5. Enclosure Walls of Heliopolis

5.1 The Late Period Enclosure Wall of Heliopolis

5.2 Area 005: Pottery

5.2.1 Pottery of the Late Period from Area 005

5.1

The Late Period Enclosure Wall of Heliopolis

Max Johann Beiersdorf

1. History of Research

While the enclosure walls of the great temple precinct of Ra-Horakhty have been documented by different fieldwork missions within the Heliopolitan region, they have thus far been discussed only sporadically and have not been the focus of individual scientific research. As part of the Napoleonic Expedition to Egypt during the years 1798 – 1801, the temple complex was recorded and the first ground plan published in the *Description de l'Égypte*. This plan (Fig. 1) indicates that at the beginning of the 19th century

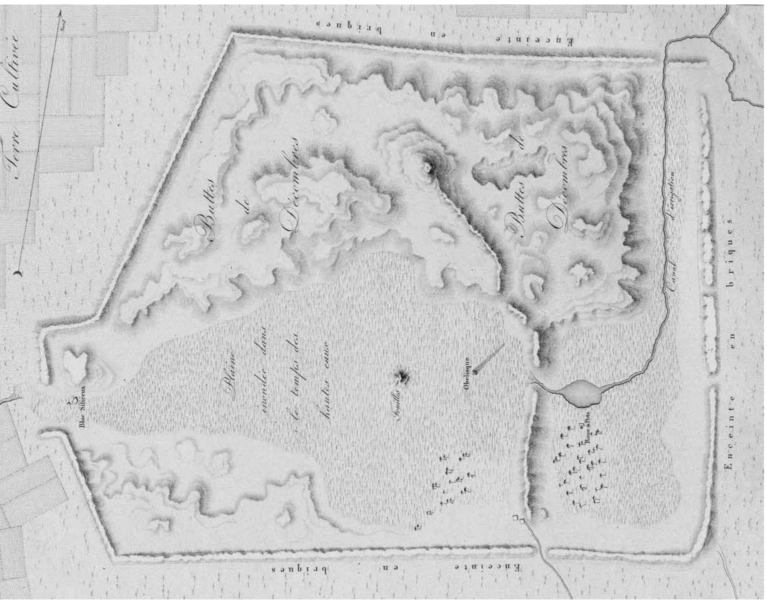

Fig. 1: Plan of the temple precinct of Heliopolis (Jomard 1822, pl. 26.1).

the walls were preserved in an almost complete state. Later, probably during his expedition to Egypt in the years 1840 and 1841, the Italian historian and military officer Camillo Ravioli visited Heliopolis and created an updated plan of the temple precinct.[1] The plan of the French Expedition and Ravioli's plan provide important information regarding the course of the temple enclosure, as well as the temple entries, wherein five gates have been documented.

In 1851, the Scottish geologist Leonard Horner conducted a geological investigation within the area in and around the temple district. In the course of his work he came across the archaeological remains of the enclosure wall in the southern part of the temple precinct. As a result, the extent of the temenos has been estimated to be approximately 1408 × 1006 m. The wall thickness was measured to 18.30 – 19.80 m (Horner 1855, 123).

The first systematic archaeological investigation of the temple precinct and its building structures was carried out by William Matthew Flinders Petrie in spring 1912.[2] While the enclosure walls did not form a focus of their investigation, the study provided important insights into the dimensions and chronology of the walls. Petrie was the first to realize that there were two enclosure walls (Fig. 2), wherein the inner wall had to be older than the outer one. Based on a comparison with the enclosure walls of the Ptah temple complex at Memphis, Petrie proposed that the inner wall dates to the reign of Ramesses II and that the outer wall was

[1] Regarding his expedition to Egypt, see Ravioli 1870. Ravioli's plan of the Heliopolitan temple complex is published by Raue 1999, pl. 5.

[2] The excavations under Petrie and MacKay were carried out from 21st March – 18th April 1912 (see Petrie / Mackay 1915, 1).

built shortly after, probably under Ramesses III (Petrie / Mackay 1915, 3).

While several other excavations were carried out at the Heliopolitan temple complex during the first and early second half of the 20th century, the two enclosure walls have not been part of any detailed scientific research.[3] Under the direction of Abd el-Aziz Saleh extensive investigations were carried out by the Ministry of State for Antiquities (MSA) in the entire temple precinct from 1976 onwards.[4] Saleh's work not only provided important insights into the western section of the temenos, particularly a gate dating to the New Kingdom,[5] but also on the construction of the outer wall.[6] He states: "The outer surfaces seem to have a little wavy plain, as being laid in alternately slight concave and convex sections" (Saleh 1983, 57). He proposed that this technical characteristic might provide "increased solidity to the whole mass of the building" (*ibid.*).

A more detailed study of the northern part of the enclosure wall was directed by Mohammed Abd el-Gelil (MSA) from 1984 onwards (Abd el-Gelil / Shaker / Raue 1996, 137–138; Raue 1999, 482–483). In 1995, the same part of the enclosure wall was reinvestigated by Hani Abu al-Azam, Dietrich Raue and Atef Tawfiq. They were able to confirm that the temple was surrounded by two parallel walls, the inner wall had bastions[7] and the outer one was built in an undulating construction technique.[8] In terms of dating, the authors stated that the inner wall has the constructive features of New Kingdom (Ramesside) fortress walls, while the outer wall

Fig. 2: Plan of the southern part of the temple precinct (Petrie / Mackay 1915, pl. 1).

[3] In 1916, several tombs were unearthed in the southwestern part of the temple area under the direction of the Italian Egyptologist Alexandre Barsanti. However, the investigation did not lead to new insights regarding the enclosure walls. For more details, see Daressy 1916, 193–212; Barsanti 1916, 213–220. An overview of the individual excavations can be found in Raue 1999, 471–480.

[4] An overview of all individual studies of the MSA, including a list of the digging areas can be found in Abd el-Gelil / Shaker / Raue 1996, 136–146.

[5] Saleh 1981, pl. VI; Id. 1983, 46–54, fig. 16 and pl. II.

[6] On a section of about 120 m in length, the wall thickness varies between 10.30 m and 17.40 m (Saleh 1981, 53 and pl. II). In some parts the wall was preserved up to a height of 3.40 m. The mud bricks have a size of 38–42 × 19–20 × 10–13 cm (Id. 1981, 54).

[7] The inner wall has a thickness of 10.40 m and is reinforced with bastions. They are 6.70 m long and protrude 2.10 m. The distance between the bastions is 17.70 m (Abu al-Azam / Raue / Tawfiq 1995, 41).

[8] The term "undulating walls" derives from the latin word *unda*, which means wave or wavy. It is used for enclosure walls which consist of alternating wall sections of concave and convex shaped layers of bricks.

more closely resembles the temple walls of the Late Period and Ptolemaic era (Abu al-Azam / Raue / Tawfiq 1995, 41 – 42).

Since 2012 the sun temple of Heliopolis is being excavated by an Egyptian-German joint mission under the direction of Dr. Aiman Ashmawy (Egyptian Ministry of Antiquities) and Prof. Dr. Dietrich Raue (DAI Cairo). As part of a dissertation at the Brandenburg University of Technology in Cottbus-Senftenberg, a systematic architectural documentation of the excavated parts of the undulating enclosure wall of the Ra-Horakhty temple at Heliopolis was conducted during the excavations of 2014 and 2015 (Fig. 3).[9] At the time of its reinvestigation, the southern enclosure wall was preserved to a height of approximately 3 m and to a length of approximately 100 m.[10] A section of approximately 60 m has been cleaned and documented by drawing to scale 1:20. In the course of the architectural building survey, the entire section was captured in frontal view (Area 005) and in partial cross-sections (squares 241 AL / 241 BL), which served to investigate the connection between the individual segments. Compared with other walls of the same type crucial insights into the construction and static function of the Heliopolitan walls could be gained.

Fig. 3: Concave segment of the undulating enclosure wall of the southern part of the temple precinct (Area 005); Photo: D. Raue.

[9] The dissertation is entitled “Die undulierenden Lehmsteinmauern der pharaonischen Spätzeit Ägyptens” and was part of the DFG Research Group 1913 “Cultural and Technical Values of Historical Buildings” from 2014 – 2017. The work was funded by the DFG and the Division of Building Archaeology of the German Archaeological Institute (DAI).

[10] The wall is covered by a 30 cm thick layer of concrete and is below the current street level. Noteworthy is the fact that the modern street “Sh. Mostorod” exactly follows the course of the ancient enclosure wall.

2. Characterization

2.1. Location and Dimension

As stated previously, the temple area of Heliopolis is enclosed by two parallel mud brick walls, which were built separately from each other. The outer dimension of the outer wall measures approximately 1185 m (E-W) to 915 m (N-S).[11] In addition, the whole temple area is divided into two almost equal parts **by an internal double wall**, which has an East-West orientation. Within the investigated area at the southern enclosure, the gap between both walls is around 2.5 m. Whether this observation can be transferred to the whole enclosure in general is not evident.[12]

The course of the enclosure walls of the northern, eastern and southern area can be reconstructed on the basis of published site plans of previous excavations, as well as by the building survey of parts of the southern wall.[13] The western section is nearly entirely unexplored, so that many questions regarding its course, dimension and especially the position of the gates remain unsolved. Indeed, most of the temple precinct, its internal architectural structure as well as its enclosure walls have not been preserved until now, mostly due to ancient stone robbery, extensive modern building activities and rising groundwater levels.[14]

Within his excavation report, Abdel-Aziz Saleh (1983, 45–61) recorded a wall that adjoins the gate of Ramesses III and for that reason he attributed it to a "fort complex" of the same king. Several structural details, as described by him, leave no doubt that this wall is in fact part of the undulating enclosure wall of the temple complex. Primarily, it is the undulating construction technique which has been used for the erection of the wall that supports this assumption (Id. 1983, 57). This is further reinforced by the characteristic slope on the outer face of the wall, as well as the brick format of 38–42 × 19–20 × 10–13 cm (Id. 1983, 54). The presence of round apertures or holes in the facade and their regular distance of 3 headers coincides with the archaeological record of the southern enclosure wall, as documented in 2014 and 2015 (Fig. 3; Id. 1983, 56–57).[15] After Saleh, the overall thickness of the brick wall is between 17.20 m and 17.60 m (Id. 1983, 47). This leads to the assumption that the convex segments have a thickness of 17.20 m, while the concave segments are 17.60 m thick. Indeed, the concave segments are on each side of the wall

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[11] Until the present, varying information concerning the overall extent of the temple area is published. Leonard Horner (1855, 123) mentioned a total dimension of 1540 × 1100 yards. Dieter Arnold (1992, 204) gives a total dimension of 1000 × 900 m. While Alan Jeffrey Spencer (1979, 67–69) and Rosanna Pirelli (1999, 58–61) listed many of the undulating walls, no data was given for the dimension of the temple precinct of Heliopolis. The given dimension of 1185 × 915 m is based on the map, which shows the reconstruction of the temenos published in Petrie / Mackay 1915 and which was overlaid on a Base Map of the U.S. Army Map Service. The map has been georeferenced and reprojected by Eva Tachatou and Kai-Christian Bruhn (Highschool Mainz).

[12] The investigation of the northern enclosure walls was conducted by the MSA from 1984 onwards and revealed a gap between the inner wall and the outer wall of 0.8 m, see Abu al-Azam / Raue / Tawfiq 1995, 44 and 42, fig. 6.

[13] The overall length of the enclosure wall can be reconstructed to a total sum of 3650 m. The building survey in 2014 and 2015 documented the southern wall over a length of 60 m, which corresponds to 1.64 % of the overall length.

[14] The construction of the Suq el-Khamis and the high groundwater level prevent further archaeological investigations in this area. The only findings of this part of the temple precinct were revealed by Petrie during his excavation in a few weeks of spring 1912. The author comment neither on the overall extent nor on the dimensions of the two walls; he describes only the northwestern section of the perimeter wall as being 1670 feet (509 m) long and 44–48 feet thick (13.41–14.36 m), Petrie / Mackay 1915, 2.

[15] Round holes in the façade of undulating walls are known from many other sites, such as Karnak, Elephantine (Fig. 7) or El-Kab. They provide evidence that with wooden beams were set into the brickwork to absorb transversal loads.

one header wider than the convex ones, which can be supported by evidence from other sites in Egypt.[16] Since one header measures about 20–21 cm the difference of 40 cm in Saleh's statement regarding the wall thickness can be explained by this constructive feature of the undulating walls (Fig. 4).[17] Since these measurements could not be verified during the architectural investigation in 2014 and 2015, Saleh's are the only available data. As a result, the thickness of the undulating wall of 17.20–17.60 m recognized at its western course might be taken as an indication for the reconstruction of the wall thickness in general.

The original height of the undulating wall has not been preserved at any point.[19] This is the case with almost every wall of this type. The undulating enclosure wall of the Amun-Ra temple at Karnak forms one of the very few cases where the original height of 21 m is preserved.[20] Taking into account the thickness of 12.55 m in the widest parts, the ratio of wall thickness to wall height is 1:1.67. Transferring this ratio to the Heliopolitan wall would result in a reconstructed wall height of 29.39 m. Although these dimensions seem very plausible from a statistical point of view, this is not certain, so that the calculation ought to be treated with caution.

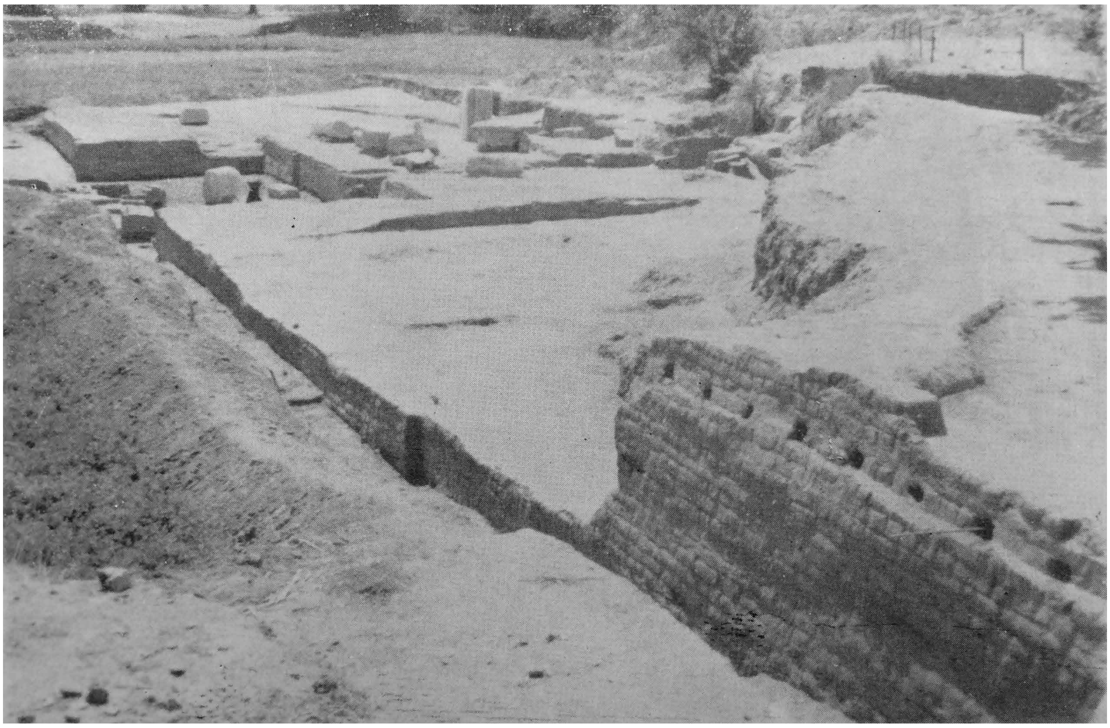

Fig. 4:
The wall of the so called "fort complex" excavated by Saleh in 1978 which is the equivalent of the undulating enclosure wall in the western part of the temple precinct (Saleh 1983, pl. XLVI B).

[16] Regarding the enclosure wall of the Amun-Ra temple at Karnak, see Golvin et al. 1990, 921, pl. IV, 922, pl. V, 924, fig. 6. For the enclosure wall of the Khnum temple on Elephantine Island, see Honroth et al. 1909, 39.

[17] Saleh 1983, pl. XLVI B shows the masonry openings in the convex segment as well as the small step in the masonry between the two segments.

[18] On the one hand, Horner (1855, 123) measured a wall thickness of 18.30–19.80 m. Petrie (in Petrie/Mackay 1915, 3) quantified the thickness of the outer enclosure in the western course only to 44–48 feet (13.41–14.63 m). Saleh (1983, 53–54), on the other hand, mentioned a thickness of 10.30 to 17.40 m for the undulating wall at the western gate from the time of Ramses III, but in the same contribution he states that the same part of the wall is between 17.20 and 17.60 m thick (Id. 1983, 47).

[19] During his investigations in 1851, Horner 1855, 123 mentioned a wall height of 4–4.9 m. Petrie (in Petrie/Mackay 1915, 2) stated that "at its best parts it is about 17 feet high, almost entirely banked up with ruins of houses and town rubbish". During the investigations in 2014 and 2015, the preserved height of the southern enclosure wall was between 2 and 3 m.

[20] Traces of the undulating wall have been preserved on the large pylon to the west as well as the east gate, both of which were built under Nectanebo I in the 4th century BC, see Golvin/Hegazy 1993, 149–150.

2.2. Dating

Regarding the dating of the Heliopolitan enclosure walls, various degrees of information can be found in the research literature. As mentioned earlier, Petrie and MacKay suggested that both walls were built during the New Kingdom; the inner one under King Ramesses II and the outer under Ramesses III (Petrie / Mackay 1915, 3).[21] Due to the fact that the wall described by Saleh adjoins the gate of Ramesses III, he dates the undulating wall to the same period in time (Saleh 1983, 58 – 59). Raue argued that the inner wall was built under Ramesses II and the outer one very likely during the Late Period, considering previous buildings from the time of the New Kingdom (Raue 1999, 85). According to recent findings, the inner wall does not date to the New Kingdom but to the Late Period and is propably consistent with the construction of a new wall under King Amasis.

Based on the study of ceramics from a destruction layer of the construction pit of the southern temenos carried out by Marie-Kristin Schröder in 2012, the outer enclosure wall can be dated to the latter decades of the Late Period.[22]

Indeed, this dating not only coincides with a majority of undulating walls known from other sites in Egypt, but indicates that the Heliopolitan temple complex in general and its enclosure in particular were part of a monumental building program initiated by the Egyptian rulers of the 30th Dynasty.[23]

2.3. Construction Technique

The most characteristic feature of the outer Heliopolitan temple enclosure wall is that it is built in undulating construction technique, as known from walls at Karnak, Dendera, El-Kab and others.[24] In contrast to traditional mud brick walls undulating ones comprise alternating concave and convex wall segments, which provide a characteristic wavy appearance. Undulating walls are to be found throughout the country from the Delta region in the north to the southern border. Even in the western oasis near Kharga and Dakhla, walls of this type have been traced.[25]

With regard to the outer wall of the Ra-Horakhty temple at Heliopolis the concave segments show a length of 19.70 m with a thickness of 17.60 m (Fig. 5). The height of the concave bending is about 60 cm. The convex segments have a length of 12.20 m and a thickness of 17.20 m. The rise of the convex curvature is about 20 cm. As the investigations in 2014 and 2015 have shown, the joint between the two segments is not continuous, but extends from the facade only

[21] Papyrus Harris I mentions that Ramesses III renewed the walls of the temple at Heliopolis, see Erichsen 1933, I, 25.7. However, the verb used, srwd, may be read as renewal or refurbishment, not new construction, which indicates that Ramesses III repaired the existing inner wall.

[22] There might be another option at hand. The inner enclosure wall shows within the mud bricks residual material of New Kingdom pottery. The layers close by that wall date to the late 26th Dynasty. It therefore cannot be excluded that certain sections of this large wall were erected later than the 19th – 20th Dynasty. It ought to be mentioned that a mudbrick wall that was erected in year 42 of Amasis (e.g., 528 BC) is said to measure 30 cubits in width, see Corteggiani 1979, 132 – 134 and 148 – 149. This would coincide with the width of the inner enclosure in the southern double wall that measures 14 – 15 m and that is connected to a late 26th Dynasty stratum in Area 234. These recent objections to earlier datings are owed to Dietrich Raue. However, it must be stated that for a secure dating of the two walls, more investigations are needed.

[23] Although a precise dating for many of the undulating walls is still lacking, some of these have been quite well investigated. For instance, the undulating walls of the Amun-Ra temple at Karnak and those of the Mut and Month precinct belong to the 30th Dynasty.

[24] For a list of other undulating walls, see Beiersdorf 2016, 90; Pirelli 1999, 58 – 61; Golvin et al. 1990, 944 – 946; Spencer 1979, 76 – 77, 82.

[25] A map showing the geographical distribution of the undulating walls can be found in Beiersdorf 2016, 89, fig. 1.

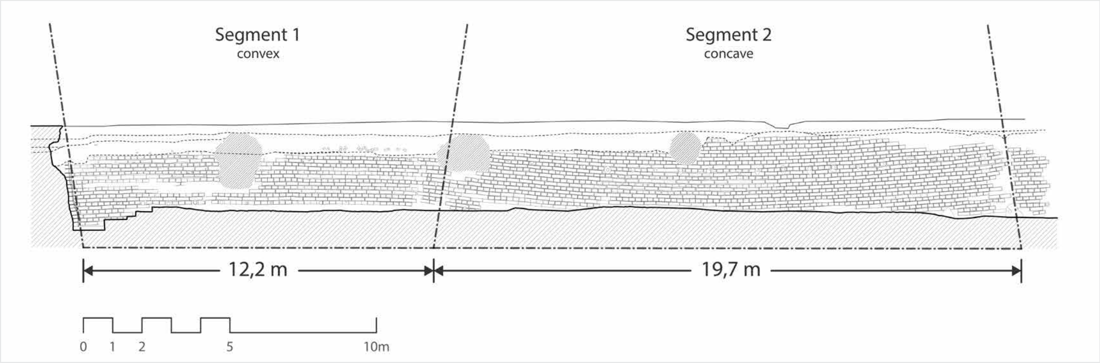

Fig. 5: Convex (segment 1) and concave (segment 2) parts of the undulating wall as documented in 2014 and 2015 (Drawing: M. J. Beiersdorf & L. Dimova).

2 – 3 m into the masonry. From a depth of 3 m, it appears as though the bricks of the concave and convex segments form a masonry bond. This observation of the wall in Heliopolis corresponds with the undulating wall of the temple of Khnum on Elephantine Island, which was studied by Otto Rubensohn and Walther Honroth in the years 1907 – 1909.[26] While Honroth believed there was a clear joint between all segments (Honroth et al. 1909, 42), Rubensohn stated that one concave and one convex segment were built as a double segment (Id. 1909, 36). This latter observation could be confirmed by evidence from Heliopolis.

In terms of the building material, it can be stated that mud bricks of various qualities were used for the construction of the wall. The average size of these is approximately 42 × 21 × 12 cm. The bricks have been set in layers of stretchers and headers into the façade by using mortar. Only at the very end of each segment are there modifications. The corner of a concave segment is made up of double layers of headers and stretchers, and there are smaller bricks of half the size of a header to fill smaller gaps in the masonry (Fig. 6). The reason for this technique might be to ensure the stability of the corners, and the smaller bricks were used to adjust the length of the inclined wall. This feature had already been observed by Honroth when he investigated the undulating wall of the temple of Khnum on Elephantine Island (Fig. 7). The inner masonry bond was made of headers without the use of mortar, which initially caused constructive disadvantages on the one hand, but it might also have brought significant time benefits on the other hand.

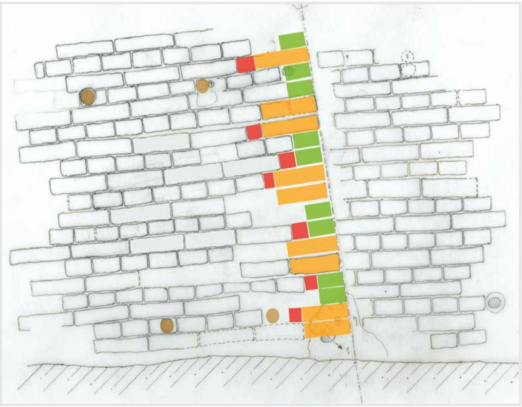

Fig. 6: Irregularities in the masonry bond at the end of a concave segment documented at the undulating wall in Heliopolis in 2014 / 15 (Drawing: M. J. Beiersdorf).

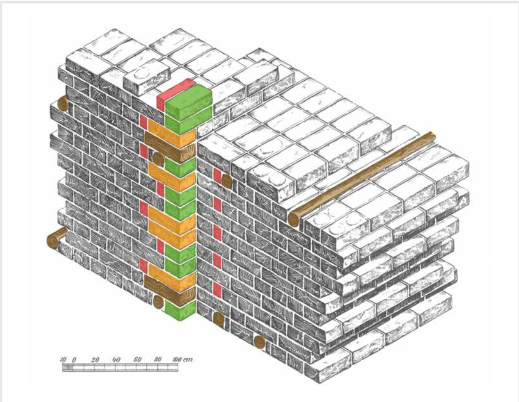

Fig. 7: The same irregularities have been documented by Walther Honroth at the temple of Khnum on Elephantine Island at the beginning of 20th century (Honroth / Rubensohn / Zucker 1909, pl. VIII).

[26] For a description of the temple wall, see Honroth et al. 1909, 35 – 43.

3. Technology vs. Symbolism – Interpretations on the Function of the Undulating Walls

While there has been no dedicated study of the entire corpus of undulating walls from Egypt, there have been several technical explanations for the undulating shape of these walls in the past.[27]

Auguste Choisy (1841 – 1909), a French engineer and historian of architecture, noted that the wavy shape of the walls prevented the panels from shifting. In addition, the organization of a construction site could be crucially optimized by this technique (Choisy 1904, 34 – 37). During the excavation on Elephantine Island between 1907 – 1909, Walter Honroth investigated the undulating enclosure wall of the temple of Khnum and proposed that the concave segments were raised up first and were followed by the convex segments in a second step. In his opinion the undulation results from the slope of the lateral walls of the segments (Honroth et al. 1909, 39 – 42). The technical interpretation of the undulating building technique was followed by scientists who did not have a specific technical background, like the English archaeologist William M. F. Petrie. He postulated a technical solution for the undulating shape of the walls by arguing that construction in sections helped to limit the weakness inherent to the scaling of wall faces.[28] All in all, structural assessment of the undulating building technique was a major theme of research from the late 19th to the middle of the 20th century.[29]

This stance changed significantly after 1962, when Paul Barguet, a French Egyptologist, established his theory that the characteristic undulating form is to be seen as an allusion to the primeval ocean *nwn*, out of which the Egyptian cosmos arose (Barguet 1962, 32). With Barguet's theory the meaning of the undulating walls shifted from technical to a more religious and symbolical function of the walls. Since then, scientific interest has mainly been focused on the ancient perception of the building as Barguet's theory became widely accepted.[30]

In the course of the investigation of the Amun-Ra precinct at Karnak by the "Centre franco-égyptien d'étude des temples de Karnak" (CFEETK) in the years 1990 – 1993 the undulating enclosure wall there has been studied in more detail. Based on an architectural building survey, the investigation revealed many constructive features of the wall that make a pure symbolical interpretation of the undulation

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[27] A summary of the research history on this subject can be found in Beiersdorf 2016, 75 – 86 and Pirelli 1999, 55 – 66.

[28] In the course of the investigation of the Osiris temple at Abydos, Petrie (1903, 6 – 7) mentioned the enclosure wall which consisted of "towers of brickwork in concave foundations, and then connecting walls between, formed in straight courses". He referred to undulating walls in his book "Egyptian Architecture", but his remarks on this technique were very general, see Petrie 1938, 10 – 12. Despite the fact that he investigated the temple at Naukratis during 1884 and 1885 and the Ra-Horakhty temple at Heliopolis in 1912, Petrie made no mention of the undulating walls. The existence of undulating walls at Naukratis was discovered in March 2019 by a team from the British Museum directed by Alexandra Villing. The results are currently in the process of publication and have been thankfully shared by Alan Jeffrey Spencer.

[29] In the first half of the 20th century, Somers Clarke investigated the city and temple enclosure of El-Kab, which is made of alternating concave and horizontal as well of concave and convex sections, see Clarke 1921, 74. In his opinion the undulating technique should prevent the brick wall from cracking due to the drying and shrinking process of the unfired mud bricks, see Clarke / Engelbach 1990, 210. During 1932 – 1934, Jean-Louis Fougerousse investigated the enclosure wall of the temple at Tanis and was convinced that this technique was used to prevent the bricks from contracting and expanding, see Fougerousse 1935, 33.

[30] A symbolical interpretation of the undulating walls, as Barguet proposed, has been stated by various Egyptologists. In 1979, A. J. Spencer published in his book "Brick Architecture in Ancient Egypt" a list of undulating walls and commented that this technique does not have any structural benefit. Instead, it is to be seen as symbol for the ocean *nwn*, as Barguet already stated, see Spencer 1979, 114 – 115. In a more recent study, the Italian Egyptologist Rosanna Pirelli focused on the technical aspects of the undulating walls and came to the conclusion that they did not provide any structural benefit, but rather had a symbolical function, see Pirelli 1999, 67 – 78. Along with her interpretation she summarized all contributions on that topic and published a list of all undulating walls known so far (Id. 1999, 55 – 67).

unlikely. Instead, Golvin et al. (1990, 927–928) argued that building a wall in sections of concave and convex shape has simultaneously economical and structural benefits.[31]

4. Undulation for Economic Reasons

Assuming that the rulers of the Late Period were anxious to protect the most important temples of the country as quickly as possible through the construction of high walls, then this required certain conditions. The choice of the building material was crucial and had far-reaching consequences, not only for the entire construction process, but also on the socio-cultural framework of a major construction program. Compared to stone, clay as a building material had the advantage that it was available along the Nile throughout the country and therefore was in close proximity to most temples. To acquire the raw material did not require any elaborate expeditions that might have to be protected by military units. Instead, the unfired bricks could be made almost anywhere by anyone along the Nile Valley. Another advantage of mud bricks is that their production is achievable in two ways: centralized and decentralized. It can be assumed that the building material for royal building projects like temple enclosure walls came mainly from larger, centrally controlled brick factories. In addition, the population also participated in the production of bricks, as we know for example from the Demotic Papyrus Zenon from the 3rd century BC.[32]

The written sources not only testify to the involvement of individuals in the production of mud bricks for royal construction projects, but also provide concrete numbers on the amount of bricks produced per capita per month. This allowed the mud brick production in ancient Egypt to be quantified and applied to major construction projects. In order to calculate how long the production of mud bricks took for the undulating enclosure wall in Heliopolis it is necessary to have a detailed knowledge of the construction volume and the number of bricks needed. A conservative estimate of the original wall height of 21 m results in a reconstructed building volume of approximately 1.7 million m^3 (Fig. 8).[33] At a wall height of 29 m, it would have been 2.3 million m^3.[34] The brick size of 42 × 21 × 12 cm and a total volume of the wall of 1.7 million m^3 leads to a total sum of approximately 161 million bricks. To produce this vast amount of bricks, 500 workers would need approximately 1,610 days, if one assumes that a squad of five workers can produce 1,000 mud bricks per day.[35] As a result, 1,000 workers would need 805 days and 10,000 workers only 80.5

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[31] For a more recent contribution on this topic, see also Goyon et al. 2004, 117–123.

[32] Papyrus Zenon 4, pl. 4 refers to a man and a woman, who agree to produce 20,000 bricks during one month, see Spiegelberg 1929, 12. The text is stored in the Egyptian Museum at Cairo; however, an inventory number was unknown at the time when Spiegelberg published his translation, see Id. 1929, 11, note 6.

[33] This calculation is based on the assumption that the temple area was separated by an undulating wall with a length of about 925 m into a northern and a southern part, see Raue 1999, 85. Without separation wall, the volume would be 1.3 million m^3.

[34] Both values do not consider the slope of the wall. Without a separation wall the volume would be 1.8 million m^3 at a height of 29 m.

[35] Kemp estimates that a group of 3 modern brick makers can produce 4,000 to 6,000 bricks per day, although he does not mention the size of the bricks, see Kemp 2000, 83. As Kemp says, the amount of bricks depends on the size. The total amount per day is higher when the bricks are smaller. Spencer, however, says that a team of 4 brickmakers is able to produce 3,000 bricks per day (Spencer 1979, 4). Goyon et al. 2004, 107–108 calculate that a group of 4 workers can produce 3,000 bricks per day with the size of 30 × 14 × 7 cm, which results in 2.2 m^3 in volume per capita per day. The calculation of 1,000 bricks per day is based on the assumption that 1 person can produce 200 bricks of the size of 42 × 21 × 12 cm per day, which is equivalent to 2.1 m^3 in volume per day.

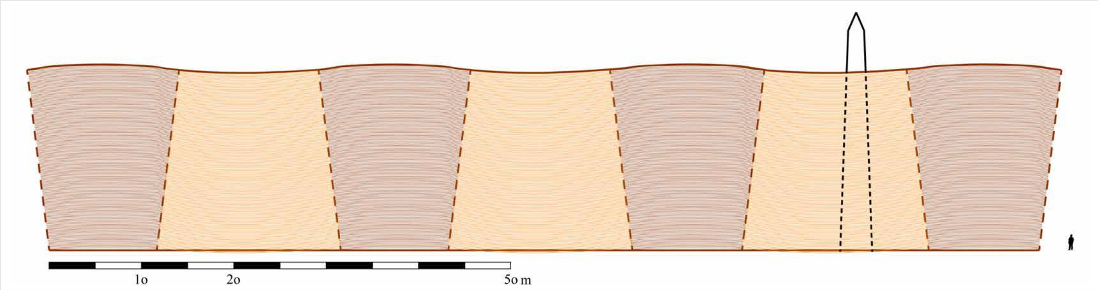

Fig. 8: Reconstruction of the undulating enclosure wall of the Ra-Horakhte temple at Heliopolis at an estimated height of 20m (Drawing: M. J. Beiersdorf).

days. This means that even the enormous amount of 161 million mud bricks could theoretically be produced by 7,000 workers within 115 days or a single flood period. This calculation refers only to the time needed for the production of bricks and leaves many other relevant factors aside which had an impact on the realization of such major construction projects, such as the space required for drying the bricks, or the supply and delivery of the necessary raw materials.

Basically, it may be stated that transport, loading and distribution at the construction site were comparatively easy. The combination of mud brick architecture and the undulating design resulted in substantial benefits regarding the building-process. By omitting mortar inside the wall, the bricks could simply be laid together and stacked vertically. Building in this way is of course much faster, because the bricks did not have to be individually mortared or placed in a mortar bed. Since most of the bricks were laid as headers, this process went even faster than in the case of a masonry bond. In addition, no specialized workers were required for this work, as these activities could also be carried out by unskilled workers under supervision. It is therefore self-evident that this in turn resulted in economic benefits.

5. Fundamental Challenges in Building Monumental Mud Brick Architecture

Large-scale construction sites require certain economic, administrative and logistical conditions to ensure an efficient working process. To realize a monumental building program throughout the country, like Ramesses II did in the New Kingdom or Psamtik I conducted at the beginning of the Late Period, required enormous financial resources. Therefore, technical solutions which minimized the costs might have been of great importance, especially during the 4th century BC when Egypt was in constant conflict with the Persian Empire. For this reason, the range of the building program and the choice of construction material depended on financial capabilities.

Apart from the economic benefits, undulating walls had to deal with certain challenges which are characteristic of monumental mud brick architecture, first and foremost, in terms of accurate load transfer. One of the biggest problems in building with clay is the shrinkage of the unfired mud bricks during their drying process. If we assume that unfired bricks have a certain amount of residual moisture at the time of their installation, then this moisture is subsequently reduced over a longer period of time. During this process of drying, the bricks lose volume. In case of monumental brick architecture, the shrinking effect can lead to significant subsidence in the brickwork. One way to avoid this problem might be the abandonment of mortar within the interior of the wall. Thus, less moisture was brought into the masonry and significantly reduced the risk of subsidence.

6. Undulation for Static Reasons

As the architectural building surveys of the undulating enclosure walls of the Ra-Horakhty temple at Heliopolis and the Amun-Ra temple in Karnak have shown, the inner masonry was constructed without any mortar. At first glance the abandonment of mortar brought constructive disadvantages, but in combination with the undulating construction technique it would have resulted in significant structural and structural-physical advantages.

Considering Hölscher's and Honroth's proposal that the walls were built in individual sections, then the abandonment of mortar initially had a significant disadvantage, because its function as a binder is to bond bricks together. Once the binder is missing the connection between the individual bricks is weakened substantially. The higher the wall, the greater the forces acting on the corners of the wall, and the greater the danger of the corners subsiding. To prevent this danger there are basically two solutions:

1) Due to the inclination of the outer walls, the permanent load in the corners is reduced
2) Due to the concave shape, the permanent load is directed towards the middle of the segment

Both methods were applied to the undulating walls, with the result that the permanent load at the corners of the wall was reduced and bricks simultaneously drifted toward the center of the segment. In this way the stability of the concave segments was significantly increased despite the absence of mortar.

From a static point of view, it makes little sense to analyze the concave and convex segments separately. Much more decisive is how the forces in combination with both segments develop over a longer period of time. From an engineering-theoretical perspective, the interaction of concave and convex wall segments forms a load state, which is called prestressing (Fig. 9). Due to the slope of the walls and its concavity, as mentioned before, the permanent load is directed towards the middle of the concave segments. Between the concave wall sections are the convex segments, which are somewhat reminiscent of wedges in shape. Assuming the convex segments were erected solitarily, they would inevitably collapse because the smaller sides tend to tilt outwards. This effect is even greater because of the convex shape of the wall in a longitudinal direction. Thus, they exert a lateral pressure on the adjacent concave segments. If subsidence were to occur due to small imperfections during the construction process or due to volume losses in the masonry, this would simply be suppressed by the effect of the prestress.

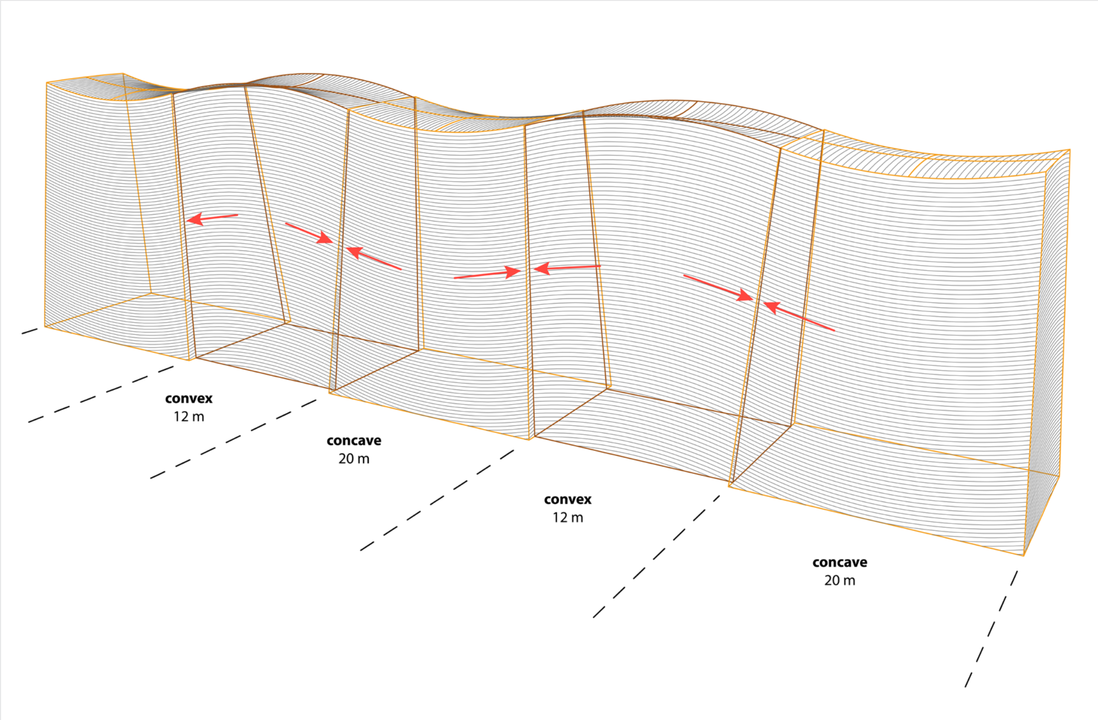

Fig. 9: The effect of prestressing is caused by the lateral pressure of the convex segments and the permanent load resulting to the center of the concave segments (Drawing: M. J. Beiersdorf).

7. Conclusion

As is common practice in antiquity to legitimize royal power, the most important temples of the country have been equipped with new property, buildings and manpower. Especially, during times of political unrest and uncertainty, the symbolic power of monumental buildings was applied as a means to strengthen the national and international reputation of the king. To minimize certain economic, administrative and logistical efforts in the mass production of mud bricks, that not only included enormous human and material resources, but also spatial and temporal capacities, a technical solution was devised. As a result, the construction of large enclosure walls in general, and of those built with a new building technique in particular, required a comprehensive knowledge of the fundamental principles of structural analysis on the one hand, and their implementation in constructive solutions on the other hand. Therefore, the undulating construction technique can be interpreted as a technological solution to realize and optimize monumental building projects in a short period of time.

Indeed, recent investigations indicate that the function of this technique might have shifted over time. Pierre Zignani demonstrated that the undulating enclosure wall of the temple of Hathor at Dendera was originally built in horizontal courses and then altered by the addition of undulating brickwork to the faces (Zignani 2001, 431–432). Regarding this record, Neil Spencer stated that “Examples of a ‘skin’ of brickwork in pan bedded courses being added to existing walls with bricks laid in level courses suggest such an appearance became important in itself” (Spencer 2006, 50).

5.1

Nevertheless, due to the undulating construction technique the temple of Heliopolis, being the largest religious complex in ancient Egypt, could be equipped with a new wall of enormous dimensions within one or two flood periods. In the 4th century BC, a time when the Persian Empire was inexorably on the rise, this technological advance was of immense importance to the kings of the 30th Dynasty.

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5.2

Area 005: Pottery

5.2.1 Pottery of the Late Period from Area 005

Marie-Kristin Schröder

In Autumn 2012 the excavations in Matariya / Heliopolis continued.[1] The investigation of the southern temenos (in the eastern part of the temple precinct) was the main focus of the work. The outer enclosure wall of the temple of Heliopolis consists of two walls in close proximity (only a 3.20 m gap between them). These walls each have a base width of 15 m (Petrie / Mackay 1915, pl. I). After the cleaning of a trench dug by the SCA (see Abd el-Gelil / Shaker / Raue 1996), the faces of both walls were documented. The outer temenos was built in segments and is an example of the so-called "undulating wall construction" (Ashmawy / Raue 2013, 3). This is characteristic for the Late Period and is studied separately.[2]

In one of the trenches, the archaeological excavations located the foundation pit of the younger temenos perimeter wall and here, a high amount of stratified broken pottery was found.[3] This material forms the focus of the study presented here. The sherds have been analysed and categorized into three main types, of which *Type 1* is closed and the *Types 2* and *3* are open forms (see below Tab. 1 with Pl. 1). Apart from a certain amount of older Pharaonic pottery, most of the pottery seemed to be dated to the Late Period (Raue, pers. com.). The older material was probably redeposited when the foundation pit of the outer temenos wall was dug and backfilled. Some of the pottery fragments discussed in this study could also be found in the gaps between bricks and within the mudbrick material itself.

Closed Forms

Type 1

The most common form found in the foundation pit of the perimeter wall was *Type 1*, a so-called "neckless slender jar"[4] (*sausage jar*, s. Fig. 1 and Pl. 1.1 – 9). This is a tall cylindrical jar with straight body and no neck and shoulder, made of Nile Silt B.[5] The rim is slightly drawn inwards with a thickened lip, while the base shows a distinct knob. The rim diameters show two different size ranges: from 6 – 8 cm and 15 – 16 cm. The vessels are manufactured in a combination of the coiling technique and turning on the potter's wheel (Budka 2010, 193).

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1 Participants were Aiman Ashmawy, Wagida Abd el-Aziz Mohammed, Hosni Badia Hosni, Amr Ismail Ahmed, Ezzad el-Maghuri Mohammed, Heba Ali Osman, Mona Ahmed Hussein, Tamer Ahmed Mohammed, Sabah Abd el-Halim Ahmed, Nadja Gouda Anany, and the restorers Heba Mohammed Ahmed, Noha Abd el-Rahman Mohammed, Ahmed Mohammed Ibrahim, Sahar Ramadan Mohammed; on behalf of the University of Leipzig: Dietrich Raue, Christopher Breninek, Pieter Johannes Collet, Morgan De Dapper, Dieter Fritsch, Tomasz Herbich, Wassim Moussa, Asja Müller, Jakub Ordutowski, Mohammed Abd el-Wahab Othman, and the author of this contribution.

2 According to Spencer 1979, undulating walls as temenos walls are known since the 21st Dynasty. The investigation of the temenos is undertaken by Max Johann Beiersdorf (see his contribution in this volume, p. 249 – 263).

3 The foundation pit is visible in the eastern section of square 241AQ.

4 Aston 1996, 76 (Group 29: "Neckless Slender Jars", fig. 221a – b).

5 The fabrics were analysed following the Vienna System (Bourriau / Nordström 1993).

Two different sub-types can be distinguished. First, *Type 1a* has 149 examples (Pl. 1.1–5) and is characterised by a concentric groove on the exterior surface below the rim. Second, *Type 1b*, which does not show this groove, has 22 examples (Pl. 1.6–8).[6] W. M. F. Petrie reproduced an example of this vessel form in a drawing in his publication of his Heliopolis excavations (Petrie / Mackay 1915, pl. X.11). He dated the jar in plate X.11 in the broad time period between the 19th and the 26th Dynasty, but did not refer to this particular vessel in the text part. Petrie's chronological evaluation is challenged by D. A. Aston (1996, 31 with pl. 58–60), who claims a dating for the jars nos. 6–11 in the Persian Period.

From western Thebes in Upper Egypt, closely related jars to Heliopolis *Type 1* were published[7] and dated to the Saïte Period after D. A. Aston (1996, 76; Id. 2003, 152).[8] A further comparison was found in the tomb of Tia and Tia in Saqqara, where chambers A and B had a secondary use in the Late Period (Aston 1997, pl. 125, 200). One jar bears a close resemblance to Type 1 at Heliopolis, although the base lacks the distinct knob as well as the thickened rim. This particular jar was dated by comparisons from Mendes / Tell el-Rub'a (Wilson 1982), where another vessel comparable to *Type 1* is listed and vaguely dated as "late" (Allen 1982, pl. XIV.1). S. J. Allen stated that pottery types of the Late Period are generally long and elongated in shape with almost straight necks and rounded bases with the characteristic knob (Id. 1982, 19). Another case of a reused New Kingdom tomb is certain in the tomb of Maya and Meryt, where a complete slender jar including the characteristic knob at the base was found, dating to the Saïte Period as was the case in the tomb of Tia and Tia (Aston / Aston 2010, 128 with fig. 31.311).[9]

In addition, in the context of the mortuary temple of Sety I in western Thebes, three pits within the perimeter wall in the north-western area contained more than 500 vessels. According to K. Myśliwiec, these vessels are characteristic for the Late Period and among them were numerous vessels of the Heliopolis *Type 1* (Myśliewiec 1987, 54–56 with fig. 352–354).

Although the overall shape of the presented jars to *Type 1* at Heliopolis is similar, the distinct internal ledge of the rim is missing for most of the parallels and the orifice is mainly drawn inwards and not rather straight as in the Heliopolis assemblage. This difference could point either to a different workshop or a slightly different dating, further finds might clarify this interesting feature.

The function of these tall jars is uncertain and can vary. Within the context of the foundation trench for the temenos, it could be assumed that the builders used them as storage jars for water while constructing the wall. Alternatively, J. Budka suggests a pottery deposition of these vessels in a ritual context, based on certain

6 During work in the Matariya store-rooms, several complete vessels of *Type 1* were found (see Fig. 1).

7 See Budka 2006, 92, fig. 6a; Id. 2010, 212–213; fig. 80.810–811. Also compare Seiler 2003, 365, fig. 19.2.

8 The dating of the afore-mentioned Heliopolis jar – published in Petrie / Mackay 1915, pl. X.11 – in the Persian Period was revised by Aston in 2012 (pers. com.) and changed to the Saïte Period.

9 Also, at the tomb of Pay and Raia at Saqqara, slender jars were found and can be added to the parallels dating to the Saïte Period (Aston 2005, pl. 130).

features in Western Thebes. Furthermore, the pits in the mortuary temple of Sety I in Qurna, can be connected with the process of the mummification, because they contained embalming material (Budka 2006, 85–103; Myśliewiec 1987, 54). However, the context of the jars within the temenos construction at Heliopolis suggests a primary use within the provision and diet of the craftsmen.

Open Forms

Type 2

A further type from the recent excavations at Heliopolis, *Type 2*, has 53 examples (Pl. 1.10–13). These are only known as rim sherds and have a characteristic lip that bends slightly inwards. This type was also manufactured on the potter's wheel, with the wheel-marks clearly visible. No comparison was found for *Type 2* at other sites.

Type 3

A bowl with a characteristic knob on the rounded base is designated as *Type 3* (Pl. 1.14). This form is likewise shown in W. M. F. Petrie's Heliopolis publication (Petrie/Mackay 1915, pl. X.8). In the recent excavations at Heliopolis, 77 base sherds of this type of bowl were documented.[10]

Conclusion

The tall jars of Heliopolis Type 1 can be dated to the Saïte Period (26th Dynasty, c. 664–525 BC; Beckerath 1997, 192). Given that *Types 2* and *3* were found in the same context as *Type 1*, a Saïte date can also be proposed for them. Taking into consideration the archaeological context of these Late Period vessel fragments found in between the temenos walls, one can assume that these vessels belong to the construction phase or the

Fig. 1: Photo of a reconstructed jar of *Type 1* from the store-room at Matariya (Photo: D. Raue).

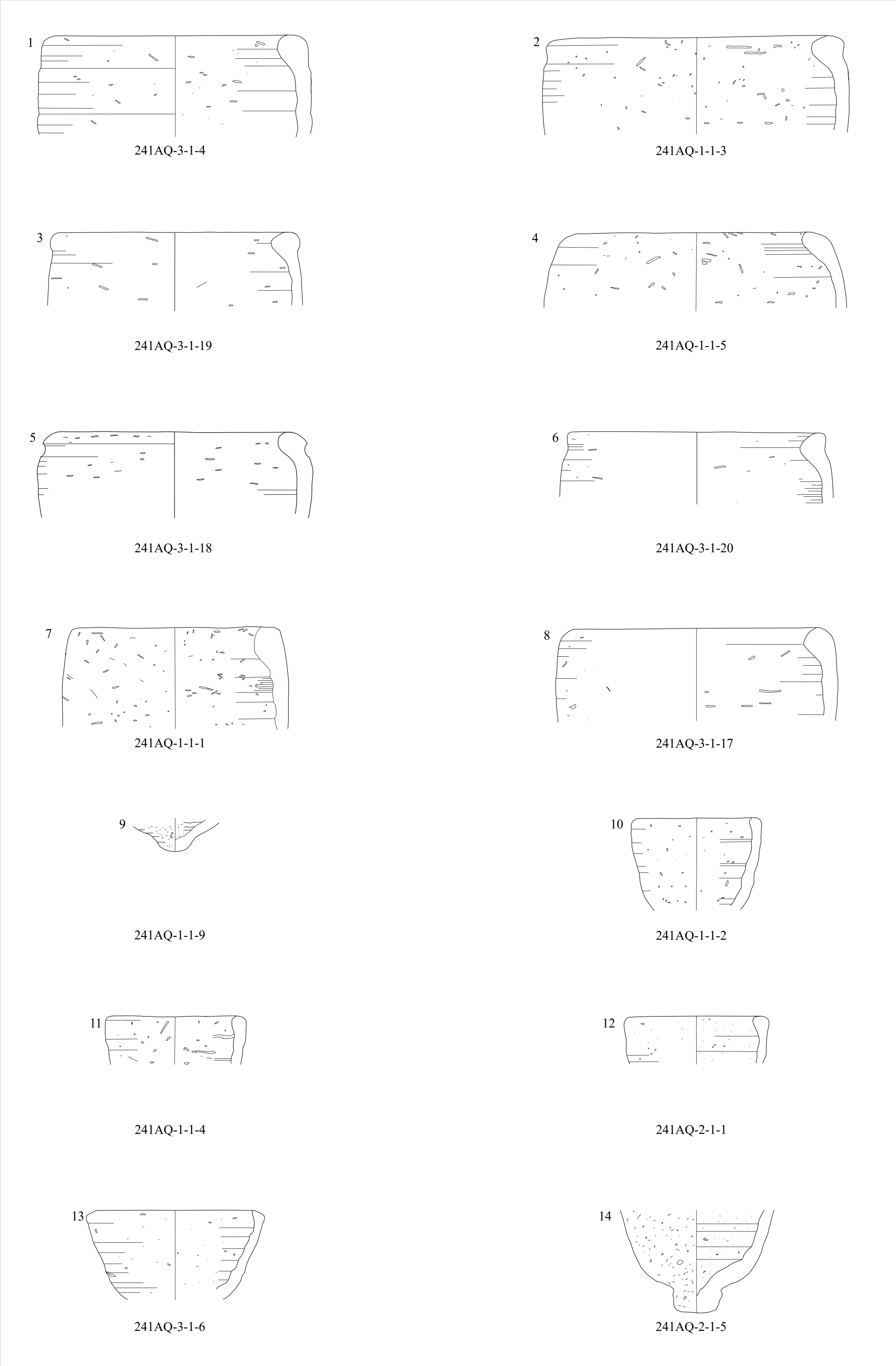
[10] However, it is possible that a number of these bases are actually fragments of the large slender jars of Type 1. But the fragment 241AQ-2-1-5 is very likely the base of a bowl.

earlier use-phase of the inner wall and offers a terminus ante quem for the outer, undulating enclosure wall. The find circumstances suggest a function of these vessels within the context of the supply for the craftsmen, especially for the many large jars of *Type 1*, which were supposedly used for water storage. One could assume, that the smaller open forms were used as dishes, maybe in order to hand out or consume the content of the storage jars. The ceramic assemblage is particularly limited in the type range. The high number of similar vessels in Western Thebes e.g., suggests a central pottery supply, in the case of the temple of Heliopolis in order to build the outer temenos wall, which was a large construction project.

Tab. 1: Pottery fragments from context 241AQ shown in the plate.

find no.	fabric	interior surface	exterior surface	dia. rim	dia. base	max. height
241AQ-1-1-1	Nile B	white *wash*	white *wash*	6.1	-	7.0
241AQ-1-1-2	Nile B	uncoated	uncoated	3.8	-	6.1
241AQ-1-1-3	Nile B	uncoated	uncoated	8.6	-	6.3
241AQ-1-1-4	Nile B	uncoated	uncoated	4.1	-	3.2
241AQ-1-1-5	Nile B	uncoated	uncoated	7.2	-	5.4
241AQ-1-1-9	Nile B	uncoated	red *wash?*	-	5.1	2.2
241AQ-2-1-1	Nile B	uncoated	uncoated	9.4	-	3.1
241AQ-2-1-5	Nile B	uncoated	uncoated	-	7.6	6.7
241AQ-3-1-4	Nile B	uncoated	white *wash*	15.2	-	6.6
241AQ-3-1-6	Nile B	uncoated	uncoated	10.0	-	5.8
241AQ-3-1-17	Nile B	uncoated	uncoated	16.0	-	6.1
241AQ-3-1-18	Nile B	uncoated	white *wash*	15.0	-	5.5
241AQ-3-1-19	Nile B	uncoated	uncoated	15.0	-	4.9
241AQ-3-1-20	Nile B	uncoated	white *wash*	16.0	-	4.6

Plates



Pl. 1: Heliopolis, *Type 1a* (1–5); *Type 1b* (6–8); *Type 1* (9); *Type 2* (10–13); *Type 3* (14); scale: 1:4 (Drawings: M.-K. Schröder).

5.2.1

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