THE LAYOUT OF THE GARDEN AND POOL COMPLEX IN PETRA. A METROLOGICAL ANALYSIS

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Introduction and Methodology[1]

Recent excavations by Leigh-Ann Bedal (1999; 2000; 2001) in the Garden and Pool Complex of Petra have revealed the site's overall layout as well as several features in detail. The pool complex in the center of the ancient city (previously known as the "Lower Market") is situated between the Great Temple, to the west, and the "Middle Market", to the east, and between the Colonnaded Street and the summit of az-Zanṭūr (الزنطور). The complex is situated on an artificial plateau (behind a retaining wall) and consists of a lower (garden) terrace with dimensions 60 x 53m, and a pool with plan dimensions of 43.40 x 23.30m and depth of 2.5m. The latter was built at the base of a quarried cliff, some 15 meters high. An island with ground plan dimensions of 14.80 x 11.80m is situated in the middle of the pool. This supported a pavilion with at least 3 large doorways. More architectural features were recovered, such as the remains of a monumental socle with dimensions reaching 3.83 and 3.67m at the center of the garden terrace. Based on parallels in the palace complexes of Herod the Great of Judea (e.g., Netzer 1977; 1981a; 1981b; 1991: 329-334; Gleason 1987-88; Gleason *et al.* 1998; Nielsen 1994: 181-208), and additional information available through the archaeological and historical record of the region (e.g., Oppenheim 1965; Wiseman 1984; Stronach 1989), Bedal has concluded that this is the site of a pleasure garden or *paradeisos* built in the style of the Late Hellenistic and Herodian pleasure gardens (**Fig. 1**). Current archaeological evidence indicates that the Petra Garden and Pool-Complex is dated to the reign of the Nabataean King, Aretas IV (9BC-40AD), with renovations and continued use as a public park under Roman annexation (post-106AD).

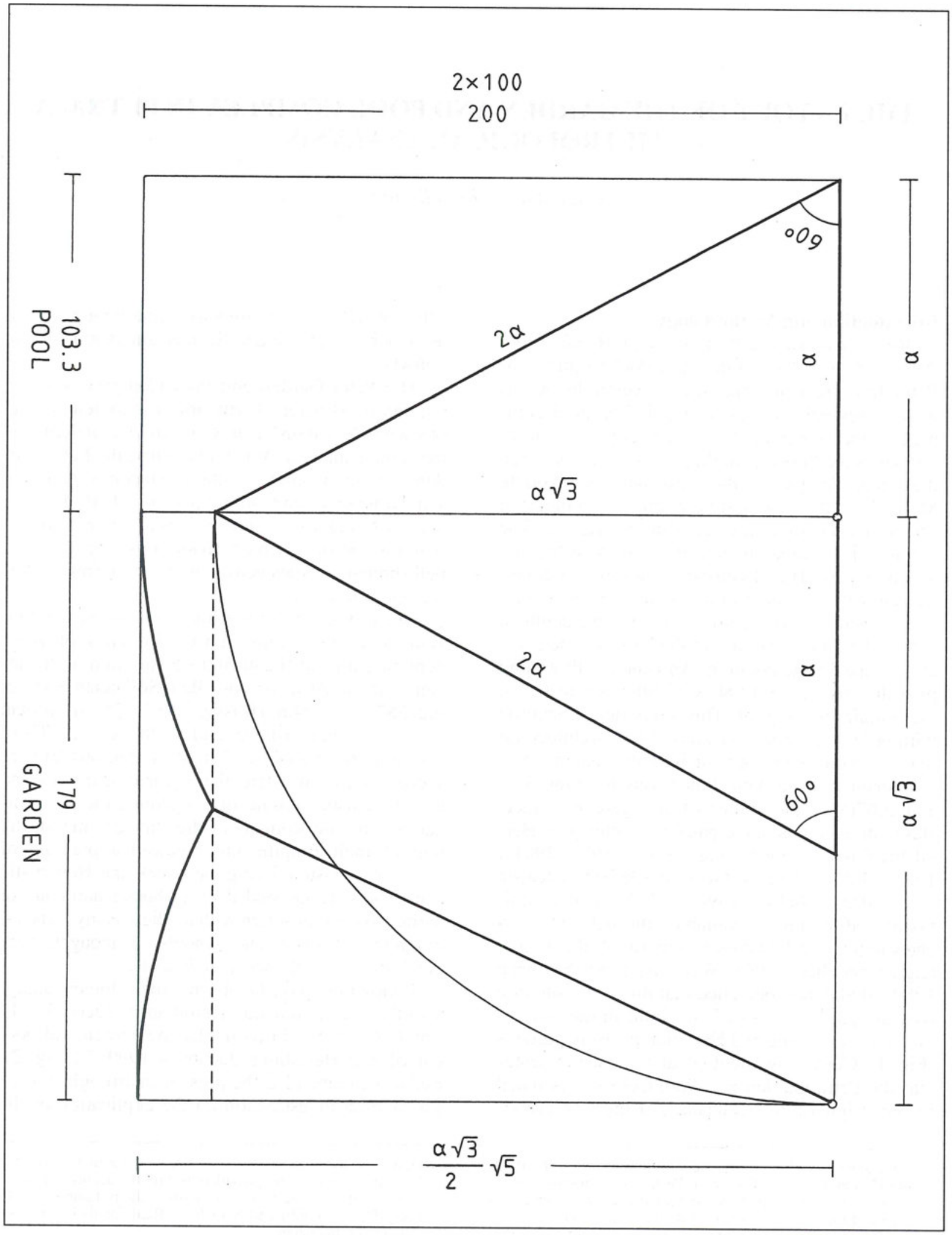
The Petra Garden and Pool Complex was laid out and constructed shortly after (or contemporaneous with) Vitruvius' *Ten Books on Architecture*. In the same manner as Vitruvius' work, the Petra Garden and Pool Complex is the product of a period of standardization and simplification of Hellenistic, ancient Greek and Egyptian harmonic or harmonious proportions, which made possible the embellishment of cities across the Roman Empire during Augustan times.

One of the aims of the study was to test the division of all dimensions with the Roman foot *(pes)*, here measured as 0.296(5)m,[2] a variation of the ancient Greek Attic or so-called Soloneian foot of 0.29387 – 0.294m (Büsing 1982: 25) or Ionian *pous* of 0.296m (0.295 and 0.296, or 0.2972m). Just like the organized and self-conscious Empire succeeded the city-state, the regional autonomy and the Hellenistic mosaic of kingdoms, the *pes* was adopted by the Romans as the standard measuring unit of their Empire and replaced a plethora of *podes* that existed during the Greek and Hellenistic eras. The latter depended on elaborate harmonic or harmonious ratios -often with a religious mysticism -, different city-states and schools of thought, very much like the alphabets and dialects.

Following up on Jacobson's metrological analysis of contemporaneous Herodian projects (Jacobson 1986; 1999), in particular the garden and pool complex at Herodium (Jacobson 1999: 71, fig. 2), Bedal recommended the present metrological analysis and an investigation on the application of the

1. I am grateful to Leigh-Ann Bedal, the director of the Pool and Garden Complex Project in Petra, for prompting me to work on the present metrological analysis, for all her guidance and for making this text look better. In addition, L.-A. Bedal pointed out in detail the visible *in situ* remains of the "Royal Palace", which is examined *en passant* in this paper, for comparisons. Also, we are indebted to the surveyors of the project, Fawwaz Ishaqat, Majdi Ubeid, and Moustafa Asmar, who provided us with the accurate dimensions of the complex. We also wish to thank Laurent Tholbecq, David Scahill and Sara Karz Reid for their kind assistance in this paper.

2. Four-figure values of 0.2947, 0.2955, 0.2957 and 0.2963m. are also favored by different scholars (Jones 1989: 37).



1. Suggested original design of the Paradeisos with harmonical ratios and Roman pedes. The relationship of the garden to the pool by means of the rule of the Sixton (Equilateral Triangle).

Roman foot in the construction of the Petra Garden and Pool Complex. Tracing the Roman *pes* in a Nabataean structure was of particular importance both because of the affinities of the Petra complex with similar Herodian projects, and because of the significance of the application of the new universal Roman measuring unit among the allies, this time across from — east of — the Jordan River.

Furthermore, the employment of harmonic/ harmonious ratios and measuring units was compared with their application on the neighboring monuments of various dates in the city center of Petra. As one of the buildings in Petra's city center, Qaṣr al-Bint was designed following the Egyptian cubit, this measuring unit was also tested on the measured dimensions of the Garden and Pool Complex, and however it did not produce any successful results[3].

Pavilion

The main dimensions of the island pavilion are as follows:

Actual width of the main doorway: 4.75m = 16.04 *pedes.*

Actual Distance between the western doorjamb and northwest corner: 2.97m = 10 *pedes*.

Reconstructed distance between the eastern doorjamb and northeast corner: 3.05m = 10.28 *pedes*. Possibly, 2.97 m = 10 *pedes*, by symmetry. Possibly, the 10 *pedes* relate to the standard ten-foot-long Roman measuring unit, the decempeda (decempeda pertica) or Roman rod (Vergil, *Ecl.* 9, 7; Chen 1980: 256-57)[4].

Overall reconstructed outer width of Northern façade: 10.69m ± = 36 *pedes* (10.66m).

This is analysed as two times 10 and 16 *pedes* for each of the two walls flanking the main entrance and the opening of the doorway respectively; or 5 over 8 moduli. The façade was designed as 5-8-5 moduli, with the 8 moduli representing the large doorway in the middle. The latter proportion derives directly from the Pythagorean triangle, with sides 3, 4 and 5, with the larger figure as 3+5 = 8, or twice 4 = 8. The doorway occupies 4.75m over a façade length of 10.69m ± or 16:36 *pedes*, that is 1:2.25 or, in integer numbers, 4:9 (2^2:3^2) of the width of the façade, following a basic ancient proportion[5]. Thus being exceptionally wide both in absolute and relative terms[6].

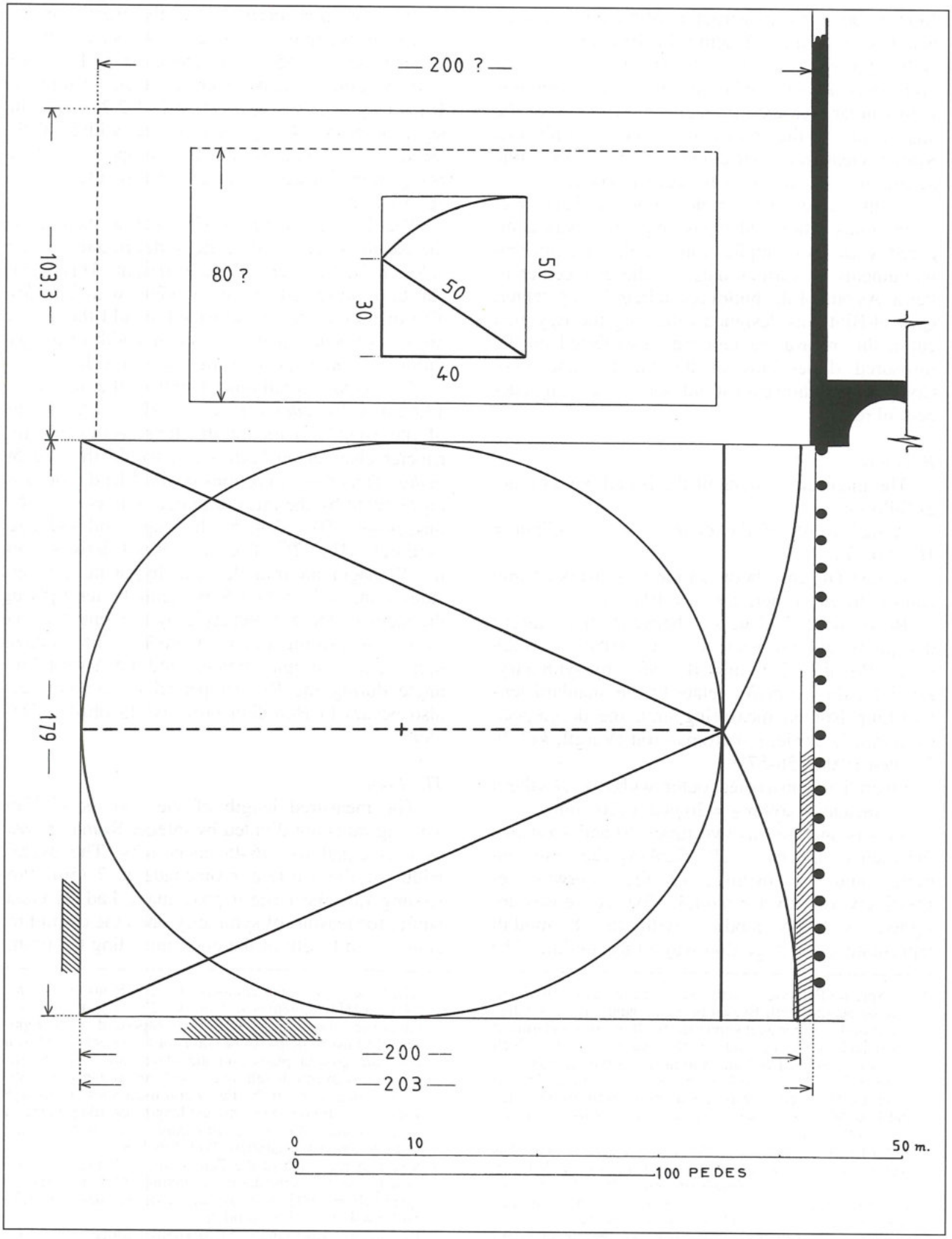
The distance of the pavilion wall to the edge of the island is measured in the northern and western sides to be between 0.55 and 0.60m. This figure can be represented, in our opinion, with 2 *pedes*. The overall width of the island should then equal around 40 *pedes*, that is the outer width of the pavilion (36 *pedes*) plus 2 *pedes* on each side.

The actual overall outer length of the pavilion is 13.62m or 46 *pedes* = 13.616m. The overall length of the island, including the four-*pedes*-wide perimeter channel on both sides, would then be 50 *pedes*. Thus the proportions of the island would be represented by the ratio of integer numbers — Roman *pedes* - 50 and 40 for the length and width accordingly **(Fig. 2)**[7]. The ratio 50:40 derives from the Pythagorean triangle with hypotenuse 5 and sides 4 and 3 (Vitruvius 9, 6), again by multiplying the sides of the 5:4 rectangle by the length of the Roman measuring rod = 10 *pedes*. The employment of both simple numbers and the "sacred" triangle during the Roman period is common and also occurs in Herodian projects (Jacobson 1986; 1999).

The Pool

The measured length of the pool is 43.36m. This figure is not divided by integer Roman *pedes*, as it is equal to 146.48 such units. The overall width of the western promenade is 7.75m. Presuming that the eastern promenade had an equal width, for reasons of symmetry, then the overall reconstructed length of the pool, including the prom-

3. N. Spremo-Petrovic_s work on the basilicas of Illyricum may be dealing with Byzantine monuments but it is referenced in this paper as it summarizes all of the standardized ratios and measuring units of the classical world, which would be followed in Late Antiquity (Byzantine *podes* of 0.288, 0.2957, 0.296, 0.303, 0.3086, 0.308(9), 0.315 and 0.32m.). Her method was tested successfully by D. Chen and J. Wilkinson on ancient basilicas and synagogues of Israel and Palestine.
4. In Jordan, the *Decempeda Pertica* (ten Roman feet) has been traced in the interaxial spaces of the colonnaded Cardo and Decumanus at Jerash (Parapetti 1983-84: pls. IV-VII), the temenos colonnade of the Great Temple in Amman (Kanellopoulos 1994: 15-18) and in the atrium colonnade north of the East Baths at Jerash (Friedland, forthcoming).
5. The ratio 4:9 or the *paramesos* of the ancient musical scale (Eukleides, *Katatome Kanonos* 19, 20; Plato, *Theaitetos* 147C, 148D; Ptolemaios, *Mousika* 27) was a prominent harmonical proportion which was supposed to be represented in the principle dimensions of the Greek temples, in both the ground plans and the elevations – width over length and overall height over width respectively. The stylobate dimensions of the Parthenon itself were a rectangle with a ratio 4:9 for the width and length accordingly; the ratio *lower diameter: interaxial column space* in the Parthenon was again 4:9 (Gruben 2000: 186-188).
6. Note that the width of the Temple of the Winged Lions is exactly four times the doorway opening: 17.42m: 4.36m respectively = 3.995: 1. Thus the façade was designed 1.5 – 1– 1.5 = 4 or 3-2-3 = 8 moduli.
7. The ancient synagogue in Maoz Haim, Galilee, has similarly an internal length of 50 Roman *pedes* with an internal width of 40 *pedes* (Chen 1980: 256-257. Pl. 21, fig.1).



2. Metrological relationships and measurements in pedes, in the Petra Garden and Pool-Complex, with the Hemidiagon of the square superimposed on the rectangle of the garden terrace.

enades, would be 58.86m or 198.85 *pedes*. This figure is suspiciously close to 200 *pedes*. It cannot be precluded that the eastern promenade was not identical with the western promenade, but slightly, wider, by approximately 0.34m, which would, therefore, raise the overall length of the pool to 200 *pedes*. Alternatively, it can be suggested that the length of the pool was designed as 200 *pedes*, but the execution was compromised. The reconstructed width of the pool would be 23.47m, had the island been symmetrically positioned within the former.

The restored overall length of the pool-complex is 1.35-1.36 times the interior length of the pool. The overall width of the pool-complex is 1.29-1.30 times the interior width of the pool. The average 1.33: 1 comes very close to the ratio of integer numbers 4: 3 = 1.333 (rule of the *Epitriton*). The latter are again sides of the Pythagoreian Triangle. It can be tentatively suggested that the pool was designed to occupy, roughly, both lengthwise and widthwise 3 out of 4 parts of the Pool part of the Complex.

The Garden Terrace

The overall interior width (E-W) of the garden terrace, from the eastern wall to the edge of the stylobate of the Lower Temenos is 60.16m. This figure is equal to 203.2 *pedes*. The same width would have been between 58.96 and 59.26m or 199.2 and 200.2 *pedes* (practically 200 *pedes*) when measured between the eastern wall and a wall, which borders the Lower Temenos at foundation level. Thus, it can be proposed that the garden terrace was designed with an interior width equal to 200 *pedes*.

The inner length (N-S) of the garden terrace was measured between 52.84 and 52.98m. The latter figures are equal to 178.5-179 *pedes* (average of 178.75 *pedes*). Possibly the garden terrace was designed with a general length N-S equal to 180 *pedes*, though it is hard to believe that the builders missed an entire pes and a half during the implementation of the original design.

Nevertheless, the ratio width-length would then be 200:180 or 10:9 = 1.111:1. However, the mere proportion of 200:179 / 200:178.75 measured *pedes* equals 1.117:1 – 1.118, a figure which is almost perfectly equal to the *Hemidiagon* of the square, 1.118:1 or W = L:2 x $\sqrt{5}$ (W= width, L = length) (Spremo-Petrovic 1971: 98-100).

Indeed, average Width = 178.75 *pedes*: 2 x $\sqrt{5}$ = 89.37 *pedes* x 2.23 = 199.30 *pedes*.

And: Width = 179 *pedes*: 2 x $\sqrt{5}$ = 89.5 *pedes* x 2.23 = 200.1 *pedes* **(Figs. 1 and 2)**.

The discrepancy of 0.1 *pes* in our calculations is equal to 0.03m.

The Relationship of the Pool to the Garden

The measured overall width (N-S) of the pool-complex, including the East-West Wall, is 30.58m or 103.31 *pedes*, a figure that makes no sense at first glance. As exhibited above, the actual length of the garden terrace is 178.5-179 *pedes*. The ratio of the two is 179:103.31 = 1.732:1, and 178.5:103.31 = 1.728:1, or, in meters, 52.98m: 30.58m = 1.732:1 and 52.84m : 30.58m = 1.728:1, almost perfectly equal to 1.732, the square root of 3 (maximum discrepancy of 2.3 over a thousand). This implies the use of the *Sixton*, and the design of the two parts of the paradeisos by means of an equilateral triangle. The square root of 3 defines the relationship between the side of the equilateral triangle and its height **(Fig. 1)**. The equilateral triangle occurs in the design of Herodian buildings (see 60o of a circle, and hexagons in Jacobson 1999: 70, 73, fig. 4).

Resuming: The width of the garden terrace (E-W) was probably designed as 200 *pedes*, or 2 x 100 *pedes*.

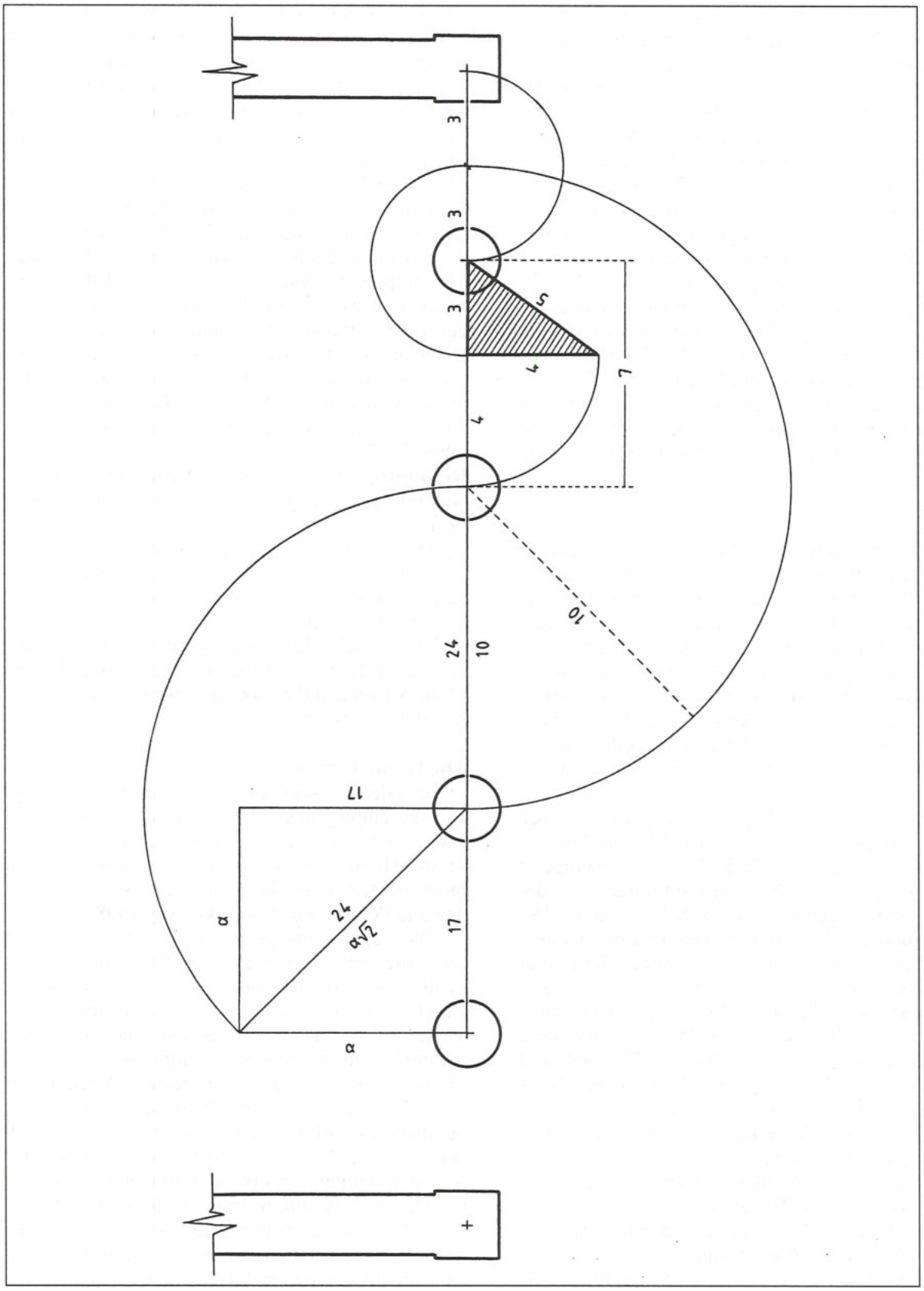
The length of the garden terrace (N-S), derived from its width and the rule of the *Hemidiagon*, depended on the square root of 5 and was defined to be 178.89 (179) *pedes*.

The overall width of the pool-complex was designed on the basis of the equilateral triangle, rule of the *Sixton* and therefore the square root of 3, and was defined as 103.31 *pedes*.

The Great Temple

In order to establish context for our metrology and the employment of Roman *pes* at Petra, it is useful to include the measurements for the portico of the Great Temple, a contemporaneous monument erected immediately to the west of the Garden and Pool-Complex (Joukowsky 1998).

The central interaxial column space is 1.415 times the space-flanking center. This figure is practically equal to the square root of 2 (=1.4142), which relates the side to the *diagon* of the square. Therefore it can be suggested that the intercolumniations of the Great Temple were designed by means of the rule of the *Diagon* (Vitruvius 6, 3.3). This ratio was approximated with integer numbers 24 and 17 (*pedes*) or 10 over 7 moduli **(Fig. 3)**. The Ratio 24:17 which was also used for the intercolumniations of the Parthenon, represents the *Mesos Harmonikos Analogos* between "spaces" 3: 2 and 4: 3, i.e., between the *Hemiolion* and the *Epitriton* (Plato, *Epinomis* 991 A). Aproportion of 24 *pedes*: 17 *pedes* (= 2 times 12:17) is composed



3. The rule of the Diagon of the square and the variation in the interaxial column spaces of the Great Temple. Spaces are also represented from center to corner with 10, 7 and 6 moduli.

of two Pythagoreian figures (17 and 12), which constitute an integer approximation / expression of the *diagon* of the square. These belong to the Pythagorean series 1: 1, 3: 2, 7: 5, 17: 12, 41: 29, 99: 70, 239: 169, etc. (Theo Smyrnaeus, *Expositio rerum mathematicarum et legendum Platonem utilium* 43, 44).

The above tables yield good results and establish the use of the Roman pes with an average discrepancy of 0.3 % or 3 over a thousand.

***Table 1**: Great Temple. Measurements of intercolumniations, in meters, moduli and pedes (each = 0.296(5)m).*

	Central interaxial spacing	Interaxial spacing flanking center	Corner interaxial spacing
Measured dimension	7.15	5.05	4.28
Roman *Pedes*	24	17	14.45
Moduli	10	7	6
Calculated dimensions in *pedes*	7.116	5.040	4.27
Discrepancy %	0.5%	0.2%	0.23%

***Table 2**: Great Temple. Ratio central interaxial spacing: interaxial spacing flanking center Diagon of the square: side of the square = Square root of 2 = 1.414*

Measured dimensions	7.15: 5.05 = 1.415
Calculated dimensions in *pedes*	7.11: 5.04 = 1.410
Roman *Pedes*	24: 17 = 1.411
Moduli	(5: 7 =) 10: 7 = 1.428
Calculated dimensions in moduli:	7.11: 4.98 = 1.427

***Table 3**: Great Temple. Ratio central interaxial spacing: corner interaxial spacing.*

Measured dimensions	7.15: 4.28 = 1.670
Calculated dimensions in pedes	7.11: 4.27 = 1.665
Roman Pedes	24: 14.4 = 1.666
Moduli	10: 6 = 1.666
Calculated dimensions in moduli:	7.11: 4.26 = 1.666

The corner interaxial column space was represented by 6 moduli, while the interaxial space flanking center with 7 similar moduli[8] and the central space with 10 such moduli. In our opinion, the narrower corner intercolumniations could be evidence for the angle contraction of a Doric order (Vitruvius 4. 3. 1-2; Coulton 1977: 61-63) and therefore, evidence for the restoration of a Doric entablature-, triglyph frieze above the Corinthian columns. If so, the Great Temple would bear similarities with the neighboring and also *tetrastyle in antis* Corinthian-Doric Qaṣr al-Bint.

As such, the variation in the spans can be combined with the hypothetical arrangement of 4 triglyphs and metopes above the wider axial intercolumnium and with 3 triglyphs-, metopes over the other intercolumnia. Strangely, the actual ratio of *interaxial column space* (center): *interaxial column space adjoining center* in the Great Temple is deliberately 1.41:1 and in Qaṣr al-Bint is almost identical, 1.40:1 (8.00m: 5.72m ±), close, but not quite equal to 1.333: 1, the ratio of the corresponding 4 triglyphs: 3 triglyphs above the two spans respectively[9].

Conclusions

It was shown above, with all reservations, that the Roman *pes* was employed in the design of the Petra Garden and Pool-Complex. Also, it has been demonstrated that the Roman measuring unit was applied in the design of the adjacent and contemporaneous Great Temple, combined with the rule of the *Diagon*. Incidentally, the plan of the Lower Temenos, as shown by Zimmerman (2000: 39) was designed by means of the *Hemiolion* (3: 2). Jacobson's theory on the application of the Equilateral triangle (rule of *Sixton*), the Pythagorean triangle, and the employment of simple integer numbers and Roman feet in Herodian architecture finds good parallels in the Garden and Pool-Complex of Petra.

However, it is noteworthy that Qaṣr al-Bint, a building of an earlier date, was designed with a different measuring unit. Despite the obvious resemblance between the two large *tetrastyle in antis*

8. 7:6 was again an ancient basic proportion which defined the length of the Royal Egyptian cubit (0.5236m) over the Common Egyptian cubit (0.4488m). Büsing 1982: 3, 4 and footnotes 5, 8. For the employment of numbers 6 and 10 during the Roman period, and the Vitruvian explanation, see Jones 1989: 60, also Jacobson 1999: 71.
9. The so-called Royal Palace east of the Temple of the Winged Lions and almost across from the Pool Complex has a *tetrastyle in antis* façade with measured interaxial column spaces of 5.05m (center), 3.72m (flanking center) and 3.35 (corner) _†with column diameter of 1.25 + m and anta width of 1.15m. Again, the narrower corner intercolumniations could indicate the angle contraction caused by a Doric _ triglyph frieze. The capitals, which are collapsed within the pronaos are, similarly to Qaṣr al Bint, Corinthian. In the instance of the "Royal Palace" the ratio of the *central interaxial column spacing: interaxial column spacing flanking center* comes close to 1.35:1, thus corresponding well to the ratio of 4 triglyphs over 3 triglyphs (1.333:1, a virtual *Epitriton*) above the two spans respectively.

Corinthian–Doric buildings, Qaṣr al-Bint was designed with the use of the Egyptian long cubit (Dentzer-Feydy 1995; Zayadine, *et al.* 2003 and personal communication with Dentzer-Feydy) while the Great Temple seems to have been designed with the Roman *pes*.

The employment of 50 *pedes* in the principle dimension of the pool's island-pavilion finds at least three other diachronical parallels in the city center of Petra: The Staircase of the Upper Market[10], the Small Temple[11], and the Petra Church[12]. A width of 50 *pedes* (and later, *podes*) provides an optimum span for the woodwork of the roofs, which can then be divided conveniently in three aisles. It may as well not be a coincidence that instead of designing a building with an approximate length or width of 50 *pedes*, one started by designing it to be exactly 50 *pedes*[13]. Possibly, this implies that the architects often designed in scale 1: 50. In this instance the length or the width of the buildings may have been represented on the drafting board with one foot, with the rest of the work done with a compass. Accordingly, the width of the garden terrace, which is practically equal to 200 *pedes* should recall the 1:200 scale, a scale suitable for the basic design of such a large piazza, which lacks any details.

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10. The staircase of the Upper Market, which is dated by Fiema (1998) to the first decades of the second century AD, is 14.66m-14.78m. wide. The latter figure is practically equal to 50 *pedes* (= 14.80m); see in Kanellopoulos 2002.
11. The cella of this building is almost square, measuring 16.3m exterior width and 13.2m. interior length/width, with walls approx. 1.5m thick. I owe this piece of information to personal communication with Sara Karz Reid. The former dimension is 55 Roman feet and the inner dimension 45 such units. Therefore, the axial width (and length) of the cella equals 16.30m–1.50m (wall thickness) = 14.80m. The latter figure equals exactly 50 *pedes* of 0.296m each.
12. Incidentally, the inner width of the Petra Church was again, 50 Byzantine *podes* of 0.3089m each. Kanellopoulos 2001: 162-164. For the latter *pous*, see Spremo-Petrovic 1971: 127.b; Chen 1990: 352.
13. The sanctuary of the Temple in Jerusalem was 100 cubits by 50 cubits (Ezekiel 43: 13-14).

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