**[Supplementary Online Material]**

**The fortification of Angkor Wat**

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**Introduction**

This supplementary material supports the main text as follows.

The noticeable differences in the quality of construction techniques and materials used to infill the gateway gaps at Angkor Wat (that is, the later phase of wall construction) are presented in Figure S1.

<FIGURE S1> <13.5cm colour>

<FIGURE S2> <13.5cm colour>

<FIGURE S3> <13.5cm colour>

<FIGURE S4> <13.5cm colour>

<FIGURE S5> <13.5cm colour>

<FIGURE S6> <13.5cm colour>

Figure S2 shows the stratigraphy of trench 33, excavated in August 2013, while Table S1 provides a full soil description of the strata. Trench 33 and the associated cores (see Figure 5 in the main article) suggest that the ground beneath the gateway gap had initially been prepared to support a substantial structure that was never built. This break in the wall was later replaced by the gateway gap infill.

<FIGURE S7> <13.5cm colour>

<TABLE S1>

The general overview of all recorded features (horizontal and vertical) in Figure S3 shows the regularities in their spatial distribution, which means they are probably all part of an integrated entity. The features were mapped and measured between December 2011 and January 2012, and later between July and September 2013.

<FIGURE S8> <13.5cm colour>

A hypothetical design of the defensive works is shown in Figure S4, with volume estimates for the platform and palisade provided (see Tables S2 & S3 respectively).

<FIGURE S9> <13.5cm colour>

<TABLE S2>

<TABLE S3>

**Hypothetical construction estimates**

The current lack of excavated archaeological data to complement that of the enclosure wall renders any reconstructions highly speculative. While permission has been sought to conduct an areal, horizontal excavation adjacent to the wall, it is yet to be granted, until this occurs, additional traces of the structure are unlikely to be identified. Nevertheless, a reasonable reconstruction of the defensive platform can be postulated from the distribution of the regular horizontal holes.

**Platform model**

The platforms must have been facilitated by 1032 regular horizontal holes. Assuming an average of seven beams per platform that results in 1032 ÷ 7 = 147 platforms.

Thus, 147 × 4.0099m3 = 590m3 of timber (see Table S2). It is most likely that the framework of the platform was made of a hardwood, of which the dominant species in Siem Reap is *dipterocarpus sp*. As Morel *et al.* (2011) note, there is a natural logarithmic relationship between the height (h, in metres) of a tree and its diameter at breast height (DBH in centimetres): h = 6.9 × ln(DBH) + 0.17 (cited in Singh *et al.* 2015: S8).

A detailed volume estimate for a tree is beyond the scope of this exercise, so a simple model assuming the shape of a cylinder will be used: V = π × r2 × h

Thus, a tree with a 1m diameter would be 31.9m in height and have a volume of 25m3. If we assume 75% of the wood is usuable (i.e. 17.25m3) then 590 ÷ 17.25 = 34 *dipterocarps* with a 1m diameter would be required to build the 147 defensive platforms.

**Palisade model**

There are 3280m of enclosure wall to fortify (i.e. 3680m minus 400m of *gopura*). As stated in the main text, the function of the structures supported by the large vertical holes is currently unknown; for the sake of convenience, they shall be referred to as ‘towers’ for this exercise. The distribution of large vertical holes indicates the presence of 120 towers around the enclosure, with an average width (i.e. length along the wall) of 5.5m. The length of wall that supports a palisade is thus 3280m—(120 × 5.5m) = 2620m.

The palisade reconstruction assumes that the small vertical postholes support two rails that run along the entire wall (2620m), which in turn support 1.5m-high bamboo spikes (each separated by a 0.02m gap). The bamboo required is 0.08m in diameter.

If we assume the lower 5m of a bamboo plant is of the required diameter, a total of 40623 ÷ 5 = 8125 bamboo plants are necessary to build the palisade (see Table S3).

**References**

Morel, A.C., S.S. Saatchi, Y. Malhi, N.J. Berry, L. Banin, D. Burslem, R. Nilus & R.C. Ong. 2011. Estimating aboveground biomass in forest and oil palm plantation in Sabah, Malaysian Borneo using ALOS PALSAR data. *Forest Ecology and Management* 262: 1786–98. http://dx.doi.org/10.1016/j.foreco.2011.07.008

Singh, M., D. Evans, D.A. Friess, B.S. Tan & C.S. Nin. 2015. Mapping aboveground biomass in a tropical forest in Cambodia using canopy textures derived from Google Earth. *Remote Sensing* 7: 5057–76. http://dx.doi.org/10.3390/rs70505057

**Figure captions**

*Figure S1. Composite photograph and block profile trace of the gateway gap on the east wall, north side.*

*Figure S2. Composite photograph and block profile trace of the gateway gap on the east wall, south side.*

*Figure S3. Composite photograph and block profile trace of the gateway gap on the north wall, east side.*

*Figure S4. Composite photograph and block profile trace of the gateway gap on the north wall, west side.*

*Figure S5. Composite photograph and block profile trace of the gateway gap on the south wall, east side.*

*Figure S6. Composite photograph and block profile trace of the gateway gap on the south wall, west side.*

*Figure S7. Trench 33, east wall (adjacent to enclosure wall); note the layers of hard compacted foundation sand (F1–F6); see Table S1 for full description.*

*Figure S8. LiDAR hillshade map of Angkor Wat with hole distribution overlaid; vertical holes, large (orange) and small (blue); horizontal holes, regular (red) and irregular (white); thoroughfares in rectilinear urban grid (black) (LiDAR courtesy KALC).*

*Figure S9. Hypothetical platform reconstruction*

**Table S1. Soil description and interpretation.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Layer** | **Munsell colour** | **Soil description** | **Non-artefact inclusions** | **Disturbance** | **Artefacts present** | **Additional notes/interpretation** |
| 1 | 7.5 YR 5/4 | Sandy clay loam. Wet, sticky, soft. | Sandstone (1–100mm) and laterite (1–50mm). Fine charcoal flecking. | Many fine- and medium-size roots. | Some ceramics. | The uppermost strata of debitage from the construction of the east *gopura*. The humic topsoil layer normally present (in the other trenches) is notably absent here.  |
| 2 | 7.5 YR 5/4 | Sandy clay loam. Wet, sticky, soft. | Laterite (10–30mm) and sandstone (10–50mm) chips present. | Medium and fine root activity. | Some ceramics. | Debitage. |
| 3a | 7.5 YR 5/4 | Sandy clay loam. Wet, sticky, soft. | Abundant laterite (10–50mm) and sandstone (10–70mm). More sandstone than laterite present. | Many roots. | No ceramics. | Debitage. |
| 3b | 7.5 YR 5/6 | Sandy clay loam. Wet, sticky, soft. | Abundant laterite (10–100mm) and sandstone (10–70mm) fragments, and one large sandstone block. | Occasional root activity. | No ceramics. | Debitage. |
| F1 | 7.5 YR 5/6 | Sandy clay loam. Dry, compact, sticky. | Laterite (10–50mm), sandstone (10–30mm). | Some roots. | No ceramics. | Foundation trench fill. |
| F2 | 7.5 YR 5/6 | Sandy loam. Dry, compact, slightly sticky. | Lenses of pink sand present (5 YR 7/3), a few small stones and charcoal. | Some roots. | No ceramics. | Foundation trench fill. |
| F3 | 7.5 YR 5/6 | Sandy loam. Wet, slightly sticky, compact. | Some sandstone chips (20mm). | Some roots. | No ceramics. | Foundation trench fill. |
| F4 | 7.5 YR 5/6 | Sandy clay loam. Dry sticky, very compact. | Many laterite chips (10–20mm), some charcoal. | Some roots. | No ceramics. | Foundation trench fill. |
| F5 | 5 YR 6/4 | Sandy, dry, compact, not sticky. | Laterite and rhyolite pieces (10mm), some charcoal. | Some root activity. | Some ceramics. | Foundation trench fill. |
| F6 | 5 YR 6/4 | Dry and sandy, very densely packed. | Some laterite and rhyolite fragments (10–50mm). | Some roots. | No ceramics. | Foundation trench fill. |

**Table S2. Platform material volume estimates.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Component** | **Number** | **Length (m)** | **Width (m)** | **Depth (m)** | **Diameter (m)** | **Volume (m3)** |
| Steps | 22 | 2 | 0.25 | 0.06 | – | 0.66 |
| Step rails | 4 | 5.5 | 0.28 | 0.1 | – | 0.616 |
| Vertical posts | 5 | 4 | – | – | 0.2 | 0.628 |
| Perpendicular beams | 7 | 3 | 0.2 | 0.1 | – | 0.42 |
| Parallel beams | 2 | 15 | 0.2 | 0.1 | – | 0.6 |
| Diagonal bracing | 11 | 1.69 | 0.1 | 0.1 | – | 0.1859 |
| Floor planking | 1 | 15 | 3 | 0.02 | – | 0.9 |
|  | – | – | – | – | **Total** **volume** | 4.0099 |

**Table S3. Palisade material volume estimates.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Number** | **Length (m)** | **Total (m)** |
| Posts | 3943 | 1 | 3943 |
| Pickets | 20960 | 1.5 | 31440 |
| Rails | 2 | 2620 | 5240 |
|  |  | **Total (m)** | 40623 |