Photogrammetric Work at Petra, 1965 - 1968
an Interim Report

by
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I. INTRODUCTION

From the very beginning of the excavations begun at Petra in 1958 by the British School of Archaeology in Jerusalem it was apparent that none of the exisiting topographic maps of the site was sufficiently accurate either to give a true idea of its size and configuration or to provide a basis for locating the various operations being carried out by the expedition. Thus, for example, the maps of Brünnow and von Domaszewski [1] and of Dalman [2] exaggerated the width of the site from east to west by almost 50%, and gave only an impressionistic idea of its topography, while Musil's[3] was equally impressionistic, though more accurate. Kennedy's map, [4] traced from aerial photographs and therefore reasonably accurate with regard to dimensions, was not contoured and showed only the wadi courses; the map of Horsfield and Canaan [5] relied on Kennedy's for its dimension and was provided with sketched from-lines which, although useful for the indication they gave of the surrounding terrain, were quite inadequate for the central part of the site where the ancient city lay. All these maps, moreover, were at a fairly small scale, ranging from approximately 1: 29,000 (Kennedy) to 1: 10,000 (Brünnow and von Domaszewski). The excellent plan of the central area published by Bachmann and his colleagues [6] was also only provided with sketched form-lines. The shortcomings of the previous survey were particularly revealed in 1964, when an investigation was begun of the Petra town walls. In that year a detailed ground survey was made of the surviving stretches of these walls, the work being conducted by Messrs. Peter Fordham and Ian Robertson of the Architectural Association in London. In addition, excavations (supervised by Mrs. Crystal Bennett, Mlle. Dominique Auscher, and the late Mr. Rafik Dajani) were made at a number of places along the lines of the northern walls, in order to establish their chronology. [7] From this work it

(1) R. E. Brünnow & A. Von Domaszewski, **Die Provincia Arabia,** Band I Strassburg (1904) Beilagen.

(2) G. Dalman, **Petra and Seine Felsheiligtümer** Leipzig (1908), map at end.

(3) A. Musil, **Arabia Petraea,** II (Vienna 1908), map at end.

(4) Sir Alex Kennedy, **Petra, its History and Monuments** London (1925), map following p. 18.

(5) **Quarterly of the Department of Antiquities of Palestine,** VII(1938), Plan A

(6) W. Bachmann, C. Watzinger, Th. Wiegand. Petra (**Wissenschaftliche Veröffentlichungen des Deutsch-Türkischen Denkmalschutz-Kommandos** Heft 3), Berlin (1921). Beilage 1.

(7) For a preliminary note on this work see **Révue Biblique** LXXII, (1965) pp. 254-256.

became clear that the intentions, methods and achievements of the Nabatean military architects could only fully be appreciated by considering the walls in close relation to the local topography, and that to this end an accurately contoured map of the site was essential. The obvious way to obtain such a map was by the use of stereoscopic aerial photographs, which fortunately were already available in the form of the 1:25,000 cover taken for the Jordanian Government in 1953 by Hunting Aero Surveys Ltd. This photography had already been used by Huntings for the preparation of a map of part of East Jordan, but unfortunately the area of Petra, although photographed, had not been included in the mapping. Despite the fact that they were at too small a scale to show archaeological detail and had been taken several years before the clearance of the central part of Petra had been initiated (in 1954) by Miss D. Kirkbride for the Department of Antiquities, the photographs were of excellent quality for topographic plotting. In June 1965 permission was granted by the Jordanian authorities for the British School to use the photographs for the purpose of producing a contoured map of the site. The original plotting was done in the latter part of the same year in the Department of Photogrammetry and Surveying at University College London, and additional information was added in 1968 from terrestrial photogrammetric survey. The final drawing of the map, incorporating the expedition's plan of the town walls and Bachman's plan of the ruins in the central area, was completed in February 1971, and is published here for the first time. Some account of the technical aspects of the work appears below, in Part II of this article.

The success of this application of photogrammetry to the archaeological investigation of Petra, and above all the support which the Department of Photogrammetry and Surveying at University College London gave to the project, prompted a further excursion into this field, namely a survey of the rock-cut architecture. Although this architecture has never come within the British expedition's terms of reference, no one concerned with the site or with Nabataean history and culture in general can but be aware of the need for accurate detailed drawings of the Petra facades. Before 1968 the only published measured elevations of rock-cut monuments were those of the Khazneh made by Newton [8] in 1910, prepared at 1:50 and published at approximately 1:200, and that of the Garden Tomb (Br. 644), made by Bachmann [9] and also published at approximately 1:200. Drawings of the Khan (Br. 4) near the entrance to the Siq are said to have been made by P.C. Hammond in 1959 prior to its conversion into the Government Rest House, but have not been published so far as the writers are aware. As for the other monuments, students concerned with a comparative

(8) G. Dalman in the **Annual of the Palestine Exploration Fund**, I, (1911).

(9) W. Bachmann et al, **op cit** Abb. 75. Bachmann also published measured sections (but not elevations) of the Tomb of the Roman Soldier (Br. 239) and the Triclinium opposite it (Br. 235).

study of their architecture have been forced to rely on the drawings published by Brünnow and von Domaszewski and it is these which still provide the basis for discussion of Nabataean rupestrian architcture, as for example in the recent books of Browning [10] and Lyttleton. [11] Although these sketches undoubtedly provides a reasonably accurate idea of the general style of the façades, they are not based on precise measurement and are sometimes very erroneous with regard to scale and proportion, as, for example, in the case of the Khazneh, as Dalman points out. [12] Moreover, von Domaszewski's drawings often omit important detail, for example the relief busts on the attic pilasters of the Urn Tomb (Br. 772) [13], while moulding are never shown except in stereotyped fashion and at far too small a scale to be really informative. In this connection it may be remarked that it is most unlikely that the mouldings used in Nabataean architecture showed no stylistic development during the course of time, and the minor variations of profile should in theory be as useful a guide to the chronology of the monuments (a controversial issue at Petra, be it remembered) as they have proved to be at other sites. [14] As for architectural scale and proportion, these have been demonstrated on many occasions to be not only indicative of the chronology of monuments but also - and perhaps more importantly - to be indicative of the aesthetic sensibility and so, it may be supposed, of the psyche of the architects and their clients. In short, it would seem that further progress towards establishing the chronology of Nabataean architecture and towards understanding the Nabataeans themselves through that architecture can only come from a more detailed study of the surviving remains, and that as a first step in this direction an accurate and minute record of the Petra façades is essential.

The application of photogrammetric methods in 1968 to achieve this end was frankly experimental. To have measured and plotted a significant number of the facades by more conventional methods would have involved months of labour, much of the time being spent on erecting and dismantling scaffolding, not easy to obtain locally and not always feasible on account of the terrain in which many of the monuments are situated. Even Newton, using a ladder on the Khazneh, was unable to reach the entablature of the upper storey of this monument. [15] Although it was recognised that the difficult terrain would make the siting of camera positions no simple matter either, it seemed clear that photogrammetry would speedily provide at least the basic data for accurate elevations of the façades, and might also be useful in recording inaccesible decorative features such as mouldings and reliefs. Some further discussion of these points is given

(10) Iain Browning, **Petra** London (1973).
(11) M. Lyttleton, **Baroque Architecture** in **Classical Antiquity,** London, (1974).
(12) Dalman, **Annual of the Palestine Exploration Fund** I, (1911), pp. 96-70.
(13) For the discovery of these, see P. J. Parr, **Palestine Exploration Quarterly** (1968), pp. 10-11.
(14) See, for example, the discussion of the Dura-Europos mouldings by Lucy T. Shoe, **Berytus** IX/1 (1948) pp. 1-40.
(15) **Ann. Pal. Expl. Fund,** I, (1911) p. 106.

below, in Part III of this report, while technical details appear in Part II. [16] The pilot scheme, of two weeks, duration in the late autumn of 1968, resulted in the photography of about a dozen facades, including the Khazneh (Br. 62), the Urn Tomb (Br. 772), the Tomb of the Roman Soldier (Br. 239), and others, representative of all the major types. The work of plotting the data obtained has not yet been completed, and only a small selection of some of the results can be presented here.

The full publication of this photogrammetric research will form part of the final report of the British School's activities at Petra between 1958 and 1968. It was originally envisaged that, following the pilot scheme, a more comprehensive photogrammetric survey of the Petra monuments might be carried out under the same auspices. However, in December 1969 a similar, and quite independent, scheme was set in motion by an expedition of the French National Geographic Institute (IGN) financed by UNESCO, apprently quite unaware of the topographic and architectural photogrammetry done by the British expedition during the preceding years. [17] It is hoped that the IGN and UNESCO will find it possible to continue this work and that a complete survey of Petra will one day be achieved.

II. TECHNICAL ASPECTS

The derivation of quantitative information from photographs involves the use of photogrammetric principles which are essentially similar for aerial and terrestrial surveys. There are important practical differences arising from the larger scales of terrestrial photographs and from the limitations which are imposed by most photogrammetric plotting instruments.

All the photogrammetric measurements concerned with Petra resulted from stereoscopic observation of overlapping pairs of photographs. Two photographs, comprising a stereopair, are viewed at any one time in a photogrammetric plotting instrument. The instrument incorporates an X, Y, Z system of axes which allows three dimensional co-ordinates within the stereoscopic model to be recorded after the correct orientation procedure has been accomplished. Alternatively the positions of a reference or measuring mark can be recorded graphically on the plotting table of the instrument, usually in the form of the plan details and contours which are familiar on a topographic map.

Before any measurement or plotting can be carried out, it is usual to complete a three-stage orientation process. Inner

(16) A brief technical account (by K.B.A.) of the photogrammetric work on the façades has been published in the **Photogrammetric Record** VI, No. 34 (October 1969) pp. 357-378, while reports have been represented at the Royal Photographic Society's symposium on 'Photography in Archaeological Research' London, December (1970), and at a joint meeting of the Society of Architectural Historians of Great Britain, held at Cambridge in August 1973. A reproduction of the elevation of the Khazneh, plotted from photogrammetric data, appeard as the cover illustration of **Photogrammetric Engineering,** Vol. 37, No. 8. (August 1971).

(17) So far as the writers are aware an account of this work has only appeared in the form of duplicated IGN and UNESCO reports, with limited circulation.

orientation of the photographs establishes the internal geometry of each picture and should present no problems when calibrated cameras are used. Relative orientation brings one photograph of a pair into its correct position and attitude with respect to the other photograph. This involves the removal of what is called y-parallax from the stereoscopic model as viewed in the plotting instrument. The third phase of absolute orientation means relating the relatively oriented model to control so that its scale and azimuth are known and so that real height or depth differences can be determined.

1. The map of Petra

The contour map of Petra (fig. 1) and the surrounding area was prepared from air photography in 1965. The original plotting scale was 1:2500 and archaeological information has been added, including the positions of tombs which have been derived from terrestrial photography taken during fieldwork in October and November 1968. Only the positions of the largest tombs can be plotted from air photographs as the vertical façades do not appear unless the tombs are particularly conspicuous and are located well away from the centre of the photographs. All the terrestrial photographs used to supplement the map were taken with a Wild phototheodolite, and plotting was carried out on a Wild A5. Plotting from the air photographs was carried out on a Thompson Watts Mark II.

There is no doubt the availability of this map marks a significant step forward in the study of Petra. The accuracy of the document should be sufficient for most users, but certain deficiencies should be noted. These derive from the use of air photographs, the scale of which (1:25,000) was really too small for plotting a map at this scale. In addition, proper ground control was not available for a thorough absolute orientation so that the contours could not be related to sea level and given real height values. Consequently, users of this map should anticipate a possible scale error in plan dimensions, though this should be very small. More significant will be arrors in height information if widely separated areas are compared in this respect.
this respect.

2. The Façades

The larger individual tombs were usually photographed with a Wild phototheodolite and smaller tombs and aspects of detail with a Galileo-Santoni stereometric camera. The phototheodolite consists of a single camera mounted with a theodolite so that camera directions may be determined and control for plotting may be conveniently observed. The stereometric camera is really a pair of cameras fixed to the ends of a rigid bar and pointing in parallel directions. In theory, less control is necessary if the camera axes are parallel and the camera separation is known. In practice, it is advisable to include extra control as a check. On some occasions it was preferable to use one camera of the stereometric pair for photography from separated camera stations and in such cases control measurements were made independently.

Plotting of details of the tombs is of three types. (Fig. 2) shows the doorway to the southern side chamber of the

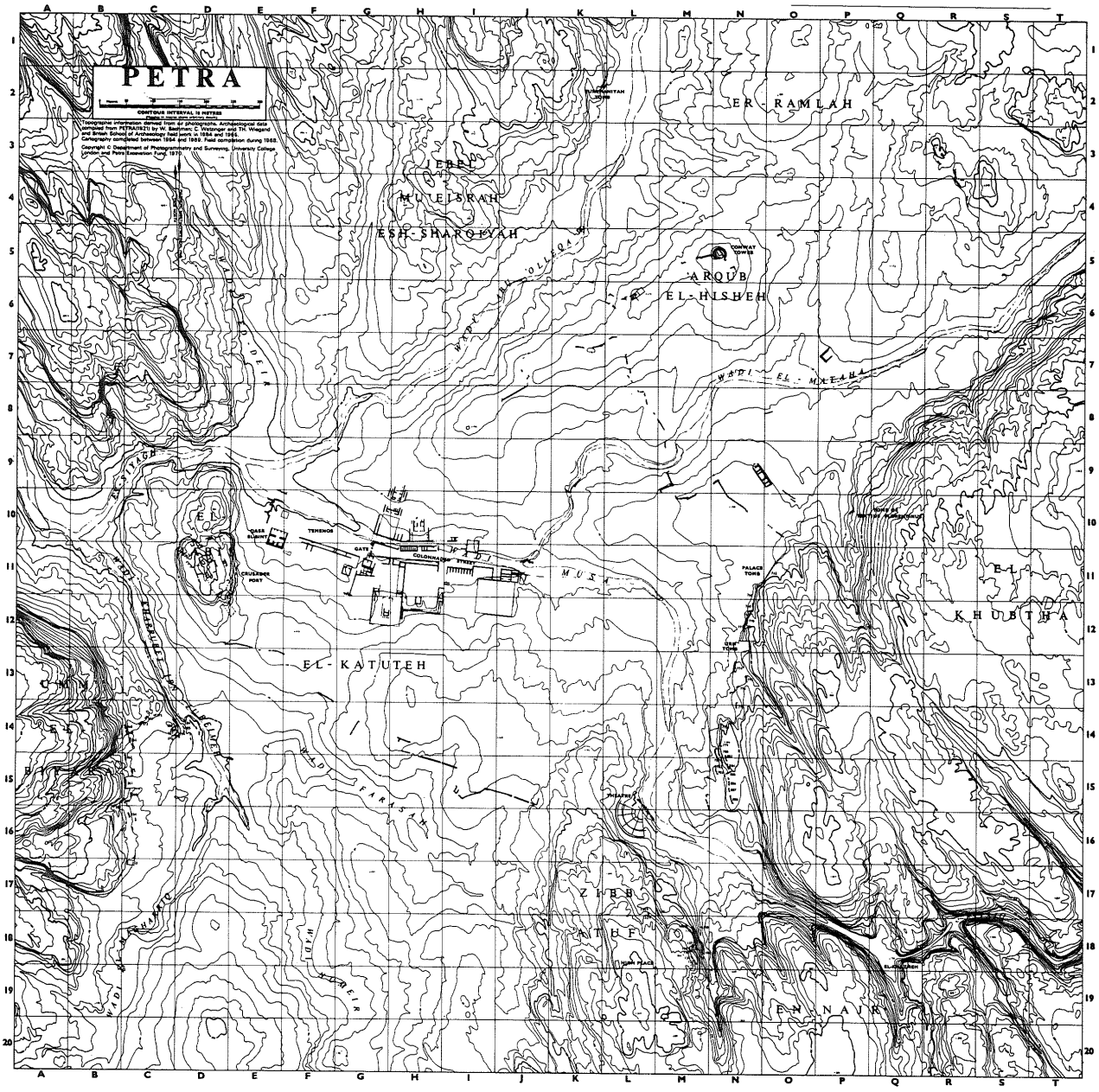


Fig. 1 : Map of Petra

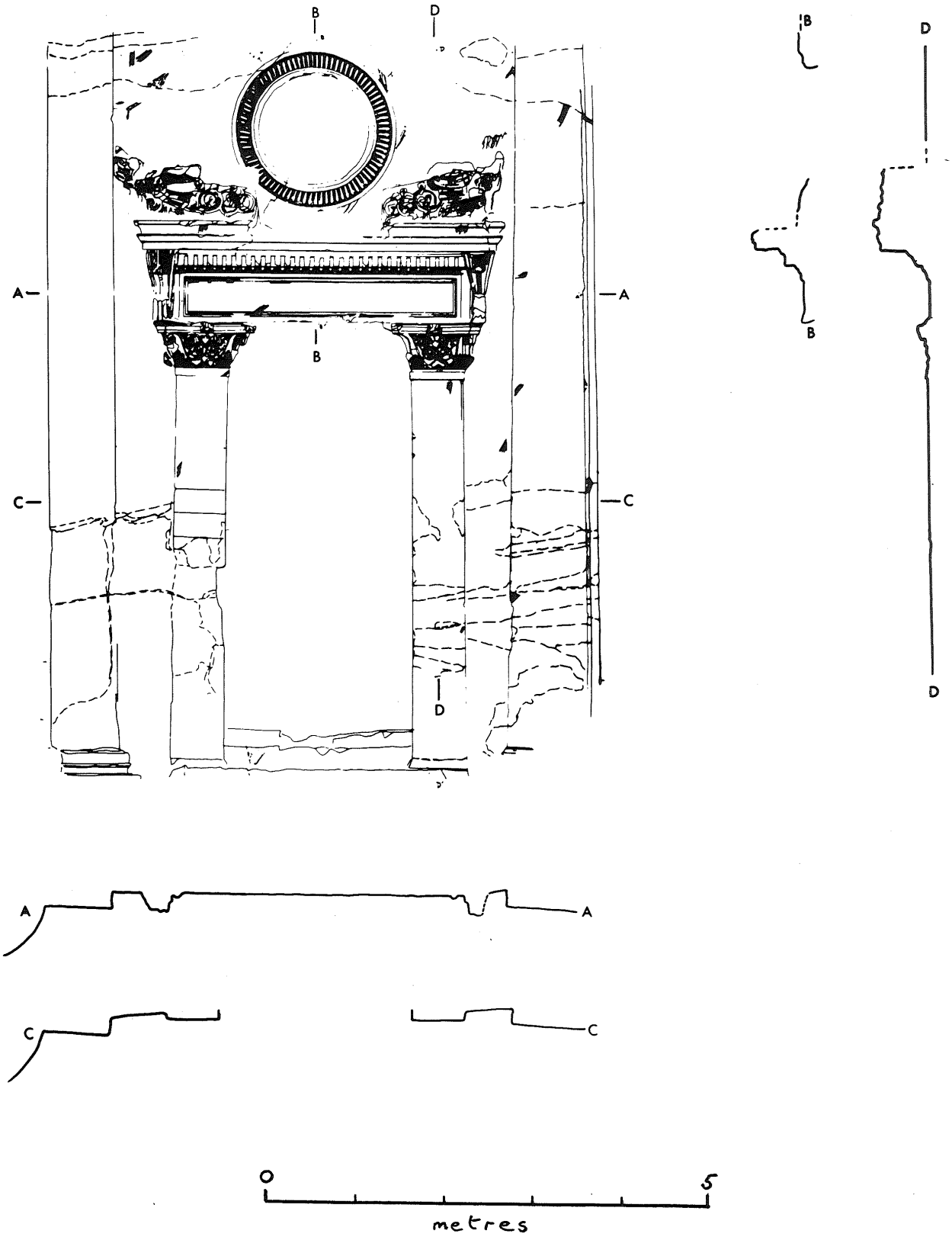


Fig. 2 : Treasury. Doorway of chamber on southern side of Vestibule

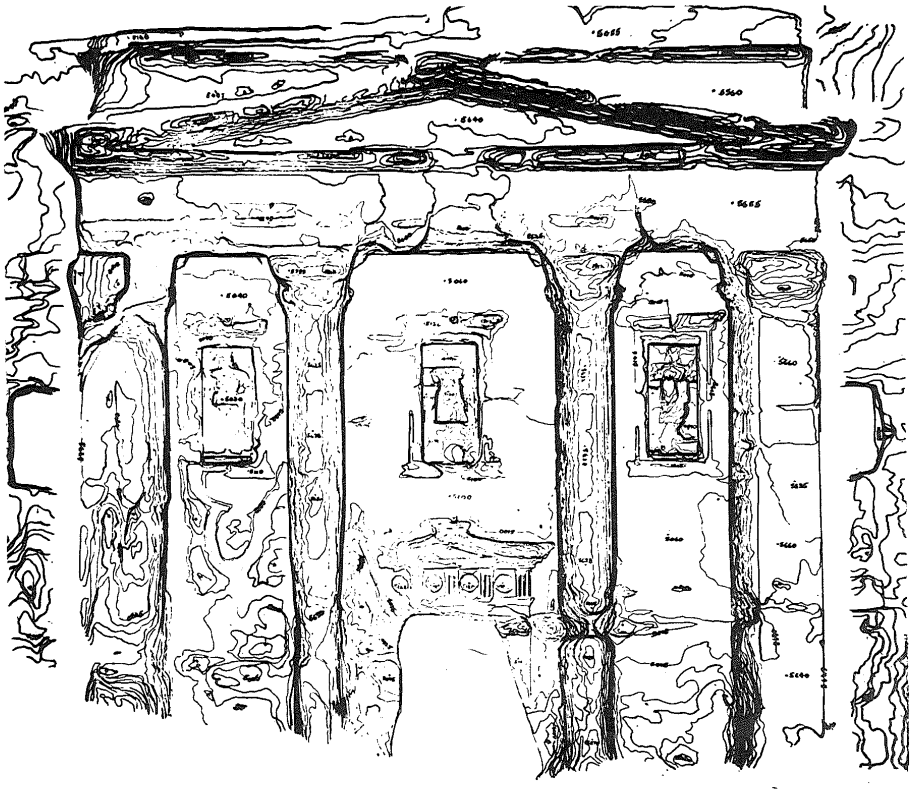
vestibule of the Khazneh (Br. 62). In this example the architectural features are well preserved, and plotting firm detail in elevation (from Galileo-Santoni camera photography on a Thompson-Watts Mk II) provides the most suitable method of presenting a record of the architecture. The original plotting scale was 1:25. The only drawback to the photogrammetric derivation of a measured drawing is that certain areas cannot be photographed because of protruding masonry. The main advantage is that measurements have an overall sympathy which it is extremely difficult to obtain by other means.

Plotting the elevation was carried out in a way which is analogous to mapping the ground from air photographs, though in this instance the datum plane was vertical instead of horizontal. The camera axes were inclined by $+12^{\circ}$ during photography and that inclination was set on the plotting instrument ($=0.20944$ rad) so that the elevation was plotted with respect to a vertical plane. Information on relief was then provided by means of sections A,B,C and D which correspond to the positions indicated on the elevation.

Some plotting instruments are provided with auxiliary devices which enable sections or profiles to be drawn directly. These have been developed because of their usefulness in engineering surveys. As the Thompson-Watts Mk II does not have this facility as a standard feature, it was necessary to use an alternative method of profile drawing. The desired section lines follow either the X or the Y co-ordinate axes of the plotting instrument and the instrument used was fitted with automatic co-ordinate registration equipment. Consequently a series of points along any particular section line was recorded on paper tape which, with a suitable computer programme, could be used as input for a computer-drawn section at any desired scale. If the section line dose not follow one of the instrument axes but is in an arbitrary direction, two instrument operators can maintain that arbitrary direction provided that one opserves the photographs while the other controls the direction of observation though the plotting table controls. An additional computational step is then necessary to relate distance along the profile to be the recorded co-ordinates.

In many instances the tomb facades at Petra are heavily eroded, and in such cases the satisfactory plotting of elevations becomes more difficult. The elevation of the Tomb of the Roman Soldier (Br. 239) on (fig. 3) is an example of this kind. That part of (fig. 3) which shows only firm detail is not very informative, but the lower part of the figure, showing contour lines joining points of equal depth (isometrons) at 25 mm. intervals, seems a much more useful form of representation. Additional survey control was provided on the site itself. Plotting of the Wild phototheodolite photography was carried out on a Wild A5.

It is appropriate to include a note on the accuracy of drawings produced by photogrammetric methods. Provided that suitable control is provided, then overall dimensions are extremely reliable. Difficulties arise over points of detail when erosion, differences of lighting or the



0 10

metres

Fig. 3 : Tomb of the Roman Soldier - detail
Tomb of the Roman Soldier - contours

obscuring of vision from one camera station may cause either misinterpretation or complete coverage. Reference has already been made to such unavoidable gaps. There are also features, such as columns, pillars and statues, which are extremely difficult to draw in two dimensions. An elevation which contains features like these will include areas which have been plotted to varying standards of accuracy. This difficulty cannot be avoided but, provided that these short-comings are appreciated, the photogrammetric method will provide an excellent consistency in dimensions which could not be measured directly, either because they are so numerous or because they are inaccessible.

III. DISCUSSION

1. The Map

Apart from its primary purpose of recording the natural topography of the Nabataean capital, the chief archaeological importance of the contour map lies in the information it provides concerning the nature and positioning of the town walls. Dalman seems to have been the first to show fortifications on a plan of the site, namely a southern wall running in an approximately straight line from the southern end of el-Habis to the mountains behind the theatre, and a northern wall running parallel to this from the Wadi Abu 'Olleqah to near the Palace Tomb. Owing to the errors of scale already noted on Dalman's plan, the size and shape of the intramural area as planned by him are grossly inaccurate. Horsfield improved on Dalman as regards scale, and also added considerable further detail to the plan of the fortifications, showing two lines (a 'First Wall' and a 'Second Wall') on both the north and south sides of the town. Both Dalman and Horsfield show the walls as continuous lines, the implication being that they are traceable on the ground throughout their entire lengths. This is certainly not the case today, and it is doubtful whether is was ever so. The 1964 ground survey revealed only disconnected stretches of walling along the presumed lines of fortification, and in many cases there was no certainty that even these were in fact parts of a defensive system. Horsfield's *'First Wall'* on the northern side of the site and his *'Second Wall'* on the southern were particularly hard to define. A full discussion of the evidence, including the results of excavation and the evidence for dating, must await final report of the British expedition's work, but a few remarks concerning the course of the defensive walls are in order here.

(a) **The southern walls.** Isloated stretches of substantial walling are discernible on the ground across the southern part of the site, between grid squares D12 and J15. The best preserved fragments are in H-J15, where the longest continuous stretch (including a short break in J15 which is almost certainly a postern gate) is some 140 m. long. Further west the fragments become shorter and the gaps between them correspondingly greater. Despite their massive nature it is by no means certain that all of these wall fragments are parts of a fortification; some could equally be parts of terrace walls or of large buildings, and only excavation can settle the point. However, the fragments plotted do

in general follow the natural line of defence on the south side of the city area, overlooking the Wadi Farasah, and there is every reason to believe that this line would have been fortified at some stage in Petra's history. These stretches of wall are cleary the basis for the line shown on Dalman's plan and for Horsfield's *'First wall'*. As for his *'Second wall'*, higher up the slope, there is nothing on the ground which convincingly testifies to its existence today; the short pieces of walling approximately on this line are much more likely to be of a non-military nature, and are not shown on the new plan.

(b) **The northern walls.** Horsfield shows two walls on the northern side of the site. His *'First wall'* follows the crests of Qabr Jumei'an and 'Arqub el-Hisheh as far as the *'Tower Sanctuary'* (or 'Conway High Place'), where it turns through 90° to run down to the Wadi el-Mataha. This it crosses by means of a great re-entrant angle, before making its way to the eastern cliffs below el-Khubtha, just beyond the tomb of Sextius Florentinus. Horsfield's *'Second wall'* follows a shorter line, from a point on Qabr Jumei'an where it supposedly branches from a tower on the *'First Wall'*, straight across the Wadi el-Mataha to the cliffs near the Palace Tomb.

One of the most important results of the recent work on the northern town walls by the British expedition has been to show that Horsfield's First and Second Walls are not connected, there being no bifurcation on Qabr Jumei'an. There are, instead, two separate defensive systems which, for the sake of convenience, may be called the Inner and the Outer Walls.

The Outer Wall. The logical point to begin a description of the Outer Wall is with the so-called Tower Sanctuary or Conway High Place (grid square N5), which, as the writer has shown elsewhere, [18] is a massive fortification (and so better termed the Conway Tower) guarding the routes into Petra from the north along wadis on either side of the er-Ramlah ridge. A fine stretch of town wall some 19 m. long, exposed first by Horsfield in 1929 [19] and systematically excavated by the British expedition in 1964 (Plate XI), joins this tower on the south west, and further in the same direction various masonry fragments and rock cuttings permit the restoration of an *'indented trace'* fortification. [20] At a point about 60 m. from the Conway Tower, however, the evidence ceases, and there are no indications of a wall running (as Horsfield supposed) further along the crest of 'Arqub el-Hisheh. Where excavations have been carried out along this crest (Trench V, in grid square L6) the structures exposed are entirely of a domestic nature. Moreover, further still to the south-west, in square L7, excavation has also shown that his First Wall does not sxist, and that there is no junction of First and Second Walls. It thus seems certain that there is no town wall along this ridge except in the immediate vicinity of the Conway Tower. Before discussing the implications of this it is advisable to look at the situation on

(18) **Révue Biblique** LXIX, (1962), pp. 64-79.
(19) **Q.D.A.P.** VII, (1938), pl. xiv/2.
(20) **Révue Biblique,** LXIX (1962), planche 1, and pp. 68-69, 74-75.

the other, south-eastern, side of the Tower.

Although there is today no town wall adjacent to the Tower on the southeast side comparable to that on the southwest, surface indications make it clear that such a wall originally existed, at least as far as a small bastion on the very adge of a rocky scarp some 25 m. from the Tower. [21] South and south-east of this bastion, on the precipitous slopes of the Wadi el-Mataha and its northern branch the Wadi en-Nasara, there are no surface remains, either in the shape of masonry or of rock-cut foundation trenches, to support Horsfield's postulation of a *'First Wall'*. (As we shall see below, the re-entrant angle shown by Horsfield as belonging to his *'First Wall'* actually belongs to our *'Inner Wall'*). In grid square P7, in the angle formed by the confluence of the two above-mentioned wadis, there are the remains of part of a large rectangular structure, at least 30 m. long, while on the opposite side of the Wadi el-Mataha, in squares N-09, are more massive walls, some of them belonging to another rectangular structure (observable dimensions c. 50 x 20 m.) consisting of two long parallel walls with a series of cross-walls. None of these structures and wall fragments seems to be precisely on the line of Horsfield's First wall, but it is possible that they formed the basis of his plan.

From the above account it wall be seen that the surviving remains of the Outer wall are by no means so obvious on the ground or so continuous as Horsfield's plan suggests. In Fact, the only undoubted fortifications in this part of the site are the Conway Tower itself and its immediately adjacent curtain walls and bastions, on the very summit of 'Arqub el-Hisheh, and the problem now arises of the nature of the defensive system into which this Tower complex fitted. A wholly satisfactory solution to this problem is impossible without further survey and excavation, but some suggestions might tentatively be made.

The site of Petra has, very obviously, been subject to enormous erosion since its abandonment; the fact that the defensive walls on either side of the Conway Tower are traceable in part only by means of their rock-cut bedding trenches is testimony enough. It is possible, therefore, that a town wall did originally exist east of 'Arqub el-Hisheh on approximately the line of Horsfield's First Wall, from the Tower to a point near the tomb of Sexitus Florentinus. The slopes it would have traversed are steep and are exposed to the violent winds and rains which are common in Petra; all traces of a fortification wall might easily have been removed. Even so, it is not easy to explain why, had there originally been a wall on this line, there are not more convincing signs of it in the Wadi el-Mataha itself or on the less steep ground in front of the Florentinus tomb, especially in view of the fact that (as we shall see) remains of the Inner Wall (Horsfield's Second Wall) are well preserved on similar terrain further south. Final proof of the validity, or otherwise, of this stretch of Horsfield's *'First Wall'* can only come from

(21) **Ibid.** especially pp. 72-74.

excavation, but on present evidence it seems possible, even probable, that a continuous wall as shown by him never in fact existed.

To the west of the Conway Tower the position is different. As we have argued, there is no evidence for a town wall on the crest of 'Arqub el-Hisheh except in the immediate vicinity of the Tower, and the surviving depth of deposit is enough to prove that erosion cannot account for its absence. A possible solution is that the twon wall here followed a line comparable to that which Horsfield postulated for the wall south-east of the Tower; namely, directly (or, more probably, diagonally) down the north-western slope of the ridge towards the bottom of the Wadi Abu 'Olleqa and so to the cliffs at the foot of Jebel Mu'eisrah esh-Sharqiyah. There are one or two indications on the ground that this may have been the case. At various points on the slopes, especially in grid squares K-L 5-6 but elsewhere also, there are fragments of walling substantial enough to be defensive, while in square K 4-5, in the bed of the wadi, there are massive foundations of a building which, though too obscure to be planned in detail, might well be a fort or gate-tower. However, the doubts that have been expressed concerni ng the line of the outer wall east of the Conway Tower, apply here on the west also; the fragments of wall in squares K-1 5-6 could as easily be terrace walls as fortifications while the structure in K 4-5 seems more likely an isolated feature than part of a continuous defensive system. In short, on neither side of the Conway Tower is there clear evidence for a continuous line of fortifications, and it seems possible that this Tower, with its flanking curtains and bastions, is simply an isolated strongpoint, crowning 'Arqub el-Hisheh, and relying on its dominating position to defend the northern approaches to an otherwise (at this period) unwalled city. On this theory, the steep western and eastern slopes of the Hisheh ridge would have provided a sufficiently effective natural barrier for much of the distance across the northern part of the Petra basin. The two wadi beds (Abu 'Olleqah and el-Mataha) would have been obvious weak points, however, and would have required special treatment, and it may well be that the massive structures visible in grid squares L 4-5 on the one side and in P7 and N-0 9 on the other, are the remains of isolated redoubts similar in function (though not in plan) to be the Conway fortification.

It is worth nothing at this point that a similar situation may have pertained on the southern limits of the city where, as we have mentioned, the recent field work has also failed to reveal convincing signs of two continuous lines of fortification (above p. 40).

In this connection it will be remebered that Horsfield records [22] the presence in the bed of the Wadi es-Siyagh west of el-Habis (in approximately grid sq. A 9-10) of an isolated *' fort '*, in precisely the same relative position to this route into Petra from the south and west as the structures we have described in grid

(22) **Q.D.A.P.** VII, (1938), p. 4.

squares K 4-5, P7 and N-0 9 are to the northern routes. There is, of course, no evidence that the Siyagh fort and the northern 'redoubts' are contemporary with one another or with the Conway Tower, but it is at least a possibility.

If this interpretation is correct, then at the time of the Conway Tower the Petra basin was defended by a system of individual redoubts located at strategic points controlling the natural approaches to the site. The Conway Tower itself was one such redoubt, though with the addition of short stretches of curtain walls and secondary bastions, forming as it were 'wings' to the Tower, which no doubt gave added protection to the defenders. Certain features of these curtains and bastions, in particular their '*indented trace*' and their method of construction in short unbonded sections, have been mentioned on a previous occasion [23] as being in the tradition of Hellenistic military architecture, and in the final report further analogies will be adduced to show that the idea of defending a site not by continuous walls but by isolated watchtowers and strongpoints is also typically Hellenistic. The implications of these matters for an understanding of the process of Hellenization of the Nabataeans will also be considered in the final report.

The Inner Wall. The course of the Inner Wall on the north of Petra presents far fewer problems than does that of the Outher. It forms essentially two sides of a triangle, the apex being on the high ground of Qabr Jemei'an (grid square L7), at the spot where Horsfield showed the bifurcation of his First and Second Walls. South-eastwards from here the wall is marked by a fairly obvious, though discontinuous, line of foundations running down the slope towards the Wadi el-Mataha, and then across to the cliffs just north of the Palace Tomb. [24] The precise manner in which the crossing of the wadi was achieved is not clear on the ground, but on the southern side of the wadi, in squares M 9-10, a great re-entrant angle is visible (already mentioned as having been attributed by Horsfield to his First Wall). The plan of this re-entrant, and its position astride a modern path leading into central Petra, make it probable that a gateway exists at this point, perhaps the main entrance to the city on this side. The spot would well repay excavation.

The western part of the northern Inner Wall is less easy to trace; the corner in grid square L7, some fragments in K7, and an excellent stretch some 60 m. long in J8 (Plate XII) are all that are certain, [25] but they are sufficient to show that the course is much as Horsfield suggested and as the topography required, namely, along the crest of the Jemei'an ridge, overlooking the Wadi Abu 'Olleqa. The main uncertainty concerns the termination of the wall towards the centre of the city. Horsfield believed it to end at a square structure (in grid square G9 but not shown on the present plan) on tht northern bank of the Wadi

(23) **Révue Biblique** LXIX, (1962), p. 77.

(24) Excavations in grid squares L 7 and J 8 showed that the Inner Wall cut across earlier houses, and incorporated some of the walls of these in its own structure. These earlier buildings are probably of the 1st century BC, judging from an initial study of the pottery, but unfortunately the levels contemporary with the Inner Wall itself were eroded, and it is not certain that the precise date of its construction will be ascertained.

Musa, directly opposite the Qars el-Bint, and this structure does indeed mark the end of the ridge. It is. however, as Horsfield himself noted, [25] perhaps a cistern rather than a tower, and there are certainly no signs today of the twon wall joining it or, indeed, approaching anywhere near it. It might be more logical to suppose that the wall turned westwards at some point along its course, perhaps at the knoll in grid square 18 where there are the remains of a small tower, and made for the lower slopes of Jebel Mu'eisrah esh-Sharqiyah, thus protecting the city from attack along the Wadi Abu 'Olleqa. But if this is the case it must be admitted that there are no signs of such a line of fortification of the ground.

From the above descriptions of the Outer and Inner fortification systems on the northern side of the Petra basin it will be clear that the Inner Wall, unlike the Outer, forms a continuous trace of conventional type, and encloses a much smaller area of the site than does the Outer. The implications of this change of character in the military architecture of Petra will be further discussed in the final report.

2. The Façades

As has been stated (p. 35) the work of plotting the data pertaining to the tomb façades has not yet been completed, and it is premature to comment in any detail upon the archaelogical results or the value of the exercise. Some of the strengths and weaknesses of the photogrammetric method, already referred to in Part II of this article, may however, be stressed. First, its greatest value is certainly the ease and rapidity with which the overall design, dimensions and proportions of the façades can be accurately drawn. Moreover, when several façades are photographed at one time from precisely related base lines, the locational siting of the façades, both horizontally and vertically (in several tiers up a cliff face, for example) can be mapped with an accuracy not previously achieved. The resultant data should be of immense value for a study of the distribution of the various types of tomb façade in Petra, which is badly needed.

On the other hand, the problems of plotting the architectural detail of the façades must not be minimised. As has been mentioned, erosion, differences of lighting conditions and the obscuring of vision, especially when the cameras are tilted, all play their part in making the final drawings far less than perfect. The very accuracy of measurement that it is possible to achieve with the plotting machines is perhaps itself a disadvantage at times, since it leads to a recording of irrelevant detail (imperfections of workmanship, flaws in the stone, etc) which if not recognised and allowed for by the plotter, can obscure the essential features of the design being studied. In this, as in most other branches of archaeology, the work of recording and interpretation must inevitably take place simultaneously, and it would seem that the techniques and skills of the photogrametrist will not, in Petra, wholly replace those of the more conventional student of architectural history, armed with drawing board, tape measure, and flexible rule.

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(25) **Q.D.A.P. VII**, (1938), p. 7.