bowls that represent intermediate increments of time, such as hours. This basic design is also elaborated upon with various decorative schemes and methods of display. The earliest remains of a clepsydra are from Egypt and date to the fourteenth century B.C.E.

[2] Meyer 2013. For the full excavation report see A. Birley 2013.

[3] Birth 2014; Lewis 2009; Meyer 2014; Tomlin 2010, 461.

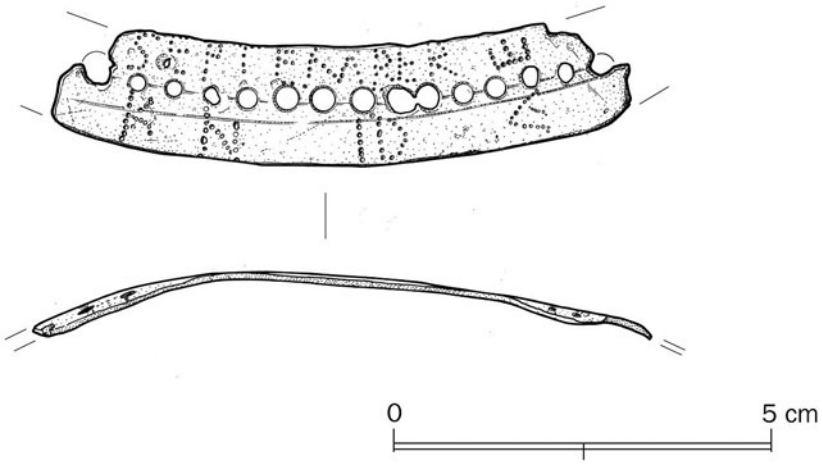

FIG. 1. The Vindolanda fragment. (© *The Vindolanda Trust*)

The Vindolanda fragment is an 83 by 21 mm portion of a flat copper-alloy annulus (FIG. 1). In its entirety this artefact would have formed a circular band with a diameter of approximately 35 cm. The Vindolanda fragment is pierced by 13 small holes, approximately 2.5 mm in diameter, spaced about 5 mm apart (centre to centre). Above the line of holes appears the text SEPTEMBER. Below the holes appear the letters K, N and ID. Running perpendicular to the line of holes and the rest of the text are the letters AE. The letters on this artefact are formed by a series of shallow punches and range in height from 5 to 7 mm and in width from 1 to 8 mm.

This text clearly identifies the fragment as a calendrical device. The name of the month September is complete, and the remaining letters are abbreviations for the Kalends, Nones and Ides, the first, fifth and thirteenth of the month. The AE inscribed perpendicularly to the rest of the text and the series of holes is an abbreviation for Aequinoctium, or Equinox. Once it is recognised that each of the holes through the fragment represents a two-day period, it is clear that this label aligns with the date of the equinox, which would have occurred between 22 and 25 September, depending on when the artefact was designed and/or produced.

When it was first uncovered, the excavators believed the Vindolanda fragment was part of a parapegmatic perpetual calendar.[4] Soon afterwards, however, Michael Lewis compared it to a passage from Vitruvius and artefacts from Salzburg (Austria) and Grand (France) to argue that it was part of a complicated time-keeping device known as an anaphoric water clock.[5] Subsequently, I argued that the Vindolanda fragment was not part of the same type of device as the Salzburg and Grand fragments, nor indeed that described by Vitruvius. I maintained that the fragment was part of a parapegmatic calendar and elaborated upon the use and significance of such an object on Rome's northern frontier.[6] Vindolanda, I argued, was isolated enough that

[4] Parapegmata (sing. parapegma) constitute a family of instruments that tracked regular cycles (such as days, weeks, months, seasons and astrological phenomena) using one or more movable pegs that were inserted into templates of various types. For further discussion of parapegmata, their application and development, and specialised uses of the term, see Lehoux 2007, especially 12–27.

[5] Lewis 2009, 13–14. An anaphoric water clock, which combines regulated water flow with a series of dials, is described in Vitr. 9.8.8–15. For a detailed discussion of the Grand and Salzburg fragments see Nordon 1990; 1994. A summary of his arguments and conclusions (in English), with a long quotation of Nordon's original French text, may also be found in Turner (2000, 540–2). For the Salzburg fragment see also Benndorf *et al.* 1903; Maass 1902.

[6] Meyer 2014.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

it would have been important to keep track of the date in order to maintain a consistent chronological relationship with other sites, especially Rome, and to adhere to the demanding schedule of rites and festivals as prescribed by central authorities and recorded on documents such as the *Feriale Duranum*.[7] Furthermore, I argued that the existence of this calendar highlights the importance and difficulty of synchronising secular and religious calendars around the Empire.[8]

In 2014 Kevin Birth further distinguished the Vindolanda fragment from the Salzburg and Grand fragments, while expanding the discussion to include parapegmata and fasti more broadly.[9] Birth demonstrated that while the Vindolanda fragment has more in common with parapegmata than it does with fasti, it does not fit neatly into either category. While it was clearly intended to receive a peg in order to track the date, the Vindolanda fragment does not demonstrate the concern with agricultural and pastoral practices generally associated with parapegmata. However, it also does not contain the details of official religion and festivals characteristic of fasti.[10] Furthermore, as Birth notes, 'the problem with labelling the object as a parapegma is that its form is unlike any other parapegma. Instead, its form and contents are most like later equatoria or perpetual calendars, but the artefact from Vindolanda pre-dates known examples of these types of tools by centuries'.[11]

Indeed, the uniqueness of the Vindolanda fragment and the lack of detailed evidence by which to date it made it impossible to take this analysis much further. There was general consensus that the Vindolanda fragment was some sort of time-keeping device (either a clock or a calendar), that it was associated with a Roman military site, and that its form, if not its purpose, was similar to a parapegma. Yet there was little agreement about the form the original artefact took. Lewis wanted to associate it with a complex time-keeping mechanism similar, if not identical, to that described by Vitruvius, while Birth maintained that 'the counter-clockwise arrangement of the months combined with the evidence that the fragment was soldered in place may suggest that it formed part of a fixed base over which something else moved'.[12] Furthermore, he argued 'the slight scratches that run between the holes and the edge support this conclusion. This is very much more consistent with an equatoria or an astrolabe than with a *horologium hibernum*'.[13] Birth was certainly correct to observe that the solder indicated that the annulus of which we have a fragment was attached to something,[14] but it was unclear how complicated the original device was. The study and interpretation of this artefact can now be advanced significantly by developments in 2016 and 2017.

[7] For the text of the *Feriale Duranum* see Fink 1971, 422–9; Helgeland 1978, 1481–6. For the argument that the *Feriale* regulated military religion in particular, see E. Birley 1978, 1510; Fink *et al.* 1940, 28–9; Fishwick 1988, 349–51; Helgeland 1978, 1481, 1487–8; Irby-Massie 1999, 14–17; Nock 1952, 202, 229, 241. The specifically military nature of this document has been questioned in Reeves 2005, especially 58–88.

[8] Meyer 2014, 114–15.

[9] Birth 2014.

[10] For discussion of the distinction between parapegmata and fasti and its complications see Lehoux 2007.

[11] Birth 2014, 407.

[12] Birth 2014, 401.

[13] Birth 2014, 401. Equitoria are instruments used to determine the position of the sun, moon and planets. They normally consist of a series of overlaid discs that rotate around independent axes. Astrolabes are similar to equitoria but predict the location of celestial bodies at specific times and places. *Horologia hiberna* are a family of time-keeping devices that measure seasonal hours using water. Some examples of this group of instruments, which includes anaphoric water clocks, are described by Vitruvius (9.8). For an introduction to the design, history and use of equitoria, see Evans 1998, 215–16, 401–10. For an introduction to astrolabes, see Evans 1998, 141–61, and for a more detailed study, see Morrison 2007.

[14] Birth 2014, 409 made the very sensible suggestion that it might have been a date indicator similar to a watch hand.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

The first of these new developments was the discovery of a small piece of copper-alloy in a field near Hambledon, Hants., and its subsequent report to the Portable Antiquities Scheme (FIG. 2).[15] This artefact is very similar to the Vindolanda fragment, suggesting that they are fragments of the same type of device. The Hambledon/PAS fragment is a strip of roughly rectangular shape that curves slightly as if it formed an annulus when intact. It has, like the Vindolanda fragment, been broken at both ends. The surviving fragment is 38.38 mm long and 12.9 mm wide. It has 16 holes punched in a line approximately 4 mm from the outer edge of the object. Each of these holes is approximately 1 mm in diameter. Inside (or above) the line of holes, the object is inscribed with AUGUS, in block capitals ranging in height from 4 to 6 mm and from 2.5 to 4 mm in width. The upright of a T and the base of a U/V are also visible, allowing us to restore with great certainty 'Augustus'. This was, of course, the name given to the month Sextilis to honour Augustus and was equivalent to our August.[16] Outside (or below) the line of holes are the remains of an N and a D in letters 4.5 and 4 mm tall and 4 and 2 mm wide, respectively. The N is an abbreviation for Nones and the D helps to form an abbreviation for Ides.[17] The expansion of these abbreviations is reinforced by their positions relative to the holes above them. The inscription of AUGUS runs from the second to the fourteenth of the holes, as counted from left to right with the letters oriented upward. The N is placed below or outside the fifth and sixth holes and the D is centred under the twelfth. These holes then correspond roughly to the Nones and the Ides of August, that is the fifth and the thirteenth.

FIG. 2. The Hambledon/PAS fragment. (© *The Portable Antiquities Scheme*)

[15] PAS unique ID SUSS-BA3CBE. See Pearce 2017 for the initial online publication of this artefact.

[16] For the renaming of August between 9 and 6 B.C.E., see Hannah 2005, 119. For primary sources regarding the renaming of Sextilis, see Censorinus 22.16, Cass. Dio 55.6.6, Macrob. 1.12.35 (also printed as SC 42 FIRA^2 1:280–1), Suet., *Aug.* 31.2.

[17] 'D' alone is a very unusual abbreviation for *idus* or *idibus*. However, it may be found in a small number of inscriptions including, for example, *AE* 2013, 2182. It is therefore tempting to restore an 'I' before the 'D' to form

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

This interpretation and the holes in the surviving fragment also allow us to estimate the size of the original object. Since the Nones of August were on the fifth of the month and the Ides were on the thirteenth it is clear that this fragment has a hole for almost every day of the month and that the days from the second to the seventeenth are preserved. Therefore, the circumference of the circle of holes in the annulus was approximately 82.5 cm and the diameter of the entire object was approximately 27 cm.

The Hambledon fragment, although similar to the Vindolanda fragment, is different in some significant ways. Both preserve a portion of one month of a calendrical device, have labels for the Nones and the Ides, include holes corresponding to the days of the month, and when complete, were annular in shape. However, the Vindolanda fragment has a label for the Kalends, and no such label is visible on the Hambledon fragment. The Vindolanda fragment also has a label for the autumnal equinox. While no corresponding label appears on the Hambledon fragment, there is no analogous astronomical event in August. The labels on the two objects were also executed differently; the text on the Hambledon fragment is incised, while that on the Vindolanda fragment is punched. In addition, the Hambledon fragment has a hole for almost every day of the month, while each hole in the Vindolanda fragment represents two days. As a result, the holes on the Hambledon fragment are much smaller. Finally, the Hambledon fragment was part of a much smaller object than the Vindolanda fragment. The Hambledon object had a diameter of just 27 cm compared to the Vindolanda object's diameter of approximately 35 cm.

It is clear that these fragments came from artefacts with the same general form and which served the same general function. The discovery of the Hambledon fragment also demonstrates that the Vindolanda fragment is not unique, but rather that this type of time-keeping device may have been relatively common. The details of the two fragments suggest that they were made in rough approximation of a similar archetype. However, the variations in size, writing technique, labelling and hole frequency indicate that they were not made by the same craftsman and do not conform to a single design. Rather, the variations between the two suggest the existence of discrete craftsmen or regional workshops.[18] Nevertheless, the relative abundance or scarcity of these objects is still very much debated.[19]

Ultimately, the Hambledon fragment does little to answer questions about the true nature of the Vindolanda 'calendar'. Pearce mentions no evidence of solder or any other attachment method on the Hambledon fragment, nor is any visible in the available photographs. Furthermore, there is no evidence of wear on the top of the artefact, such as Birth quite reasonably thought might have been indicative of rubbing between the fragment and another piece, perhaps a pointer to indicate the date.[20] These details bring into question Lewis' suggestion that the Vindolanda fragment was part of a mechanical device as complicated as Vitruvius' anaphoric water clock. Rather, it seemed until recently that this was another example of a relatively simple calendrical device that is, as Birth suggested, more akin to an astrolabe or equitoria.[21]

None of the initial arguments regarding the details of the Vindolanda fragment's original form, however, explain the function of the Hambledon fragment. While a simple calendrical device makes sense in a military environment or even a civic context in which festivals, sacrifices and

the most common abbreviation for *idus* and *idibus*. While no trace of an 'I' is visible on the artefact, *idus* or *idibus* remains the most likely resolution of this abbreviation.

[18] For the suggestion that the Vindolanda fragment was made by an amateur, see Birth 2014, 407.

[19] Turner (2000, 536 and 542) highlights this point in a discussion of anaphoric water clocks. Turner maintains that even the men named by Vitruvius as innovators of these devices were but a few of the many who were preoccupied with their designs. He also argues that anaphoric water clocks 'if not common, could at least have been relatively familiar in the public places of the Roman empire during the first centuries of our era'.

[20] Birth 2014, 409.

[21] Birth 2014, 401.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

official business had to be tracked and performed at specified times, Hambledon is a rural site about 12 km north of Portsmouth. The precise nature of the site has yet to be determined; however, it is unlikely to have been either a military or an urban settlement. There are known villas in the general vicinity of Hambledon, but nothing is known about ancient habitation in the village.[22] Likewise, the unstratified context in which the Vindolanda fragment was found and its fragmentary state suggest that it may have been transported some distance before its deposition as scrap and it cannot be definitively associated with the military or civilian administration of the site.

FIG. 3. The Frankfurt clepsydra. (© *Archäologisches Museum Frankfurt*)

[22] For the archaeological environment around Hambledon see Hampshire County Council 2015 and the Ordnance Survey's map OL8.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

Fortunately, this ambiguity was largely resolved by Alexander Jones in 2016. Jones recognised that the Vindolanda fragment looks very much like the rim of an artefact that came into the possession of the Frankfurt Archaeological Museum from a private collection in 2000 (FIG. 3).[23] This object is a bowl about 21 cm tall. Its diameter at the top varies from 36 to almost 40 cm, presumably as a result of damage after its creation, and its rim is incised with abbreviations for the names of the 12 months, the Kalends, Nones and Ides of each month, the equinoxes, the summer solstice (*solstitium*) and the winter solstice (*brevitas*).[24] These are identical to the markings that survive on the Vindolanda fragment, and differ from those of the Hambledon fragment only in the inclusion of the Kalends, which do not seem to appear (or at least are not visible) on the latter. In addition, the bowl of the device has a 1.7 cm hole at its base, and a 0.4 mm hole beside it. The smaller hole was drilled through a gold patch which had, temporarily, plugged a larger outlet. By drilling through the gold patch the outflow of this hole could be precisely regulated over a long period, since gold, unlike bronze, does not corrode. Also within the bowl are 12 series of up to 12 soldered dots descending from the rim and each corresponding to one of the 12 months as marked on the rim. These soldered points are then connected with lateral, curving lines (FIG. 4). It is clear that this is a relatively simple outflow clepsydra.

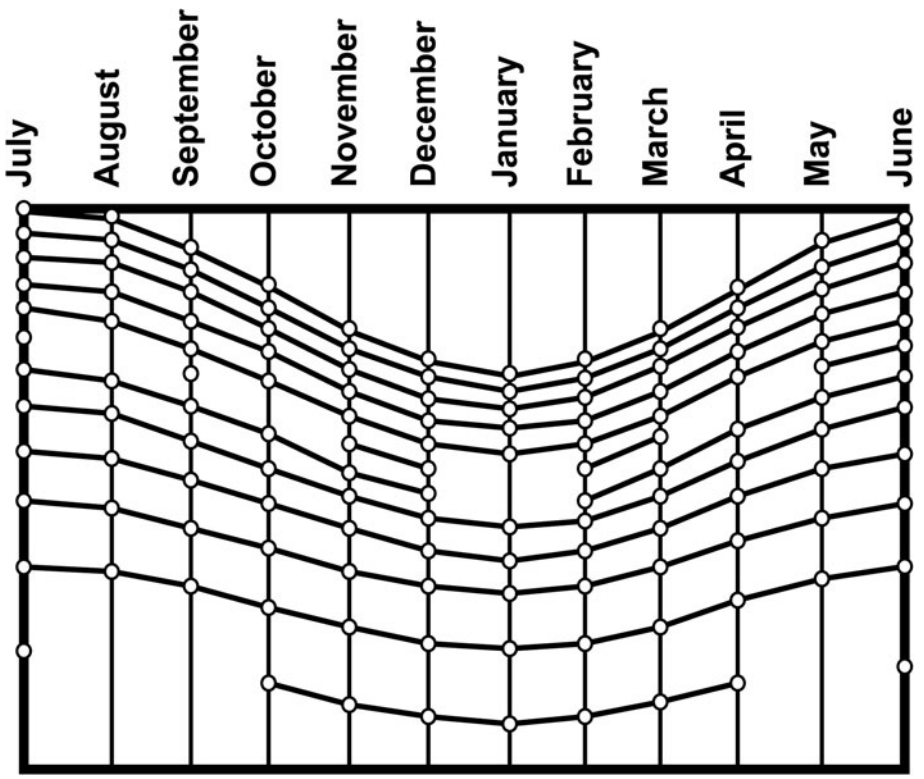

FIG. 4. Schematic drawing of the hour lines on the Frankfurt calendrical clepsydra (after Stutzinger 2001, 10 Abb. 5).

[23] I owe thanks to Professor Jones who shared his discovery with Professor Birth, who passed it on to me. For a detailed description of this object and discussion of its history and significance, see Stutzinger 2001.

[24] This use of *brevitas* is, perhaps, unique. The term *brumales brevitates* appears in Vitr. 9.8.15 and is a clear reference to short winter hours. *Brumalis* is also used in contrast to the *solstitialis* in Vitr. 9.7.7.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

The operation of this device is quite simple. The large and small holes in the bottom of the bowl were plugged before filling the bowl with water up to the highest of the lines connecting the soldered dots below the appropriate date. Then the small hole was unstopped, allowing water to drain slowly from the bowl. The passing of temporal (seasonal) hours could then be read as the water level reached each subsequent horizontal line until, after 12 hours, the water level reached the small hole and water ceased to flow. Finally, the large hole in the bottom could be opened to drain the remaining water and clean the device.[25]

The form and labelling of the rim of the Frankfurt clepsydra are nearly identical to the Vindolanda and Hambledon fragments in their original states. While no visible signs survive of the methods by which the Frankfurt clepsydra was made, metallurgical analysis has revealed that the bowl and the annulus (rim) of the Frankfurt clepsydra are made of different material and, in fact, some solder remains in two places.[26] This is significant because it explains the signs of solder on the Vindolanda fragment and the state of repair of both the Vindolanda and Hambledon fragments; the rims, which display calendrical information, have simply been separated from the bowls (clepsydrae) with which they were originally associated. This combination of calendrical devices and clepsydrae, which might be called calendrical clepsydrae, is novel.[27] No example was known before the discovery of the Frankfurt artefact but it is now possible to refer to the Vindolanda, Hambledon and Frankfurt objects as calendrical clepsydrae with confidence.

THE USE AND FUNCTION OF CLEPSYDRAE

Some significant differences between the artefacts and peculiarities about them raise questions about the contexts in which they were used. These three fragments all included holes representing the days of the year. However, while the Vindolanda calendrical clepsydra seems to have a hole for every two days of the calendar year, the Hambledon and Frankfurt artefacts have a hole for, nominally, every single day. However, the Frankfurt example includes 368 holes around its rim. This is two and three quarters more holes than the Julian calendar, or any solar calendar, specifies.[28] The Hambledon calendrical clepsydra has a similar problem. Close examination reveals that the dates (i.e. the holes) and labels (i.e. Nones and Ides) are not easily compatible. The inconsistency of time-reckoning in the Roman world is well summarised in Seneca's comment that 'philosophers will agree more often than clocks' (and here the Latin word is *horologia*), but this cannot be the case for calendrical devices.[29]

Among these three, the Vindolanda fragment was the most accurate perpetual calendar, although it, too, is flawed. The Hambledon fragment is not even accurate for a single month and the Frankfurt device has too many days per year. Similarly, if each hole on the Vindolanda fragment is to represent two days, it would be difficult, if not impossible, to differentiate between 30- and 31-day months and to track a 365-day year. Not even leap years work very well because, though they have an even number of days (366), a 29-day February compounds the already difficult question of what to do with months with an odd number of days. Therefore, these devices would have been all but useless as scientific tools for tracking the sun

[25] Stutzinger 2001, 22.
[26] For metallurgical analysis of the Frankfurt clepsydra, see Stutzinger 2001, 11–12.
[27] The novelty of the Frankfurt and Vindolanda devices was first recognised by Professor Birth (pers. comm.).
[28] It is also interesting to note that the number of holes in the Frankfurt calendrical clepsydra belies Turner's contention (2000, 538) that the number of holes in the extant fragments of the anaphoric water clocks from Grand and Salzburg was dictated by the size of the discs in which they were drilled. Indeed, the Frankfurt clepsydra is the smallest of the four objects discussed here and the only one with holes corresponding to every day of the year.
[29] Sen., *Apoc.* 2.2.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

or celestial movements. This is, of course, a surmountable problem. All that was required was someone with sufficient knowledge to correct the date as marked on these devices using a more precise calendar, which may have taken a form similar to the *Fasti Praenestini* or the Calendar of 354, though it need not have shared the medium or contained the level of detailed information of either.[30] Just such a person is mentioned in *CIL* 12, 2522, which records C. Blaesius Gratus' gift of a *horologium* and a slave to attend to it in Talloires, France, about 40 km south of Geneva. However, problems of adherence to the solar calendar did not affect the primary function of calendrical clepsydrae. They were all certainly time-keeping devices but the context in which they were used is not immediately clear, except that the activities with which they were associated required limited precision.

The Frankfurt artefact may, however, resolve this problem. The lateral lines of the Frankfurt calendrical clepsydra mark differing lengths of time: intervals between lines 1–9 (top-to-bottom) measure half an hour each (hours being of varying lengths throughout the year), intervals between lines 9–11 represent 1 hour each, the interval between lines 11 and 12 measures 1.5 hours, and the remaining space between line 12 and the nozzle represents 4.5 hours (see FIG. 4). This configuration creates a total of 12 hours of varying lengths.[31] The lines that mark these intervals of hours and fractions of hours are not straight. Rather, they rise and fall, and the intervening spaces widen and narrow. This is because they are meant to mark temporal (i.e. seasonal) hours, instead of fixed (i.e. equatorial) hours. Thereby every day of the year consisted of 12 daylight hours and 12 hours of darkness and the duration of those hours varied to fill days and nights as their lengths changed with the seasons. The lengths of the hours then correspond to the appropriate date on the calendrical elements of the devices. Furthermore, the Frankfurt device is designed to track daylight temporal hours, not nocturnal hours as one might expect from a scientific instrument related to celestial observation.

There is one more piece of evidence from the Frankfurt calendrical clepsydra that may indirectly help to explain these intervals. On the outside of the bowl is a dedicatory inscription from Mapilius Mapilianus, subprefect of the waters of Borvo. This inscription reads: '*Mapil(ius) Mapilianus su(b)pr(a)efect(u)s aquarum dei Borvonis ex aere fracto excitatoriam f(ecit) ex voto s(olvit) l(ibens) m(erito).*'[32] There are two words that are of particular interest in this dedication. The first is *excitatoria*, which seems to indicate some sort of signalling device, perhaps a bell that accompanied the calendrical clepsydra. The second is Borvo. Also known as Bormo, Bormanus and Bormanicus, Borvo was a Gallo-Celtic healing deity often associated with hot springs. Dedictions to Borvo appear at Bourbon-Lancy (*Aquae Bormonis*) in Lugdunensis, Bourbonne-les-Bains in Germania Superior and many other locations throughout the Gallic and German provinces.[33]

As Stutzinger has pointed out, this association of Borvo with healing and springs may help to explain the Frankfurt artefact.[34] The apparently arbitrary markings for times on the inside of the Frankfurt calendrical clepsydra align closely with the schedule of access to baths that is preserved on the so-called Vipasca Tablets.[35] These tablets outline rules for the administration of a mining community in modern Portugal. Among other things, clauses in the text dictate that whoever wins the contract to manage the baths at Vipasca must keep them heated and open to

[30] For the *Fasti Praenestini*, see Degrassi 1963, 107–45. For the Calendar of 354, also known as the *Fasti Furii Filocali*, see Degrassi 1963, 237–62; Hannah 2005, 139–55; Lehoux 2007, 192–4.

[31] Stutzinger 2001.

[32] 'Mapilius Mapilianus subpraefect of the waters of Borvo made (this clepsydra) from scrap bronze and the signal (?) in accordance with a vow. He fulfilled (that vow) freely and deservedly.' Transcription follows Stutzinger 2001, 30. Cf. *AE* 2003, 1279.

[33] For discussion of Borvo and the distribution of inscriptions naming him see Stutzinger 2001, 30–9.

[34] Stutzinger 2001, 38–9.

[35] *CIL* 2, 5181; *ILS* 6891.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

women from dawn to the seventh hour, and to men from the eighth hour of the day to the second hour of the night.[36] Similarly, the author (or authors) of the *Life of Hadrian* in the *Historia Augusta* record that he reserved specific hours of the day for the sick to attend baths.[37] These, of course, need not have been the schedule for all baths, but are representative of the way baths were managed.[38]

Lucian also maintains that clocks were integral to the ideal bath-house. In his *Hippias*, also known as *The Bath* or *Balneum*, he extolls the architectural expertise of Hippias and notes that the bath-house he designed and built had many admirable features including 'two indicators of the time, one that bellows on account of water and one that shows the time by the sun'.[39] These two devices are clearly a water clock of some kind and a sundial. Lucian's inclusion of these time-keeping devices suggests that they were common and useful amenities in a bath, even if they were not ubiquitous. This source may also illuminate the meaning of *excitatoria*, the signalling device, in the inscription on the Frankfurt artefact. While there is no reason to believe that this device made the same type of noise as the device from Hippias' bath, it makes sense that there would be a mechanism that communicated the passage of time. This would be particularly desirable in public baths and bathing shrines in order to delineate the periods allotted to different groups.

The connection between time-keeping devices and bath-houses is further reinforced by the clock fragment and astrological tablets discovered at Grand in France (FIG. 5).[40] While the clock fragment comes from a different type of water clock, it may still be associated with a healing shrine. In antiquity Grand was known as *Grannum*, in reference to the Celtic healing-god Grannus, who was worshipped at the site in association with Apollo. At least three inscriptions mentioning Grannus confirm the connection between Apollo-Grannus and the city[41] and suggest that Grand was one of the great centres of the healing cult of Apollo-Grannus in antiquity.[42] In fact, it was so important and renowned that Caracalla and Constantine visited the temple there in 213 and 309 C.E. respectively.[43] Given the importance of this cult centre and of bathing in Roman medical practice generally, it is logical to associate this clock with a bath of some kind.[44]

The link between Grand and healing is strengthened by the discovery there of two ivory diptychs of the second century C.E., inscribed with elaborate astrological charts.[45] Astrology was an important, though controversial, tool of ancient medicine.[46] It also required accurate knowledge of the movements of celestial objects which could be tracked by the use of calendars and clocks. Thereby, an instrument like the Vindolanda, Frankfurt and Hambledon calendrical clepsydrae could have been invaluable to medical practitioners who utilised astrology, although these specific devices were not accurate enough for scientific astronomy.

[36] *ILS* 6891, ll. 19–21.
[37] SHA, *Hadr.* 22.7.
[38] Fagan 1999, 26; Yegül 2010, 33–4.
[39] Lucian, *Hippias sive Balneum* 8: ὡρῶν δὲ διττὰς δηλώσεις, τὴν μὲν δι' ὕδατος καὶ μυκήματος, τὴν δὲ δι' ἡλίου ἐπιδεικνύμενον (text follows Harmon's 1913 Loeb volume).
[40] For a discussion of the archaeological context in which the Grand tablets were discovered, see Bertaux 1993.
[41] *AE* 1937, 55; *AE* 1983, 716; *CIL* 13, 5842. For more conservative readings see *AE* 2006, 856 and *AE* 2013, 104, 105 and 108.
[42] Birth 2014, 398; Nordon 1994, 17; Stutzinger 2001, 37, 39; Turner 2000, 540. See also Stutzinger 2001, 37, no. 69. For more on Apollo-Grannus, see Davillé 1927; Glaser and Birkhan 1978; Vipard 2013; Weber 1978; 1981. For recent scrutiny of this interpretation see Deschezleprêtre 2010.
[43] Jullian 1907–1926, 44–5. Cf. Cass. Dio 77.15.3–7; *Pan. Lat.* 7.3.2–3.
[44] Fagan 1999, 85–103.
[45] For a brief descriptions of the Grand tablets see Dechezleprêtre 2010, 86–7. For more in-depth discussion see Abry 1993.
[46] For the link between astrology and medicine see Barton 1994, 50, 53–4, 91, 179–80; Dechezleprêtre 2010, 87.

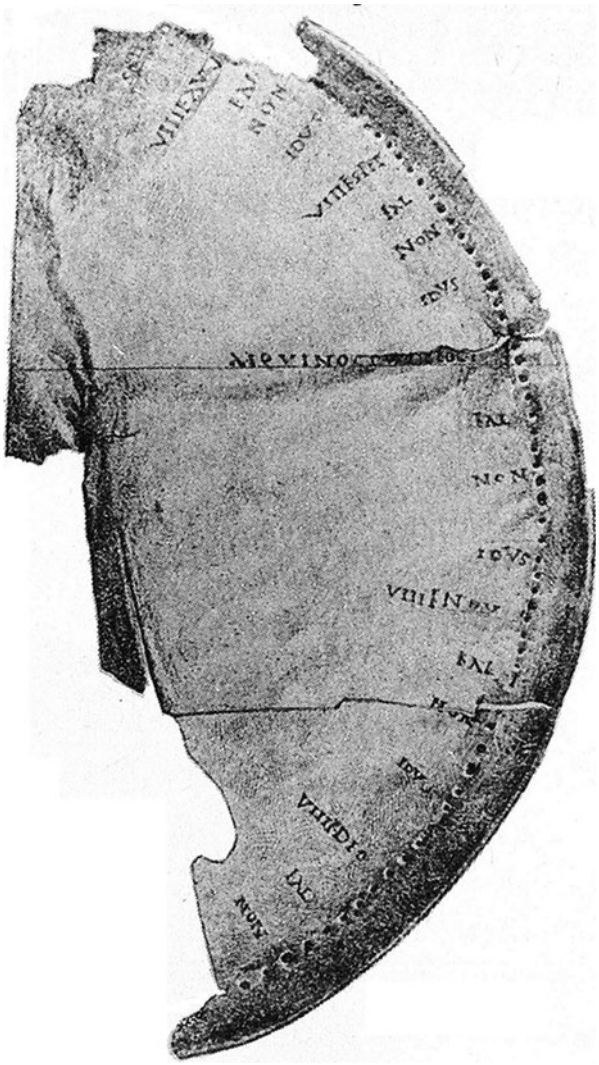

FIG. 5. The clock fragment from Grand, France (after Fröhner 1888, pl. 43).

The tablets and the Borvo-Apollo and Grannus-Apollo connections strengthen the association of clocks with baths and healing shrines, suggesting that we should search for such a link at Vindolanda. While there is no direct means by which to connect Vindolanda to Apollo-Grannus, he is attested in Britain. A dedicatory inscription to him was erected at the fort in Inveresk, Scotland (known as *Curia*, *Coria* and/or *Evidensca* in antiquity),[47] by Quintus Lusius Sabinianus, a *procurator Augusti* during the occupation of the Antonine Wall (*c*. 140–*c*.

[47] This *Coria* ought not to be confused with modern Corbridge, which may have shared the name. It is tempting, however, to see a connection between the two.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

158 C.E.).[48] Neither the unit that garrisoned Inveresk nor the one that occupied Vindolanda in the Antonine period are known, but there may have been a connection between the two locations and thereby a direct transmission of the worship of Apollo-Grannus. For now, it is enough to recognise that Apollo-Grannus was worshipped in Britannia in the second century at least.

There is also plentiful evidence for baths at Vindolanda. The site boasts a first-century bath-house just off the south side of the fort plateau,[49] a third-century bath-house in the extramural settlement on the west side of the fort[50] and baths associated with commanders' residences.[51] Furthermore, the Vindolanda writing-tablets hint at their importance to the garrison and its extramural settlement. The first-century baths are mentioned in tablet 155 (l. 1)[52] and perhaps 322 (l. 2n);[53] bath slippers (*balnearia*) are mentioned in tablet 197 (l. 2, n3) and perhaps 732;[54] and a *balniator* named Vitalis appears in tablet 181 (l. 8).[55] The tablets themselves are unique but do not reflect atypical practices on Roman military sites. The mention of the *balniator* is probably the most remarkable, but there is no reason to believe this position was unique to Vindolanda. Furthermore, while the writing-tablets, which date to the end of the first and beginning of the second century C.E., are probably at least a century removed from the time the Vindolanda calendrical clepsydra was created, there was certainly an active bath-house at Vindolanda when the device was in use.[56]

The prominence of the extramural settlement at Vindolanda and the position of the third-century bath-house within it are tempting incitements to hypothesise that the Vindolanda calendrical clepsydra was used to enforce rules of segregated bathing as described in the Vipasca Tablets and the *Historia Augusta*. On the other hand, it is also possible to see connections between Vindolanda and a bath-shrine similar to the one suggested by the inscription on the Frankfurt calendrical clepsydra and reinforced by the evidence from Grand. While there is no trace of hot springs at Vindolanda, there are several fresh-water springs on the site. One of these springs, west of the third-century fort, is still flowing and was monumentalised with a stone water-tank connected to the third-century bath-house by a stone aqueduct.[57]

Furthermore, this spring lies just 15 m east of a Romano-Celtic temple.[58] The proximity of the spring and temple might suggest their association with a water- or healing-related deity. This association was further strengthened in 2012 when a dedication by *cohors I Tungrorum* to the previously unattested goddess Ahvardva was discovered 12 m south of the temple, near another cistern.[59] *Cohors I Tungrorum* occupied the site from approximately 85 C.E to soon after 92 C.E.

[48] *RIB* 2132. For the dating of Sabinianus' tenure and thereby the inscription, see A.R. Birley 2005, 310–11. For archaeological indications that the site was only occupied during the occupation of the Antonine Wall, see J.P. Gillam's and Grace Simpsons' reports on the pottery from the site in Richmond 1980, 300–3.

[49] A. Birley 2001, 15–37; R. Birley 2009, 59–61.

[50] A. Birley 2001, 4–8; R. Birley 2009, 128, 159–60.

[51] A. Birley 2001, 8–9; R. Birley 2009, 104–5, 151.

[52] Tablet 155 includes mention of 18 men assigned to the bath-house, probably as builders (*structores*) though the text is poorly preserved.

[53] If this reading is correct, it suggests more than one bath-house at Vindolanda, including one specifically for slaves.

[54] The three words preserved on this tablet are all shoe types. It may have been part of an order or inventory of footwear. Tablet 732 is very fragmentary.

[55] Tablet 181 is an account registry listing men, their debts and credits and their positions.

[56] Because the Vindolanda fragment was discovered in an unstratified context it is difficult, if not impossible, to date archaeologically. Although Birth (2014, 395) reports that it 'has been dated to the third or fourth centuries AD', this is largely speculation based on its discovery in the topsoil of the third- to fourth-century fort.

[57] Blake 2014, 49–51.

[58] For the temple excavations and report, see Blake 2003, 2–13. For report on finds associated with the area around the spring, see A.R. Birley *et al*. 2013, 291.

[59] For the context of this discovery, see A.R. Birley *et al*. 2013, 289–91. For further discussion of nearby water tanks and cisterns, see R. Birley 2009, 45–8, 85; Blake 2003, 11–15.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

and again from 105 C.E. until it left for service in Scotland early in the reign of Antoninus Pius, though a veteran of the unit is attested at Vindolanda on a diploma of 146 C.E. After the abandonment of the Antonine Wall, the cohort was posted at Housesteads, very near Vindolanda.[60] The Tungrians' origins along the banks of the Maas (Meuse) in Germania Inferior also bring them tantalisingly close to known locations of the worship of Borvo, while linguistic evidence indicates that Ahvardva was a Celtic or Germano-Celtic water divinity, not unlike Borvo.[61] The use of the same 'distinctive soft yellow sandstone' for the inscription, the temple and the water-tank suggests that the three are related,[62] but it would be overly ambitious to argue strenuously that the Romano-Celtic temple at Vindolanda was dedicated to Ahvardva; a small statue of Fortuna[63] and an altar to either Hercules Magusanus or the Veteres were discovered near the temple in 2012 and may equally be associated with it.[64] In fact, it has also been suggested that the inscription adorned a hypothetical shrine adjacent to the water-tank.[65] Nevertheless, the temple, shrine and inscription provide tantalising connections between the Vindolanda calendrical clepsydra, the Frankfurt calendrical clepsydra, activities at Grand and healing divinities associated with water.

There is also another possible way in which Vindolanda and by extension the Vindolanda calendrical clepsydra may be connected to baths and healing cults. John Wallis, an antiquarian of the latter half of the eighteenth century, recorded that there were, in his time, sulphur springs in the Allen Valley just south of Vindolanda. Wallis wrote:

> A quarter of a mile above the romantic ruin of *Staward le Peel*, on the edge of the river *Allen*, is a sulphur-spring, dedicated to St. *Mary*, called the *Haly-Well*. It is in the *Sinus* of a sloping freestone-rock, wherein are lodged large pellets of sulphur; the aperture and sides tinged by it with a silvery colour. It is of a nauseous foetid taste and smell. Being so near the *Allen*, the floods often encroach upon it, and force it to change its situation in the rock, breaking out again in some other aperture. The situation is extremely pleasant; a bank of tall oaks and other forest-trees on both sides of the river; an upright stone-pillar by it, fit to rest a book on; the river within a few yards forming a cascade, called *Cyprus-Linn*; under it a large and deep bason.[66]

Staward Pele, as it is now known, was a fourteenth-century fortified tower about 6 km south of Vindolanda on a promontory overlooking the Allen Valley. Its remains are now in a sad state of repair, but when examining it in 1885, C.C. Hodges reported that:

> He had long been aware of the presence of a large number of stones of Roman workmanship in the remains of the gateway to the Pele, but it was only on the 29th of August last that he observed a Roman altar in the upper portion of this ruin.[67]

This altar was subsequently investigated by Eric Birley in 1937 who found it still perched precariously at the top of the ruins, but when he revisited it in 1947, two of the stones above it had fallen off. Subsequently, on 8 July 1949 a Trinity College, Oxford student named Michael

[60] *RMD* II, 97. For further discussion of *cohors I Tungrorum*'s movements, see A.R. Birley *et al*. 2013, 191–6.
[61] A.R. Birley *et al*. 2013, 298–300.
[62] A.R. Birley *et al*. 2013, 291.
[63] B. Birley 2014.
[64] *RIB* 3343; *AE* 2003, 1040. For further discussion see A.R. Birley 2003, 59; Tomlin and Hassall 2003, 369; cf. Blake 2014, 49.
[65] A.R. Birley *et al.* 2013, 291.
[66] Wallis 1769, 19–20.
[67] Society of Antiquaries of Newcastle-upon-Tyne 1885, 94.

https://doi.org/10.1017/S0068113X19000035 Published online by Cambridge University Press

de Lisle, who was staying with Birley, visited Staward Pele and found that the altar had fallen from the tower.[68] Further examination has yielded the following reading:[69]

> I(ovi) O(ptimo) M(aximo) | [c]oh(ors) IIII G[al]l(orum) | [cu]i p[r]ae(est) [Su]lpi|cius Ṗuden|[s] pr [a]efect(us) [a]ram [p]osuit, | v(otum) [l(ibens)] m(erito) s(olvit).
>
> To Jupiter, Best and Greatest, the Fourth Cohort of Gauls, under the command of their prefect Sulpicius Pudens, set up this altar and willingly and deservedly fulfilled its vow.

This would not be particularly remarkable, except that Sulpicius Pudens and the Fourth Cohort of Gauls are known to have been stationed at Vindolanda.[70] Furthermore, the size of the altar and the inaccessibility of the peel tower's site suggest that this altar was not transported from Vindolanda to be incorporated into the tower,[71] but rather that it was dedicated in a shrine on the site, a hypothesis that is further supported by the presence of other Roman stones in and around the remains of the tower.[72]

This inscription, the other Roman stones and the site's strategic location above the river and within sight of Vindolanda on a clear day recommend a Roman presence at Staward Pele, near the site of Wallis' spring. While there is no further evidence of Roman buildings in the valley, Wallis' upright pillar may represent the scanty remains of a shrine, nymphaeum or bath beside the spring. Furthermore, additional activity in the valley is attested by the presence of a Roman-period altar at the church in Beltingham, near the confluence of the Allen and the South Tyne.[73] This altar was dedicated to an otherwise unattested local divinity named Satiada, Saitada, Saiiada or Sattada by the *curia* of the *Textoverdi*, the local inhabitants of this area.[74] This inscription is sometimes attributed to Vindolanda on the assumption that it was transported to the site in the seventeenth or eighteenth century. However, even the entry in *RIB* recognises that this may not have been the case. *RIB* states 'Its place of origin is unknown; it may have been brought from Vindolanda, or it may have come from a local shrine'.[75] Indeed, the latter argument is more inviting.[76] Moving the stone from Vindolanda would have required transporting it about 5 km over rough terrain. On the other hand, the sites of Staward Pele and the spring reported by Wallis are between 3 and 4 km away along the gently sloping banks of the Allen and the course of a known Roman road. Furthermore, the name Satiada or Sattada may be related to the Celtic root *sāti*, meaning saturation and thereby refer to a water divinity; it has been observed that 'Gallic analogies suggest that unknown feminine deities of local worship are usually stream or fountain nymphs'.[77] The connection to this deity and the 'Roman' population at Vindolanda and elsewhere in this area is strengthened by the use of

[68] For this narrative, see E. Birley 1950, 132–4.

[69] Originally published in E. Birley (1950, 134–7) and updated in *RIB* 1688. This text follows A. Birley and A.R. Birley (2010, 36) which takes into account the most recent discoveries. It was Robin Birley who initially recognised Sulpicius Pudens as the dedicator of both the Staward Pele altar and the Dolichenus altar from Vindolanda (A.R. Birley, pers. comm.).

[70] For evidence of *cohors IV Gallorum* at Vindolanda see *RIB* 1686, 1687, 1705, 1706; *AE* 2010, 790; and *Notitia Dignitatum* Occ. XL 41. Cf. A. Birley and A.R. Birley 2012; A.R. Birley 2008, 176; R. Birley 2009, 18, 118, 155–7, 183; Tomlin 2010, 444 and 467.

[71] For a similar assessment see R. Birley 2009, 157.

[72] E. Birley 1950, 139.

[73] *RIB* 1695.

[74] For further discussion of this inscription, see A.R. Birley 2002, 50. On the etymology and origin of the name *Textoverdi*, see Rivet and Smith 1979, 470–2. On the nature of the *curia Textoverdorum*, see Stevens 1934.

[75] *RIB* 1695.

[76] R. Birley 2009, 157.

[77] For the possible association with streams and fountains, see Stevens 1934, 139. Jackson (1953, 325) tentatively suggests an alternative interpretation related to grief. For the Celtic root *sāti* see Centre for Advanced Welsh and Celtic Studies, University of Wales 2015.

Latin and a distinctly Roman altar type for this monument. These two inscriptions make it reasonably clear that there was religious activity related to the garrison from Vindolanda and the affiliated local population of the Allen Valley and provide a second possible context for use of the Vindolanda calendrical clepsydra.

CONCLUSIONS

There is significant evidence to connect calendrical clepsydrae of the type preserved at Vindolanda, Hambledon and Frankfurt with baths and healing shrines and this has a profound effect on the way we interpret the Vindolanda fragment and the community around the site. Of the four artefacts discussed in detail here, two have very clear connections to healing shrines.[78] One was discovered at Grand, a known centre for the worship of Apollo-Grannus, a healing god. Another, the Frankfurt calendrical clepsydra, has an inscription that connects it directly to baths and to Borvo, another healing divinity often synchretised with Apollo.

This leaves the Hambledon and Vindolanda calendrical clepsydrae. We have very little information about the context of the Hambledon fragment, but it does not appear to be associated with a military installation or a significant civilian settlement. Rather, the site may have been a villa or rural shrine. While it is tempting to ascribe a military function to the Vindolanda calendrical clepsydra, such as the measurement of night watches as proposed by Aeneas Tacticus[79] in the fourth century B.C.E. and Vegetius[80] in the fourth century C.E., it is the only such device associated with the military and the only clepsydra of any kind ever discovered at a Roman military site, as far as I am aware. Furthermore, the fragmentary state of the Vindolanda calendrical clepsydra and its recovery from an unstratified context also allow speculation about its original use at some distance from the granary and headquarters building adjacent to which it was found. For these reasons it may be preferable to look for other contexts in which the calendrical clepsydra could be used. Large-scale public baths are known in Roman Britain at Bath/*Aquae Sulis* and Buxton/*Aquae Arnemetiae*,[81] and shrines for the worship of springs are also common in Roman Britain, most notably on the Hadrian's Wall frontier at Carrawburgh, where 14 inscriptions were erected in honour of the goddess Coventina and at least 13,487 coins were discovered in a stone enclosure meant to capture the outflow of a natural spring, which was in turn incorporated into a stone-built shrine.[82] This complex included elements similar to the spring, tank and Romano-British temple west of the stone forts at Vindolanda. Furthermore, Pudens' inscription, the sulphur springs nearby and the inscription on the Frankfurt calendrical clepsydra provide an intriguing triangulation between the

[78] The Salzburg fragment, mentioned briefly above, is also relevant to discussion of time-keeping devices in the Roman world, but is of limited use here. It was part of a much larger device than were any of the other four and its discovery is not well documented. The most we can say is that the director of the Salzburg museum, Alexander Petter, conducted exhaustive investigations soon after the appearance of the fragment and concluded that it came from the north slope of the Kapuzinerberg in Salzburg itself (Benndorf *et al.* 1903, 32). We might speculate about the presence of a shrine of some sort here, but the monumental scale of the device (its face was about 1.7 m in diameter) may suggest that it was a centrepiece of the colony akin to the Tower of the Winds in Athens and various other time-keeping devices known from around the Greek and Roman worlds.

[79] Aeneas Tacticus 22.24–5.

[80] Vegetius 3.8 notes that the length of the watches (four per night) was measured by a clepsydra.

[81] The existence of baths at Buxton is inferred from its Roman name and the springs that made it famous as a spa in the Victorian period. However, the baths themselves have remained elusive. For information about Buxton, see Burnham and Wacher 1990, 176–8. For Bath, see Cunliffe 1984.

[82] Allason-Jones and McKay 1985, especially 1–19, 50–76. For further connections between Coventina's Well and other Celtic shrines of which the Vindolanda temple and well or the potential shrine in the Allen Valley may be further examples, see Allason-Jones and McKay 1985, 3.

Vindolanda fragment, healing shrines and the Allen Valley. The recent discovery of the Hambledon fragment and the recognition that it and the Vindolanda fragment were parts of calendrical clepsydrae similar to that now housed in Frankfurt have opened new and exciting avenues for the study of these objects. Further discoveries are likely to propel this research in new directions, but it now seems likely that the Vindolanda and Hambledon calendrical clepsydrae were associated with water and healing deities.

ACKNOWLEDGEMENTS

I am very grateful to everyone who helped make this paper possible, including the excavation team at Vindolanda, who discovered the Vindolanda fragment, and the Vindolanda Trust for sponsoring those excavations and for allowing me access to the artefact. I am also indebted to Professor Anthony Birley and Dr Andrew Birley who read early drafts of this paper and provided many helpful comments. Special thanks are due to Professor Kevin Birth with whom I have had many fruitful conversations about time-keeping and who has been extremely generous with his time in those conversations and in reading drafts of this paper. Of course, any errors that remain are entirely my own.

Department of Classics, University of Western Ontario
ameyer26@uwo.ca

BIBLIOGRAPHY

Abry, J.-H. (ed.) 1993: *Les Tablettes astrologiques de Grand (Vosges) et l'astrologie en Gaule romaine: actes de la Table-Ronde du 18 mars 1992*, Collection du Centre d'Etudes Romaines et Gallo-Romaines: Nouvelle Série, Paris

Allason-Jones, L., and McKay, B. 1985: *Coventina's Well: A Shrine on Hadrian's Wall*, Oxford

Barton, T. 1994: *Power and Knowledge: Astrology, Physiognomics, and Medicine under the Roman Empire*, Ann Arbor

Benndorf, O., Rehm, A., and Weiss, E. 1903: 'Zur Salzburger Bronzescheibe mit Sternbildern', *Jahreshefte des Österreichischen Archäologischen Institutes in Wien* 6, 32–49

Bertaux, J.-P. 1993: 'La découverte des tablettes: les données archéologiques', in Abry 1993

Birley, A. 2001: *Vindolanda's Military Bath Houses: The Excavations of 1970 and 2000*, Greenhead

Birley, A. 2013: *The Vindolanda Granary Excavations*, Greenhead

Birley, A., and Birley, A.R. 2010: 'A Dolichenum at Vindolanda', *Archaeologia Aeliana* series 5, 39, 25–51

Birley, A., and Birley, A.R. 2012: 'A new Dolichenum, inside the third-century fort at Vindolanda', in M. Blömer and E. Winter (eds), *Juppiter Dolichenus*, Orientalische Religionen in der Antike 8, Tübingen, 231–57

Birley, A.R. 2002: *Garrison Life at Vindolanda: A Band of Brothers*, Stroud

Birley, A.R. 2003: 'The altar', in Blake 2003, 59–60

Birley, A.R. 2005: *The Roman Government of Britain*, Oxford

Birley, A.R. 2008: 'Cives Galli de(ae) Galliae concordesque Britanni: a dedication at Vindolanda', *Antiquité Classique* 77, 171–87

Birley, A.R., Birley, A., and de Bernardo Stempel, P. 2013: 'A dedication by the Cohors I Tungrorum at Vindolanda to a hitherto unknown goddess', *Zeitschrift für Papyrologie und Epigraphik* 186, 287–300

Birley, B. 2014: 'A statue of *Fortuna*', in Blake 2014, 183–4

Birley, E. 1950: 'A Roman altar from Staward Pele and Roman remains in Allendale', *Archaeologia Aeliana* series 4, 28, 132–6 and 139–40

Birley, E. 1978: 'The religion of the Roman army: 1895–1977', *Aufstieg und Niedergang der römischen Welt* 2.16.2, 1506–41

Birley, R. 2009: *Vindolanda: A Roman Frontier Fort of Hadrian's Wall*, Stroud

Birth, K. 2014: 'The Vindolanda timepiece: time and calendar reckoning in Roman Britain', *Oxford Journal of Archaeology* 33(4), 395–411
Blake, J. 2003: *Vindolanda Research Reports 2003: The Excavations of 2001–2002, Volume II*, Greenhead
Blake, J. 2014: *Vindolanda Research. The Excavations of 2007–2012 in the Vicus or Extramural Settlement ('Area B')*, Greenhead
Burnham, B., and Wacher, J. 1990: *The Small Towns of Roman Britain*, Berkeley
Centre for Advanced Welsh and Celtic Studies, University of Wales 2015: Proto-Celtic–English wordlist. Avalable at http://www.wales.ac.uk/Resources/Documents/Research/CelticLanguages/ProtoCelticEnglishWordlist.pdf (Accessed April 2018)
Cunliffe, B. 1984: *Roman Bath Discovered*, London
Davillé, C. 1927: 'Apollon Grannus', *Revue des études anciennes* 29, 55–6
Degrassi, A. 1963: *Inscriptiones Italiae* XIII.2, Rome
Dechezleprêtre, T. 2010: 'Les tablettes astrologiques', in T. Dechezleprêtre (ed.), *Sur les traces d'Apollon: Grand la gallo-romaine*, Paris, 86–91
Evans, J. 1998: *History and Practice of Ancient Astronomy*, Oxford
Fagan, G.G. 1999: *Bathing in Public in the Roman World*, Ann Arbor
Fink, R.O. 1971: *Roman Military Records on Papyrus*, Cleveland
Fink, R.O., Hoey, A.S., and Snyder, W.F. 1940: 'The Feriale Duranum', *Yale Classical Studies* 7, 1–221
Fishwick, D. 1988: 'Dated inscriptions and the Feriale Duranum', *Syria: Archéologie, Art et Histoire* 65, 349–61
Fröhner, W. 1888: *Collection H. Hoffmann. Catalogue des objets d'art antiques, vases peints, marbres, bronzes, argenterie, poids grecs, ivoires*, Strasburg
Glaser, F., and Birkhan, H. 1978: 'Ein Heiligtum des Grannus Apollo in Teurnia', *Jahreshefte des Österreichischen Archäologischen Institutes in Wien* 52, 121–7
Hampshire County Council 2015: 'The Atlas of Hampshire's Archaeology' available at https://www.hants.gov.uk/landplanningandenvironment/environment/historicenvironment/archaeologyatlas (Accessed December 2018)
Hannah, R. 2005: *Greek and Roman Calendars: Constructions of Time in the Classical World*, London
Harmon, A.M. 1913: *Lucian, vol. 1*, Cambridge, MA
Helgeland, J. 1978: 'Roman army religion', *Aufstieg und Niedergang der römischen Welt* 2.16.2, 1470–1505
Irby-Massie, G.L. 1999: *Military Religion in Roman Britain*, Leiden
Jackson, K.H. 1953: *Language and History in Early Britain*, Edinburgh
Jullian, C. 1907–1926: *Histoire de la Gaule*, Paris
Lehoux, D. 2007: *Astronomy, Weather, and Calendars in the Ancient World: Parapegmata and Related Texts in Classical and Near Eastern Societies*, Cambridge
Lewis, M. 2009: 'A Roman clock at Vindolanda', *Current Archaeology* 228, 12–17
Maass, E. 1902: 'Salzburg Bronzetafel mit Sternbildern', *Jahreshefte des Österreichischen Archäologischen Institutes in Wien* 5, 196–7
Meyer, A. 2013: 'The "Calendar" fragment', in A. Birley (ed.), *The Vindolanda Granary Excavations*, Greenhead, 119–20
Meyer, A. 2014: 'Notes on the Vindolanda "calendar": related artefacts and the purpose of the Vindolanda fragment', in R. Collins and F. McIntosh (eds), *Life in the Limes: Studies of the People and Objects of the Roman Frontiers*, Oxford, 109–15
Morrison, J.E. 2007: *The Astrolabe*, Rehoboth Beach
Nock, A.D. 1952: 'The Roman army and the religious year', *Harvard Theological Review* 45, 186–252
Nordon, M. 1990: 'Sur un objet en bronze découvert à Grand en Lorraine en 1886', *Bulletin d'Association Nationale des Collectionneurs et Amateurs d'Horologerie Ancienne et d'Art* 57, 27–42
Nordon, M. 1994: 'El reloj anafórico de Grand, en Lorena: Verdaderos y flasos enigmas alredor de un vetigo', *Arbor* 149, 13–52
Pearce, J. 2017: 'SUSS-BA3CBE: a Roman calendar', available at https://finds.org.uk/database/artefacts/record/id/841970 (Accessed April 2018)
Reeves, M.B. 2005: *The Feriale Duranum, Roman Military Religion, and Dura-Europos: A Reassessment*, unpub. PhD thesis, The State University of New York at Buffalo
Richmond, I.A. 1980: 'A Roman fort at Inveresk, Midlothian', *Proceedings of the Society of Antiquaries of Scotland* 110, 286–304

Rivet, A.L.F., and Smith, C. 1979: *The Place-Names of Roman Britain*, London
Society of Antiquaries of Newcastle-upon-Tyne 1885: *Proceedings of the Society of Antiquaries of Newcastle-upon-Tyne*, vol. 2 no. 12
Stevens, C.E. 1934: 'A Roman inscription from Beltingham', *Archaeologia Aeliana* series 5, 11, 138–45
Stutzinger, D. 2001: *Eine römische Wasserauslaufuhr*, Berlin
Tomlin, R.S.O. 2010: 'Inscriptions', *Britannia* 41, 441–69
Tomlin, R.S.O., and Hassall, M.W.C. 2003: 'Inscriptions', *Britannia* 34, 361–82
Turner, A.J. 2000: 'The anaphoric clock in the light of recent research', in M. Folkerts and R. Lorch (eds), *Sic Itur ad Astra: Studien zur Geschichte der Mathematik und Naturalwissenschaften, Festschrift für den Arabisten Paul Kunitzsch zum 70. Geburtstag*, Wiesbaden, 536–47
Vipard, P. 2013: 'Les inscriptions romaines de Grand (Vosges). Première partie: épigraphie lapidaire et en bronze', in T. Dechezleprêtre (ed.), *Grand: Archéologie et territoire*, Grand, 30–120
Wallis, J. 1769: *The Natural History and Antiquities of Northumberland and of so much of the County of Durham as Lies between the Rivers Tyne and Tweed*, London
Weber, G. 1978: 'Reste römischer Steinarchitektur in Faimingen. Bestandteile des Apollo-Grannus-Heiligtums?', *Germania: Anzeiger der Römisch-Germanischen Kommission des Deutschen Archäologischen Instituts* 56, 511–21
Weber, G. 1981: 'Neue Ausgrabungen am Apollo-Grannus-Heiligtum in Faimingen. Zwischenbericht', *Bericht der Römisch-Germanischen Kommission/ Deutsches Archäologisches Instituts* 62, 103–217
Yegül, F. 2010: *Bathing in the Roman World*, Cambridge