Stefanie Wefers. **Die Mühlenkaskade von Ephesos. Technikgeschichtliche Studien zur Versorgung einer spätantiken bis frühbyzantinischen Stadt**. With contributions by Richard Brüdern, Anja Cramer, Guido Heinz, Tatjana M. Gluhak, Fritz Mangartz, Kuno Menchen, Cees Passchier, Gül Sürmelihindi and Alice Waldner. Monographien des Römisch-Germanischen Zentralmuseums, volume 118. Publisher of the Römisch-Germanisches Zentralmuseum, Mayence 2015. X and 322 pages, 66 plates, 41 colour plates, 6 additional plates.

During the Austrian excavations of a habitation area (Hanghaus 2) on the northern slope of Mount Koressos (Bülbüldağ) in Ephesos, a number of water-mills were excavated under the direction of Hermann Vetters, who recognized their nature in 1977 and mentioned them briefly in a series of preliminary reports (1981, 1982, 1984). These included only little information, and, in spite of the obvious importance of the finds, they were to play a very small part in discussions in water-mill literature for thirty years – even after the significant observation that one of the water-wheels powered something even more remarkable than an ordinary grain-mill, namely a fairly well-preserved saw-mill for cutting stone.

The saw-mill was published in 2010 by Fritz Mangartz and Stefanie Wefers, and in the present volume it is treated only in passing, with the exception of its water-wheel, which is discussed among the seven others and, particularly, in the section ›Praktische Rekonstruktion des Wasserrades der Steinsäge (WT2)‹ (pp. 145–152). The final publication of the grain-mills was delayed due to lack of funding, but this problem was soon solved and the work further promoted by an interdisciplinary cooperation between various Austrian and German institutions: The Romano-Germanic Central Museum Mayence, the Leibniz Research Institute for Archaeology, the Austrian Archaeological Institute, and the Institute for Cultural History of the Austrian Academy of Sciences.

The authors present their material in a strictly logical order, starting from a rigorous description of the building remains and leading up to the concluding discussion of the urban location of the mills and their importance for the economy of Ephesus. It is an exemplary archaeological publication, but it challenges those readers who consult it from their interest in early milling – a fact somewhat alleviated, though, by excellent summaries in German and English (pp. 203–209). The discussions would also have become more lucid and easily understood, if the eight water-wheels or mill-chambers had been assigned their own, continuous designations rather than retaining their original, incoherent room numbers.

The first major chapter, ›Baubefund‹ (pp. 11–76), presents, in great detail, the walls, floors and other material remains of the easternmost part of the terrace building. The text is (unavoidably) difficult to read and understand, but the reader is assisted by an abundance of excellent plans, elevations, profile drawings and photographs.

The origin of the water cannot be established with certainty, but it was presumably supplied by the old Değirmendere aqueduct that had carried water from sources about forty kilometres south of Ephesos, at least since the mid-second century A. D. (pp. 56; 117). In the terrace building, the ground level drops about

thirty meters over a distance of about one hundred meters (fig. 7). The water runs in a »Gerinne mit Radgerinne«, described in detail (pp. 13–40), next to a steeply sloping lane, called Stiegengasse 3.

At the highest level, a reservoir (4,50 to 2,50 m) served as a kind of mill-pond in case of shorter interruptions in the water supply (»Staubecken, SR31«, pp. 55–57). The rest of the chapter describes the uppermost mill-chambers B16, B17 and B20/35 (pp. 57–69), the central 41c, 44 and 46 (pp. 40–49; 70–76), the large saw-mill area WT2 (pp. 49–55), and the lowest mill, the »Mühle Oktogon/Heroon« or »N-Mühle«, constructed between the remains of the Androklos Heroon and the Oktagon (pp. 49–55). Little evidence is to be found in this chapter for the mills as such.

Altogether, there was room for eight water-wheels. A ninth wheel is sometimes mentioned in passing as »die Celsius-Mühle«, but explained only much later: a badly damaged undershot mill »links neben« or »vor der Celsius-Bibliothek«, almost certainly powered by the same water as the eight wheels in Hanghaus 2 (pp. 159; 188).

The chapter ›Funde‹ (pp. 77–100) treats metal objects (pp. 77, with catalogue pp. 219–222) and pottery (pp. 98–100) very briefly, whereas the presentation of the millstones (pp. 77–97) is a contribution of great general interest. A detailed catalogue with drawings of most fragments is to be found later in the book (pp. 303–318, pls. 53–56), while here we have an extremely well substantiated exhibit of not only the Ephesian material but also, for comparison, conclusions based upon 157 powered stones from thirty-five sites in various parts of Europe, covering the entire first millennium A. D. (enumerated in notes 144–145).

Considering the multitude of ancient powered stones that have long been available for research, our knowledge of them is remarkably limited. Contributions by scholars such as Daniel Castella, Dietwulf Baatz, Andrew I. Wilson and Robert J. Spain have provided important knowledge of their appearance and function, but, in many ways, Stefanie Wefers affords a new foundation for research.

Fragments of 129 powered stones came to light in various parts of Hanghaus 2 and Stiegengasse 3 – but in no more than three of the mill-chambers; sixty-six fragments used in later walls are not included in the catalogue (pp. 79; 91). Of the catalogued finds, sixty-two per cent are runners (which break more easily), about sixteen per cent lower stones, the rest is indeterminable (pp. 79 s.). In my private list of ancient powered stones, almost two thirds are runners, but at Ephesos they amount to almost eighty per cent.

For sixty-seven Ephesian stones, the diameter can be estimated (the mathematical formula used for the calculation is presented in fig. 104). The runners are slightly larger (58–151,5 cm, mean value 90,8 cm) than the lower stones (42,3–88,6, mean value 73,1 cm) (p. 81). It should, however, be pointed out that Catalogue number 16 with its diameter of 42,3 centimetres is a striking exception. All other lower stones have diameters between 63,5 and 88,6 centimetres (fig. 106), and I very much doubt that Catalogue number 16 was really a powered stone.

Compared to the Roman Imperial, European material referred to by Wefers, the Ephesian stones are larger: mean diameter of runners 75,1 centimetres, of lower stones 71,1 centimetres. Dividing the comparative material into three periods, Wefers gets a remarkable result: Roman stones have a mean diameter of 69,5 centimetres, those from Late Antiquity and the earliest Middle Ages 84,3 centimetres, those from the end of the first millennium 75,7 centimetres (p. 83). In other words: first an increase, then a reduction. Wefer does not comment upon this development, but it might be connected with the eventual break-through of horizontal-wheeled mills, whose stones are generally smaller.

The inclination of the grinding surfaces can be established for fifty-three stones (the calculation method is presented in note 132): 0,382–21,801 degrees, mean value 4,751 degrees for the runners; 1,185–20,283 degrees, mean value 5,696 degrees for the lower stones (pp. 80 s.). Wefers questions (with rather weak arguments) the common conception of a gradually decreasing inclination – which seems quite obvious to me. The fact that the two smallest Ephesian stones have a rather steep slope could be a further argument for their being hand driven. The slower rotation of querns requires a higher inclination for passing the meal out of the mill.

The upper side of the runners can be flat, but more often somewhat convex or concave, whereas the grinding surface is mostly slightly concave (p. 84). Four lower stones have a central hole, 5,5–13,3 centimetres wide, while twelve runners have slightly larger ones, diameter 8,7–16,5 centimetres. The latter measurements agree well with my own experience of European stones: normally between eleven and eighteen centimetres.

Around the central hole, mostly on the grinding surface, nineteen runner fragments preserve cuttings for the rynds, which can be double, fourfold and perhaps threefold. Most cuttings are rectangular, 3–11,3 centimetres long, 1,8–4,8 centimetres wide and 1,5–5,8 centimetres deep (pp. 85 f.).

Three runners have cross-shaped grooves on their upper sides, possibly stone-mason's marks (pp. 89 f.). On the other hand, as far as may be judged from the drawings, no fragment shows traces of the striation of the grinding faces that is a normal, though not regular, occurrence on powered stones in western Europe. The grist is ground more effectively when the ears of the corn are crushed between the sharp-hewn edges of the furrows. Moreover, these furrows help the ground meal pass out of the mill.

The first literary reference to the dressing of millstones is to be found in the Life of Saint Austrigisilus, bishop of Bourges in France (Vita Austrigisili episcopi

Biturigi 13). This dramatic event allegedly took place about A. D. 600, but we have archaeological evidence of dressed stones at least from the second century onwards (London, Walbrook). The appearance of the striation varies, but the most common shape is a »harp-shaped« pattern which recurs, for instance, on a third-century runner from the Saalburg fort and on two almost contemporary stones from the Woolaston villa in England.

Wefers does not comment upon the remarkable absence of dressing on the Ephesos stones. Perhaps the phenomenon was not as common in the East as in the West? It is worthy of note that, at the fifth to sixth century, central mill in the Athenian Agora, five stones out of six lacked all kinds of dressing. Considering the extreme thinness of these stones, this could, however, be the result of excessive wear; perhaps the miller did not dare redress the stones for fear that they might crack.

Geochemical studies of the Ephesian stones (pp. 93–97) prove that they were made from rhyolitic ignimbrites and, thus, not quarried in the immediate neighbourhood but probably imported from the region of Çandarlı and Dikili, the Foça peninsula or the island of Melos.

The numismatic material, 599 coins found in »Mühlstuben, Werkstätten und zugehörigen Bereichen wie z. B. der Stiegengasse 3«, is mentioned only in passing in the chapter on finds (p. 97). Instead, they are presented in a detailed catalogue (pp. 223–301) and as the core of the next chapter, ›Chronologie und Bauabfolge‹ (pp. 101–116).

A careful analysis of the architectural remains results in a relative chronology of three basic phases following upon the destruction and abandonment of Hanghaus 2 in the third quarter of the third century (pp. 101–104 fig. 8):

Phase I. 41c, 46 and possibly more mills in the upper part of Hanghaus 2.

Phase II. The Oktagon or Heroon mill and possibly others in the upper part of Hanghaus 2.

Phase III. SR31 (reservoir), B16, B17, B20/35, 44, WT2 (saw-mill).

The finds of pottery and coins in and around mill-chamber 44 offer approximate dates for the separate phases, but otherwise the coins from the original excavation are seldom stratified. However, three soundings, in 1989, 1993 and 1999, gave additional finds that helped to establish absolute dates (pp. 104–116 figs. 121–130).

The first mills were erected immediately after an earthquake in the mid-third century (pp. 4; 106–107). Hanghaus 2 was too badly damaged to be restored, even though some rooms in the uppermost part of the building may have been used as dwellings for persons working in the mills and workshops (p. 185). In mill-chambers 41 c and 46, no coin was found dated after A. D. 395/408 (p. 107). The pottery, too, dates them to the fourth century (p. 115).

The Phase II mill between the Oktagon and the Heroon was established after A. D. 400 and abandoned before A. D. 600 (p. 115). The Phase III mills must have been constructed after the year 562. They may have been destroyed as early as A. D. 616, but were more probably used till the mid-seventh century or possibly even longer (pp. 109; 113–116). Seventh-century coins are so unusual in Ephesos that their absence here is of little consequence (figs. 129–130).

The chronology presented here is perhaps the most surprising part of the book. In his preliminary report of 1984, Hermann Vetters dated the entire row of water-mills to the rebuilding of Hanghaus 2 after the earthquake of 612/616. Instead of a long, continuous series of Byzantine mills, we are now left with three groups of mills, dated in the third to fourth, fifth to sixth and sixth to seventh centuries respectively. The prerequisites for this new chronology are presented in great detail and impossible for an uninitiated reviewer to question. Vetter's dating is not even mentioned, much less discussed in the book (but it was, admittedly, proposed before the three stratigraphic soundings).

There is, in itself, no reason to doubt the new dates. Archaeology has shown that the third century involved a real boom for water-powered mills. The remarkable fact is rather that at no period the entire thirty-metre water-head was used as it was in the Barbegal establishment, but some mills at one time, others at another. True, the uppermost section of the Janiculum mills in Rome was apparently abandoned as early as about A. D. 400, but still, in many ways, the chronology of the Ephesos mills remains a mystery.

The next chapter, ›Wasserräder und Wasserkraft‹ (pp. 117–183), aims at determining the shape of the water-wheels and estimating their efficiency. The calcareous water has covered the walls with thick layers of sinter that preserves scores from the perimeters of the wheels in rooms B16, B17, B20/35, and 41c. Their diameters can, thus, be determined as between 2,60 and 3,20 meters. In B 20/35, a larger wheel was replaced at some time by a smaller one. Their width was probably between forty and sixty centimetres. The waterhead varies from 3,86 to about 6,25 meters (pp. 116; 118 f. 125–127). Three wheels were breastshot, 41c, 46 and WT2, and five overshot, B 16, B17, B20/35, Oktogon/Heroon, and 44 (pp. 138–144 fig. 149–156).

Three stones with score marks supply information on the wheel-shafts (pp. 178–180 figs. 25–26; 115; 184). The diameter of their ends is estimated between fifteen and twenty-five centimetres, perhaps up to thirty. The metal journal of mill-chamber 46 was at least sixteen centimetres long, with a diameter of between two and four centimetres.

Concerning details of the wheels and the rest of the woodwork, the reconstructions are totally dependent on parallel material and representations (p. 124). The greatest interest is devoted here to the discussion and analysis of finds of water-wheels from a number

of ancient mill-sites, including some Early Mediaeval examples up to the twelfth century (pp. 127–138). This survey shows wheel diameters of 1,30 up to 3,00/3,60 meters (mean value 2,37 meters), widths of between 0,21 and 0,80 meters (mean value 0,384 meters) and eighteen to thirty buckets (mean value twenty-five).

The results of these studies of both the Ephesian mills and the comparative material is to be found in colour plates 34–36 (reconstructions of 41c, 44 and B17), convincing in most respects. The greatest uncertainty concerns the size of the vertical cog-wheels. The mills in the Bath of Caracalla and the Athenian Agora permit quite accurate estimations in this respect (0,95/1,12 meters), but no such evidence is at hand in Ephesos.

Another problem concerns the shape of the buckets: »Gebrochene oder durchgehende gerade Schaufel?« (pp. 160–164). Richard Brüdern, the author of this section, argues against Robert Spain's theory of »broken« buckets as early as the third century (Bath of Caracalla) and reckons, instead, with straight buckets for the Ephesos mills. No certain conclusions are possible, but generally I see no reason to question the reconstructions.

An unusual and interesting study (pp. 120–123, by Cees Passchier and Gül Sürmelihindi) tries to establish how long the mills were active by studying sections through the sinter that preserves discernible annual layers. Five samples show that »total deposition time was 70–100 years, most likely [about] 80 years. After about 50 years a cleaning operation was carried out«.

Two sections, ›Theoretische Leistung der Wasserräder‹ (pp. 153–175) and ›Wirkungsgrad‹ (pp. 176 f.), both by Brüdern, are devoted to an estimation of the power generated by the Ephesos water-wheels. Basic facts are gathered in figure 175, but a number of necessary data remain unknown, and the calculations are based to a certain extent on conjectures:

(a) The water-supply is estimated at 0,166 cubic meters per second (p. 176). – (b) The shapes of the buckets and their numbers (estimated at 22/28 in fig. 175). – (c) The diameter of the cog-wheels (0,95/1,12 meters?). – (d) The diameter of the millstones is assumed to be 90 centimetres, as their varying sizes cannot be attributed to specific mills (pp. 173 f.).

Calculations of the power generated by the different water-wheels (pp. 157–159; 164–173) are summarized in a table in page 176: for the breastshot wheels between 2,08 and 2,59, for the overshot ones 1,515 to 2,68 kilowatt. Brüdern suggests that the transition from breastshot to overshot wheels may be the result of decreasing water-supply from the aqueduct (p. 177).

In the section ›Nutzung der Wasserkraft‹ (pp. 178–183), Wefers discusses other parts of the woodwork and the different floors of the mill-chambers. She raises the question of other possible applications of the water-power than grain- and saw-milling, but finds no evidence for this.

In the concluding chapters, ›Ephesos und der Mühlen- und Werkstattkomplex‹ (pp. 185–192), and ›Vergleich mit anderen wasserkraftgetriebenen Mühlenanlagen‹ (pp. 193–196), Wefers tries to place the mills in a wider context: first the town of Ephesos, then the Roman-Byzantine world. She suggests that Hanghaus 2 was in the possession of a single person or family towards the end of the third century A. D., in which case it would have been easier to arrange the construction of various connected mills. But she emphasizes the fact that there would have been room for more mills in the thirty-metre drop and that it was not – as presumably Barbegal – a project supported by the authorities (p. 191).

This review has various aims. Perhaps the most important one is to offer readers looking for information on ancient water-milling a short-cut into a book that is far from easy to grasp, but contains a wealth of important information. I have already described it as »an exemplary, archaeological publication« and, from a technical point of view, it is almost perfect. I have seen no misprints, and it is illustrated with an abundance of high-quality drawings and photographs. The authors are well acquainted with relevant water-mill literature and recent scholarly discussions. The methods used and the bases of calculations are clearly described, and such mistakes that unavoidably happen during excavations are honestly stated (pp. 98; 107). This is a very important addition to the literature on ancient water-mills.

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