Masonry Techniques of the Early Sixth Century City Wall of Resafa, Syria

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ABSTRACT: Although the Persians never came near Resafa during the war of 502–506 AD, the war's events did have effect on the building of the new city wall. It seems certain that the walls were begun ca 500 AD, a time of relative peace. They demonstrate that effort was not in question as the wall's elaborate structural design was developed. In Resafa we find three-leaf solid masonry with ashlar faces and a core of fairly squared blocks for which walling techniques found in the Limestone Massif stood example. There, two-leaf walls can be found, as well as voussoirs with grooves like ones found in Resafa. The war definitely slowed down building progress in Resafa, forcing the builders to finish only the curtain wall and to neglect the towers, while improving the security of the water culverts. The massive structure was approved and later copied at the north wall of Halebiye-Zenobia.

INTRODUCTION

State of knowledge, project aim

Resafa's largest building structure, the city wall, is known principally from the work of Walter Karnapp who provided a thorough appraisal of the original fortification (Karnapp 1976). Later, the city wall was a minor theme in an article on the city's water supply (Brinker 1991), relating to the water culverts passing through the defences. Further detailed investigations only concern the elaborate decorative elements seen almost solely within the main gates (Brands 2002). Yet, in all studies, little is recorded on the actual style of walling techniques or on the joints between the main wall units such as the towers and the curtain wall. For this reason, sections of the walls remain as blank spaces on the drawings. In consequence, questions concerning the original assembly methods and the sequence of work during the erection of the wall, as well as those dealing with later phases of rebuilding and repairs, remain unanswered. Filling these gaps is the aim of the subproject "The City Wall of Resafa" within the project "Resafa – Sergiupolis / Rusafat Hisham, City of Pilgrimage and Caliph's Residence" conducted by Prof. Dorothée Sack, Berlin University of Technology. This paper will present some of our latest insights on the design of the wall and the structural techniques used for the masonry and will compare these features with similar building structures at other sites.

Setting

Resafa was an ancient military, pilgrimage, and trading centre situated at the northern fringe of the Syro-Arabian steppe and its city walls still stand exceptionally high today, even though large parts have disintegrated or lie beneath debris. The walls are part of the city's late antique remains that are closely related to the cult of St Sergios notable from the mid-fifth century onwards (Fowden 1999, pp. 60–100). At the beginning of the sixth century, under the reign of Anastasius I (491–518 AD), the inhabitants of Resafa managed a huge construction programme including at least two of the site's major churches (Basilica B and the tetraconch church), the water supplies with their dam, canal and cisterns, as well as the city wall – see Fig. 1. According to an inscription, it is certain that Basilica B was begun in 518 AD (Gatier; Ulbert 1991, p. 179). It was built, together with the tetraconch church and the north gate of the city wall, by closely related, if not the same, groups of craftsmen (Brands 2002, p. 6), probably starting with the city wall (Brands 2002, pp. 197, 595).

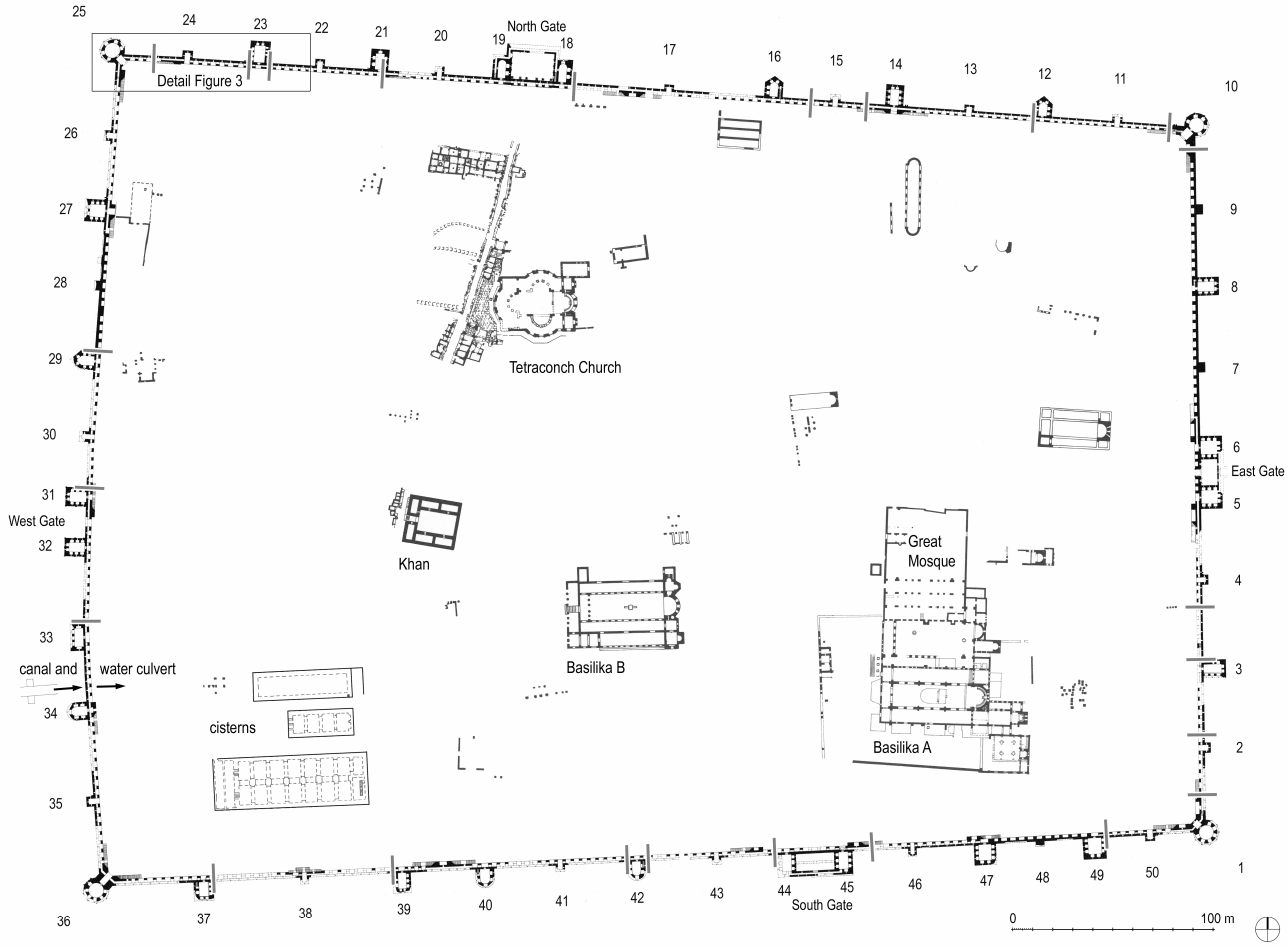

Figure 1: Site plan of Resafa; The short lines cutting the city wall show the positions of identified wall junctions; (Karnapp 1977, Fig. 4 combined with Ulbert 1986, Fig. 1 and additions by author)

Our investigations, when compared with the known facts, allow us to assert that the beginning of building the new city wall of Resafa was in the period from 499 to 501 AD (Hof, in prep.). Some details at Resafa make sense only if the walls were begun before the outbreak of the Roman-Persian War of 502–506. After three months of siege, the Persians had finally entered the Roman city Amida using its water gates. The fall of Amida in 503 AD triggered notable changes in the plan of Resafa, where the builders of the wall became aware that some features of the water culvert at the south-west section had to altered. They reduced the cross sectional dimensions of the culverts, so a person could not get through, and they redesigned one of the small towers, so that it became habitable and thus permanently guarded – see Fig. 1, tower 33. The original concept for the unprotected water passage indicates a certain degree of artlessness of the builders, and this would certainly not have been the case if the walls of Resafa had been begun after the siege of Amida; so the year 503 is seen as a *terminus ante quem*. It is also certain that building could not have started much earlier than this date because the walls were altered during an early building phase, therefore after construction had begun. This new proposition about dates will be of further importance when we discuss related sites further below.

STRUCTURAL FEATURES

Wall construction

The city wall of Resafa was originally built solely of gypsum stone, a brittle material that deteriorates when exposed to sunlight. Nevertheless, gypsum is the main local stone and easy to cut when freshly quarried. Later repairs and rebuilding brought some additional materials into the structure. Limestone was exclusively used for the vaults, replacing wooden floors in the towers (Karnapp 1976, p. 25–26). Together with brick, limestone was also used in small quantities for repairs to the curtain wall. The gypsum of the original wall faces are worked to neatly-squared ashlars. The blocks vary considerably in size, Karnapp provides the figures (Karnapp 1976, p. 15), and just to give an indication, the average course height is about 60 cm. The ashlars are laid out in regular courses with continuous bed joints – see Fig. 2 (left). The vertical joints of the wall faces are staggered, exactly as demanded by high quality masonry. Broken courses with joggled bed joints do appear as masonry joints and indicate independently-erected wall stretches. These wall junctures are examined later.

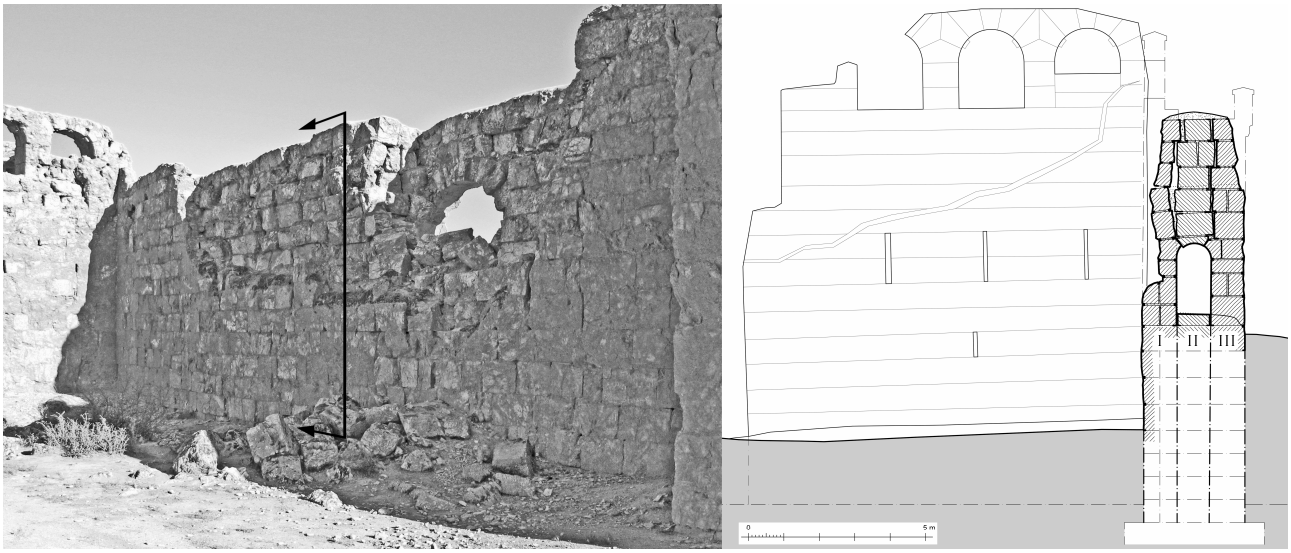

Figure 2: Resafa city wall, north wall between towers 23 and 24; view from north west (left), transverse section viewing east towards tower 23 (right)

The curtain wall is 2.80 to 3.10 m thick. The cross section between the towers 23 and 24 given in Fig. 2 (right) shows that the overall construction is that of a three-leaf masonry wall, which consists of an exterior (I) and interior leaf (III) and an inner core (II) of anyhow fairly squared and also coursed blocks. Chinks were filled with smaller stones set in gypsum mortar, but it is important to stress that the amount of rubble is very low. The three leaves are represented clearly in the second storey with the galleried wall-walk: Here the inner leaf (III) is broken up to form the piers of the gallery arches, the core leaf (II) is left out as the alley of the wall-walk and only the outer leaf (I) with its loopholes is left as an outer shield. These three main leaves divide the wall into almost equal thirds of about 1 m thickness and it is a noteworthy and somewhat puzzling feature that they hardly bond with each other throughout their total height. Each leaf is one to two stones thick, except for the exterior leaf (I), which is almost uniformly two stones thick with hardly any bonding through-stones, meaning it is made up of two separate sub-leaves itself. The clearly distinguishable separate wall leaves may mean that we have to consider different specialized stone-cutters working within each group of workmen and responsible for different degrees of stone quality, for example, for finished stones such as voussoirs or cornices and neatly dressed ashlars for the wall faces, or simply for roughly cut stones for the core. And so, at least to some degree, the organisation of the building site may be responsible for some constructional details. Advantages of labour division during construction led to disadvantages in longevity. In a typical scene of disintegration that the thin exterior ashlar-shell easily breaks away – see Fig. 2 (photo, left half). Only when the second face half also collapses, destroying the outer face completely, the arches of the galleried wall-walk are exposed – Fig. 2 (photo, right half). The section of the wall in Fig. 2 (right) shows that in the top part the second half of the exterior leaf is already warping out heavily. It also reveals that the courses are just about equal through the entire thickness of the wall. This is important since we now know that the three leaves were always laid out simultaneously.
Further information derives from the observation of joints between different structural elements of the city wall especially between the curtain wall and the towers. These rarely are bonding in their courses over the entire preserved height. But the opposite case of completely untied towers, simply abutting against the curtain wall, is also seldom seen. Moreover, the majority of corners are a mixture of both techniques: usually bonding in lower courses and running independently at points further up, as can be seen in Fig. 2 (right).

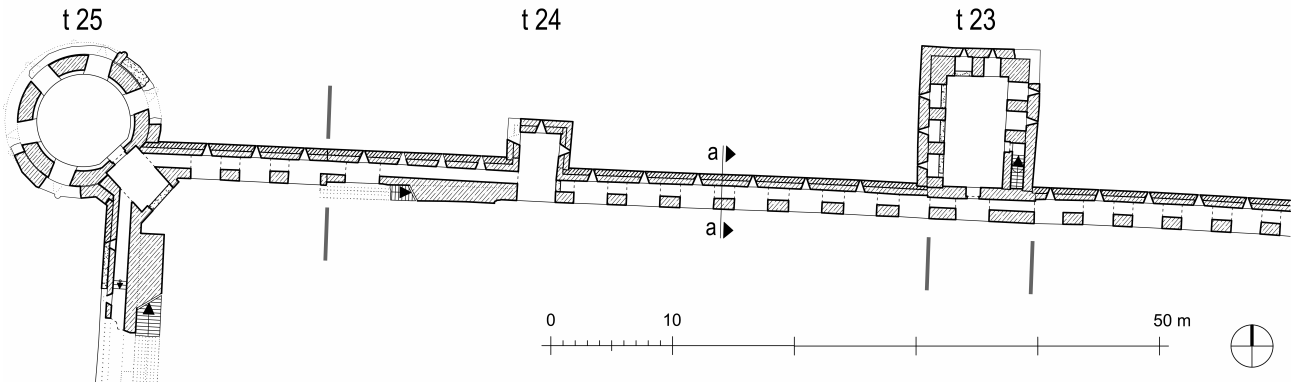

Figure 3: Resafa city wall, north wall between towers 23 and 25; partial plan from geodetic survey 2006–2008

The look into the body of the wall shows that the curtain wall is the main structural member and that the towers are abutted against it. But there is not necessarily a total lack of bonding between their outer faces, which may bond to a small degree as just described. So, conceptually, the towers are three sided annexes. Two subphases of building can be deduced from the joints between the towers and the curtain wall: at first the curtain wall and the towers arose simultaneously and thus show equal course heights bonding into each other, disguising the abutting character of the towers. At about half of its original height, and often even lower, the towers were probably left unfinished, in order to raise the curtain wall alone, presumably to complete it as a protective shield. The towers were completed later and their masonry courses are clearly off-set to those of the curtain wall. A possible reason for this is given below when speaking about Dara-Anastasiopolis.

Wall junctures

Several wall joints running almost through the total height of the wall parts that are still standing have been identified and are shown in the plans of Fig. 1 and 3. They are marked by oblique bed joints between the ashlars and staggered courses all the way up to the top of the galleried wall walk, forming an almost vertical break in the wall. As far as the remains allow, these joints can be tracked on the in- and outside faces of the wall. Fig. 4 shows some examples with the junctures emphasised. Due to the poor condition of the ruins over wide spreads the tracked wall joints remain fragmentary Fig. 1. Even so, we may say, that the stretches differ considerable in length. They can frame as little as just a piece of curtain wall. But a small tower or a large tower, or even both, often belong to a single stretch as well. Stretches with more than two large towers most probably have to be further subdivided but, without excavations, the ruinous condition of the wall allows no more evidence.

Figure 4: Resafa, city wall, three examples of wall joints: north wall between towers 24 and 25, view from the outside (left), east wall between towers 9 and 10, view from the inside (second to left), south wall between towers 45 and 46, view from the outside (second from right) and the same joint from the inside (right)

Oblique joints in single ashlars can certainly be found more often on the wall's faces, revealing the point where a new stone delivery from the quarries had begun. These are different from where the continuous vertical wall joints divide sections of the wall that were erected apart from one another. This is underlined by the fact that the wall joint visible in the vertical plane of the wall's faces usually corresponds with a slight change of direction of the wall in plan. In Fig. 3 the same wall joint between towers 24 and 25 can be seen in ground plan as presented in Fig. 4 (left). In this case, even the gallery pier is split by the wall joint. Only the new precise measurement of the wall demonstrates that some corrections of the diverging wall directions had to be accomplished in the wall partition between tower 24 and the wall joint – look for the clear off-set of the wall walk at tower 24 and the wedge shaped interior wall partitions to the west.
We hope that the analysis of the remaining joints will give us enough hints to reconstruct the original theoretical plan of the building design and then the real sequence of building that took place. The wall stretches between the junctures probably do not cover building stages in a time-related aspect, since in that case the joints would be stepped rather than being almost vertical as they are. It is more likely that they indicate the range of responsibility of different construction supervisors. So, the joints are fissures where different groups of workmen, including quarrymen, met each other and had to compensate for their misaligned courses.

Stone Marks

On a few spots of the ruins, carved symbols and marks have been found. Those published are all unique, found only at a single spot. Only two or three signs may be recognized as mason's marks (Karnapp 1976, p. 50, Figs. 256, 259). During our investigations we have now discovered marks which, unambiguously, were carved by masons, not in the sense of a mason's signature, but rather as a securing structural measure. They may have acted, additionally, as 'assembly' marks, indicating a necessary order of arrangement during laying out. Fig. 5 gives some examples, not only found at Resafa. These new marks are found exclusively on voussoirs and can only be seen when the arch has collapsed or the voussoir has almost completely slipped out of place.

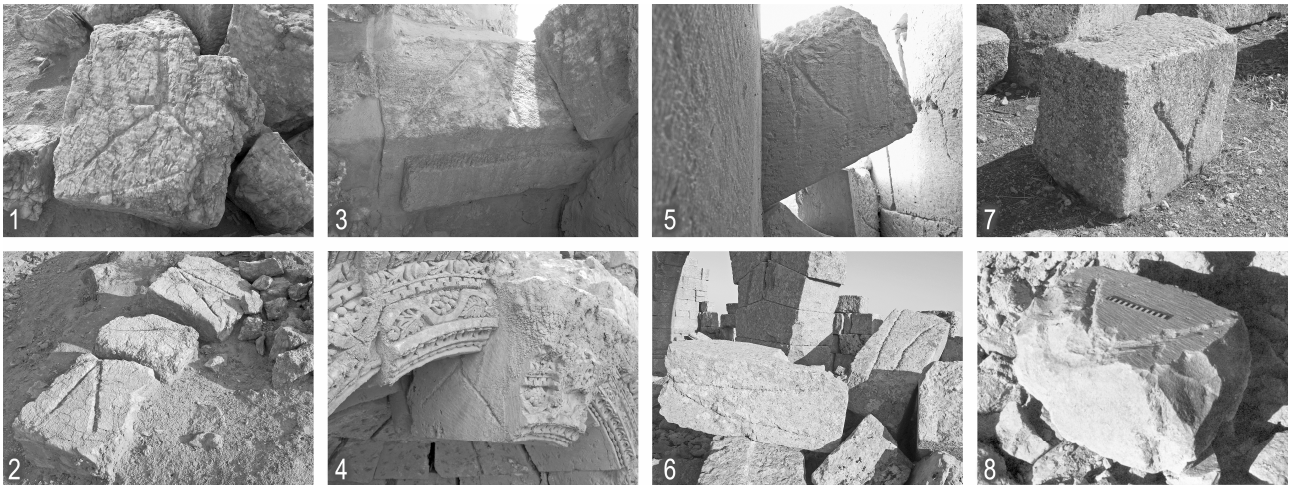

Figure 5: Voussoirs with grooves. Resafa, city wall, North Gate, debris (1), Resafa, city wall, West Gate, debris (2), Resafa, city wall, tower 43, *in situ* (3), Resafa, Tetraconch Church, baptistery, *in situ* (4),Resafa, Basilica B, staircase (5), Brad, Northern Church (6), Qal'at Sim'an, Church of Saint Simeon (7), Qasr al-Hair ash-Sharqi, Small Enclosure; (Grabar 1978, p. 18 Fig. 43) (8)

Narrow grooves are cut into the joint-face of the voussoir forming an arrow shape or just a simple V. Up to now, the marks not only appear on the city wall as shown in Figs. 5 (1–3) but also at the tetraconch church: Fig. 5 (4) and at Basilica B: Fig. 5 (5) – once again stressing the relationship of these three large scale edifices. Most of the examples were found among the debris, having the advantage that they can be studied from several sides. This shows that the grooves are only on one of the two voussoir's joint faces. Only some few examples were luckily found in situ. They reveal that the arrow or V-forms are always pointing upwards.

Two functions can be assumed for the grooves. The first may be seen as an instruction to the stone layer about how to position the arch member correctly in the sense of 'this side up'. But in this case smaller marks would have done the job just as well, and so these grooves are more probably meant as a securing measure for the radial joints. Similar techniques are known up to modern times: "There are many ways of making a joggle joint. The […] grooves may be cut in both the stones and an independent joggle of slate, pebbles, or Portland cement fitted, the joggle being really a kind of dowel." (Bartlett 1958, p. 20). Such a joggle, filled with a special mortar forming a cast dowel, is also given in the case of the arrow-shaped grooves called 'Abeurador' on voussoirs in Sardinia, as presented on the first Congress of Construction History (Frulio 2003, p. 936). Some of the grooves found at Resafa may also have been meant to be poured full with a thin running mortar, since in these cases the groove increases in profile towards the top forming a kind of funnel, Fig. 4 (1). Some examples found around the north gate belong to this type. All of the grooves, as far as the stone is preserved well enough, are drawn all the way up to the extrados edge of the voussoir, emphasising the pouring-hole function. However, the groove's profile usually is consistent in diameter and the abutting voussoir does not have a symmetric groove forming a mould for a 'dowel'. Mortar remains covering the voussoir's joint surface – not only its groove – show finely dispersed small shivers of gypsum and the mortar does not give the impression that it was applied by pouring. Rather it probably had a paste-like consistency that could be spread by a trowel. Possibly only sliding friction during the laying of the voussoir was to be set up by this measure. And maybe only the voussoirs near the keystone with the steep joints had a groove design suitable for pouring.

The examples given above helped to explain the function of the grooves, but what about their near historical coherency? Luckily, since this detail is not notable from the outer appearance of a structure, the search, so far, has come up with a number of important examples. Some were found at monuments in the north Syrian Limestone Massif. Some simple ones, similar to the one from Basilica B, were found at the Northern Church of Brad (561 AD) (Tate 1992, p. 336), – see Fig. 4 (6). Another example, also in the region of the Jabal Sama'an, at Qal'at Sim'an (St. Simeon Monastery), dated in the last quarter of the fifth century (Mango 1976, p. 48), is given in Fig. 4 (7). It has been already pointed out by others that the paths of building traditions found in Resafa not only lead to major cities as typical model developing centres, foremost Antioch and Apamea, but also to the Limestone Massif (Brands 2002, pp. 6, 198 and Strube 2002, pp. 105–106). With the voussoir grooves of the Jabal Sama'an region we now have a construction detail, standing on the one hand for a certain structural understanding of the user and on the other for an aspect of practical stone layer's work that certainly was not invented twice in northern Syria within only about a century. The same may be said for the next site where grooved voussoirs can be found and for which now Resafa itself most certainly stands as an example: Qasr al-Hayr ash-Sharqi (Qasr al-Hayr East), a building complex about 70 km south of Resafa, originally constructed under the Umayyad caliph Hisham ibn Abd al-Malik in 110 AH/728–9 AD, the same caliph who established his part-time residence at Resafa at about the same time. Fig. 4 (8) shows a voussoir found in the Small Enclosure of Qasr al-Hayr. Its grooves were described by Oleg Grabar as "probably for pouring mortar between the stones […] although the grooves are perhaps too shallow" (Grabar 1978. p. 26). This is exactly as in Resafa.

Comparisons to related structures

Now that it is very likely that the beginning of the city wall of Resafa can be dated shortly before 500 AD, comparisons can be drawn with other structures from which we have long known that they are probably close, but until now could not have said in what order. I will present four noteworthy structures: the city walls of Dura Europos, Dara-Anastasiopolis, and Halebiye-Zenobia and beyond these fortifications the Church of Julianus at Brad.

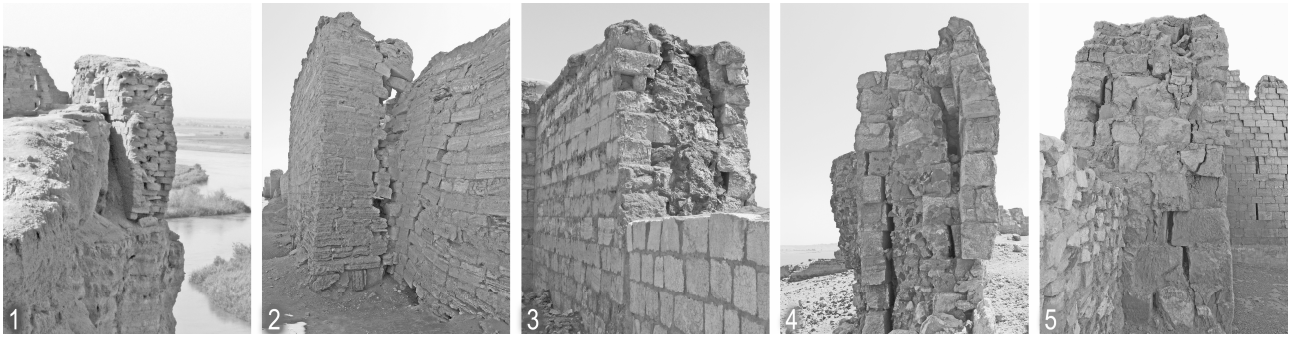

Figure 6: Dura-Europos. East wall at citadel (1), city wall west side (2);
Halebiye-Zenobia. South side (3), east side (4), north side (5)

The walls of Dura Europos are clearly an earlier structure than Resafa. The masonry wall replaced an older one of brick in the third century BC (Gregory 1996, 153–163 with further references). What makes these Hellenistic Seleucid walls interesting for our comparison is that they are also made throughout of gypsum blocks. Yet, the three- to four-meter thick masonry is that of a single-leaf ashlar wall, Fig. 6 (1). It is constructed of neatly-squared stone ashlars laid with an absolutely sufficient quantity of bonding stones, typical for Hellenistic masonry Fig. 7 (1). It can withstand a considerable degree of distress as caused by earthquakes, sinkholes or siege machines. Fig. 6 (2) shows a stretch of wall under which apparently a doline has caved in, so, that the walls above have sagged as a result, but still stand. Since undermining ground in order to cause the walls above to collapse was a well known instrument of siege, the walls of Dura Europos were constructed to withstand such attacks. Their only weakness lies in that the gypsum stone comes in rather poor quality and so its specific, strongly-developed, sediment layers constitute the brittleness of the stone in general and its weathering hazards. The ashlars at Dura Europos are often laid 'incorrectly' in respect of the natural, stratified layers of the stone. They come edge-bedded or even face-bedded, with the load running parallel through the stone beds instead of across them. In Resafa the ashlars are always oriented with lying beds, meaning that the blocks were cut and chosen with special care at the quarries. Certainly, in the first place, that means that the quarries at Resafa provided enough good material, but it can also be assumed that not every block was accepted. This adds up to the impression that no effort and expense were spared to build the walls of Resafa. This again tells us that they must have been begun, at least, in times of peace and relative secureness.
The city wall of Dara-Anastasiopolis is historically related to that of Resafa. Dara lies about 260 km north east of Resafa, and its walls were begun only about five years later in 505 AD as direct reaction to the Persian attack (Gregory 1996, 80–88 with further references). Its walls are known to have been built in a haste within only two or three years (Zach. of Myt. VII, 6, p. 166), so in almost no time at all. Structurally the walls of Dara and Resafa lay quite far apart, since the haste at Dara went hand in hand with ill-mannered walling techniques, very soon making repairs necessary. Multiple phases of changes and repairs have been recorded, namely two (Crow 1981, p. 16, and again Croke; Crow 1983, p. 154), six (Whitby 1986, p. 744) or three (Zanini 1990, pp. 248–249). The discussion, which parts are to be considered on Anastasius I's or on Justinian II's account can not be recapitulated here. For sure is that due to the poor quality of the masonry, especially the original base construction, most of Dara's walls have been destroyed. The preserved walls pieces are three-leaf with limestone ashlar faces and mainly a rubble core, similar to Fig. 7 (2). The core at some places of later repairs does show that some strains were taken to secure it. Vertical courses of fairly squared blocks obviously were meant to stabilize the wall. Whitby assumes that they were meant to reduce the extent of collapse, if something or someone undermined the wall (Whitby 1986, p. 742 and Fig. 41.3). Important about Dara in our case is the fact that the sources report, the building programme of the fortress at Dara was of absolute top priority. Workers, especially masons were paid excellent wages in order to entice them to the construction site near the dangerous border (Zach. of Myt. VII, 6, p. 166 and Jos. Styl., § 90 p. 109). This most certainly meant an unintended break in building activity at Resafa, even though the threat of a Persian attack was also imminent here. But at the time of 505 AD and the succeeding years, the resources of money and workmen were cut off for this place of minor military relevance. It seems quite acceptable to assume that the notable change in walling technique described above, namely the finishing of only the curtain wall leaving the towers behind to be finished later, fits perfectly into these conditions.

Halebiye-Zenobia is a Late Antique fortress city about 100 km east of Resafa on the west bank of the Euphrates. Thanks to the work of Jean Lauffray, we know that the walls today date from two phases. The original structure was probably built during the reign of Anastasius I (491–518) under the same conditions as Dara, therefore right after the Roman Persian War ending 506 AD (Lauffray 1983, p. 34). The south and east partitions of the remains today belong to this early phase. As shown in Fig. 6 (3 and 4) and Fig. 7 (2), the masonry is similar to that we know of from Dara-Anastasiopolis: two wall faces of ashlars, gypsum as in Resafa, bear a core of gypsum and basalt rubble. These walls are a further example of the masonry type preferred at locations close to the Persian border shortly after a war that did not let the Romans look so superior. Since a huge building programme had to be accomplished along the border, the resources of money and building specialists had to be divided and at the same time, the new fortifications had to be finished very quickly. Even though the emerging new walls of Resafa must have been known, there was no time to copy the elaborate technique of the massive walls used there. But this seems to have been understood as a considerable mistake only about forty years later. The walls at Halebiye-Zenobia must have been in such a bad state after only one generation that the whole north wall was replaced under Justinian I (527–565) in about 545 AD (Lauffray 1983, p. 148), this time copying the method of Resafa. As can be seen in Fig. 6 (5), two exterior faces of gypsum ashlars encase a core of roughly squared gypsum blocks Fig. 7 (3). The builders of these late walls of Halebiye-Zenobia avoided the faults of the walls at Resafa in two ways: first, they did without a galleried wall-walk half way up the wall and thus they did not have to split the wall in three vertical planes and, second, by letting the ashlars of the wall faces bond a little better into the core masonry, even though they still do not bond exceptionally well compared with Dura-Europos. The style of three separate walls erected one behind another to form a thick wall is apparent to a greater extent than that of a single-leaf thick wall.

Next we shall take a look at the Church of Julianus at Brad (402 AD) (Tate 1992, p. 336). The later North Church there was already mentioned as one of the locations, where voussoirs with grooves were found. The Julianus Church is of interest because of the walling technique found there. Georges Tate has described and categorised the masonry types found in the Limestone Massif. Even though the walls there never have more than two leafs, the "Appareil double orthogonal" (double-leaf ashlar masonry) as found at the Church of Julianus (Tate 1992, pp. 23–24, Fig. 21) comes very close to what we find in Resafa: two separate and independent faces or parallel shells forming one wall. It seems that the void between the faces was left more or less hollow. Tate only gives a section through the related "Appareil double quadrangulaire" (double-leaf masonry of four-sided blocks) but since the two types only differ in face, not in section, the section-drawing fits both (Tate 1992, P. 88, Fig. 131). A section, drawn after his illustration, is given in Fig. 7 (4).

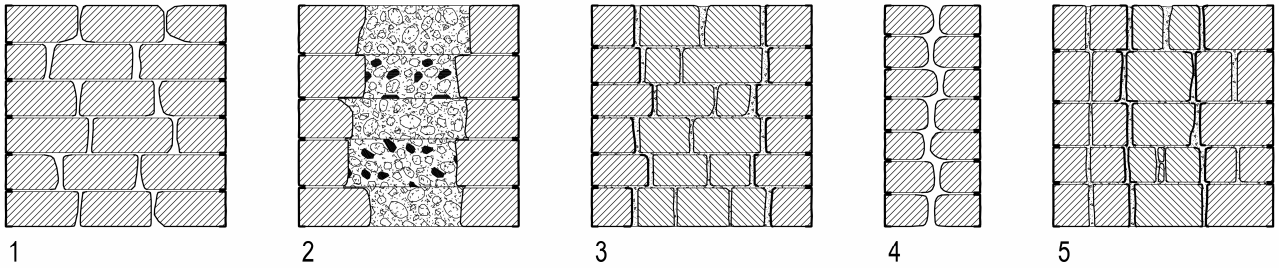

Figure 7: Schematic wall sections. Dura Europos, city wall (1), Halebiye-Zenobia, south and east sections of city wall (2), Halebiye-Zenobia, north section of city wall (3), Brad Church of Julianus (4, according to Tate 1992, p. 24, Fig. 21 and p. 88 Fig. 131), Resafa city wall, beyond the range of the wall-walk (5)

CONCLUSIONS

The start to building the city wall at Resafa was probably in ca 500 AD – otherwise the solid, time- and labour-consuming masonry can hardly be explained, and the signs of building alternations and pause in work can be only understood on the basis that the ambitious building programme had to be set behind for some time in the aftermath of war.

The walls at Resafa, their principal section is given in Fig. 7 (5), were meant to be very stable and, compared with Dura-Europos, only the best of available stone was chosen, indicating immediately that such high standards could not have been imposed shortly after a devastating war. The elaborate walling technique was probably developed out of the masonry tradition found in the Limestone Massif in north-western Syria. Yet there had been hardly any experience with such thick walls and the masons seem not only to have doubled, but indeed to have tripled, an ordinary single leaf ashlar wall. As Dara-Anastasiopolis and Halebiye-Zenobia show, the knowledge of the regions further west was in their minds, and not Resafa, when creating a double-shelled wall with a rubble and mortar core. But the builders were certainly aware of the fact that the available mortar was far from the cementitious quality which gave the walls of the early Western Empire such incredible stability. As Cyril Mango has long pointed out, 'Byzantine' masonry, especially the type he calls 'Constantinopolitan' is kept together by the facing and did not have a monolithic core responsible for stability (Mango 1976, pp. 9–10). In the Eastern Empire, it was generally known that, if the faces were lost, the rest of the wall

would disintegrate rapidly. For this reason, bonding layers of brick were supposed to hold the faces together. Bonding brick courses can be found on the south side at Halebiye-Zenobia.
But what was the alternative to a brittle core held together by more or less braced faces, especially when aiming at a multi-face shell concept allowing division of labour, as an organisational advantage, and wall-hollows like wall-walks, as a functional means? One idea is to leave the core empty, but this was only suitable for walls of restricted thickness. Or, the core had to be stable enough to be able to stand by itself, like a wall within the wall. Then, so it seemed, even little bonding efforts had to be made. Looking out for examples for this unique three-leaf masonry is not easy. Dura, Dara and early Halebiye do not fit, and besides the first were begun later then Resafa. But with the double-leaf masonry at Brad we might have a simple model. But the separately drawn up three-wall shells in Resafa over the long run had one major error compared to Brad: the voids between the wall faces or shells were not real hollows as at Brad but more like thicker vertical joints in which randomly mortar was filled. Over time, small bits of stone and mortar chunks fell down with additional sand drift bringing more fill material. Trickling downwards, the fine debris exerted a thrust against the wall faces, working like a wedge and gradually splitting them apart.
The further development of Late Roman construction features in Umayyad architecture and Early Islamic construction has been traced in respect to bonding-timbers in masonry (Utrero Agudo 2006, p. 3438) and reduced-span centering for vaults (Acre 2006, 199–200). With the voussoir grooves at Resafa we may add a further feature of technology reception and merging that might have spread to the western Mediterranean region by the Arabs.

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