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CONSTRUCTING THE ASSYRIAN SIEGE RAMP AT LACHISH: TEXTS, ICONOGRAPHY, ARCHAEOLOGY AND PHOTOGRAMMETRY

Summary. *This research examines the Assyrian siege ramp at Lachish, the only such known from the ancient Near East and the oldest in the world. The combination of different sources (texts, iconography and archaeology) enables us to reconstruct how this monumental war installation was erected. We used photogrammetric analysis, facilitated through small Unmanned Aerial System (sUAS) imagery, to digitally map the landscape and evaluate different potential scenarios with regard to the construction and use of the ramp.*

INTRODUCTION

The Neo-Assyrian of the ninth to the seventh centuries BC was the first large-scale empire that controlled wide parts of the ancient Near East, from Iran to Egypt. The mighty Assyrian army developed efficient military technologies and tactics and was able to win any open battle or to take any fortified city. In 701 BC, Lachish was attacked by the Assyrians led by King Sennacherib. Lachish was a flourishing Canaanite city in the second millennium BC and the second most important city in the Kingdom of Judah from the late tenth to the early sixth centuries BC (Fig. 1). The siege ramp constructed at the site by the Assyrians is the only surviving physical example of their military prowess in the entire Near East. This case is also outstanding in the amount of data available for a single historical event.

Our information on the siege of Lachish in 701 BC comes from a variety of sources.

The Biblical text. The Assyrian assault on the kingdoms of Israel and Judah and the battle for Lachish are mentioned in a number of books in the Bible (2 Kings 18:9–19:37; 2 Chronicles 32; Isaiah 36–37). Assyrian siege ramps are mentioned twice (2 Kings 19:32; Isaiah 37:33). The Biblical text inspired Lord Byron to write the celebrated poem 'The Destruction of Sennacherib' in 1815, before any archaeological activity had taken place in Mesopotamia or the Levant. Biblical scholars have dealt intensively with these traditions (Childs 1967; Machinist 1983; Gonçalves 1986; Gallagher 1999; Aster 2007). They did not, however, pay any attention to the technical aspects of the war.

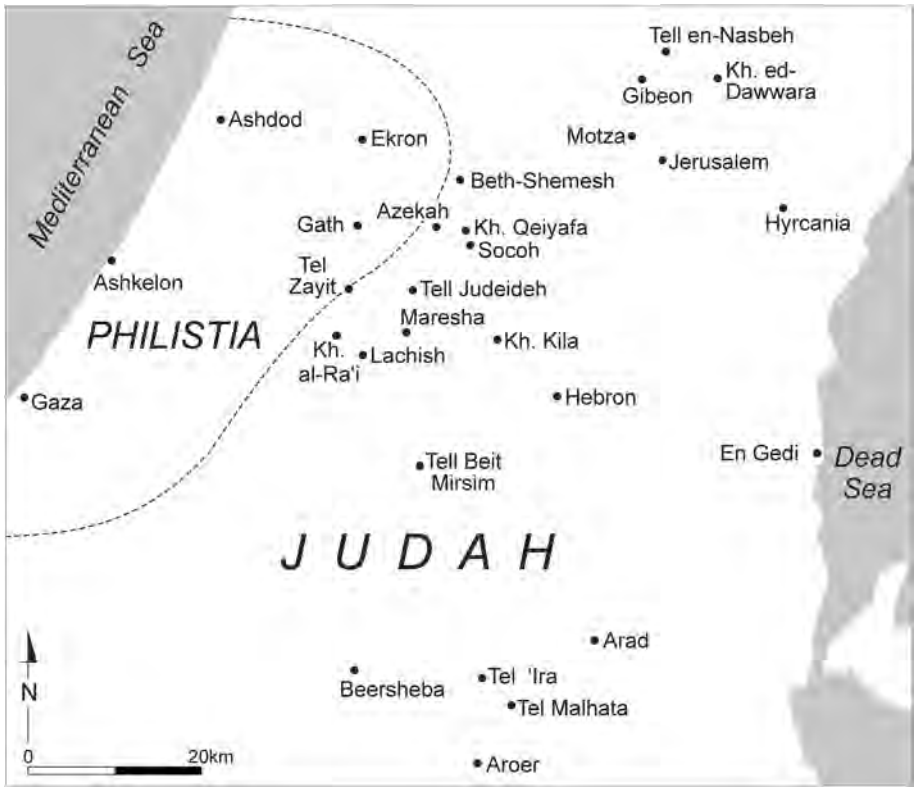

FIGURE 1
Map of the Kingdom of Judah and the location of Lachish.

Assyrian reliefs. These were first discovered in Mesopotamia in 1846 by the pioneering excavations of Paul-Émile Botta at Khorsabad. They represent the Assyrian army in various battles. In 1847, Austin Henry Layard excavated at the Assyrian city of Nineveh and uncovered the palace of Sennacherib, with its famous relief in Room XXXVI that depicts the Assyrian attack on Lachish (Layard 1849; Ussishkin 1982; Russell 1991; Uehlinger 2003). In this relief, Assyrian forces are shown assaulting the city with battering rams on two siege ramps, one at the gate and the other to the right of the gate (Fig. 2). The Assyrian reliefs have been intensively discussed in the literature relating to various aspects of ancient warfare (Yadin 1963, 380–462; Scurlock 1997; Kern 1999; De Backer 2009; Fagan 2010; Dezső 2012).

Assyrian texts. Akkadian inscriptions, including chronicles and sometimes letters, describe various Assyrian activities in Judah (Luckenbill 1924; Na'aman 1974; Grayson and Novotny 2012). Various scholars have emphasized the rhetorical and propaganda aspects of these documents (Tadmor 1985; 1997; Russell 1993; Laato 1995).

Archaeological data. Excavations at various sites in the Near East have uncovered cities destroyed by the Assyrian army. A siege ramp, however, has been identified only at Lachish. The site was extensively excavated in the past by three expeditions, the first in the 1930s (Tufnell 1953), the second in the 1960s (Aharoni 1975) and the third between 1974 and 1994 (Ussishkin 2004). A fourth more recent expedition excavated between 2013 and 2017 (Garfinkel, Hasel and

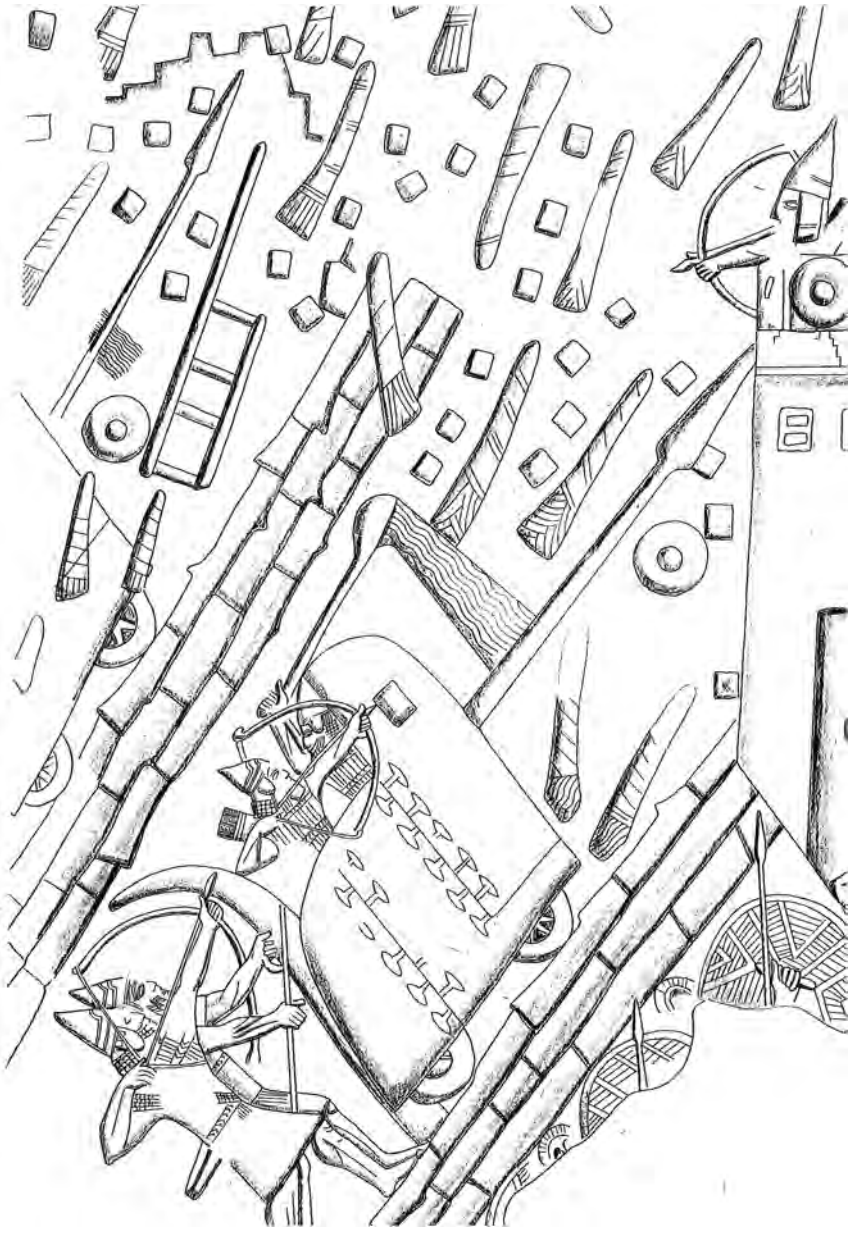

FIGURE 2
A small segment of the Assyrian siege ramps on the Lachish relief uncovered by Layard in the palace of Sennacherib at Nineveh in 1847, now at the British Museum. Note the siege engine with its wheels on a paved 'road' (Ussishkin 1982, fig. 78, drawing by Judith Dekel).

Klingbeil 2013; Garfinkel *et al*. 2019; 2021). Based on the Lachish relief, Wright (1955, 11) suggested: 'Great ramps of soil, evidently brought up from the valley and piled against the bastion, may have been part of the Assyrian siege-ramps, for in the relief the attack seems to be centred around the gateway area.' Likewise, Barnett (1958, 162–3) suggested that the Assyrian siege ramp should be located in the south-west corner of the site.

In 1973, during a visit to the excavations, Yadin suggested that the heaps of stones in the south-west corner of the site might be the remains of the Assyrian siege ramp (Ussishkin 2004, 699). Excavations in this location indeed uncovered the siege ramp relating to the city of Level III (Figs. 3–5; Ussishkin 1982, 49–58; 2004, 695–767; Eph'al 1984). Ussishkin suggested that the ramp was plastered and estimated its length as 50–75 m.

The case study of Lachish Level III comprises a nexus between the four different sources mentioned above. This unique situation enables scholars to cross-reference the data as indicated below, an approach that cannot so easily be employed at other sites. The comparisons thus made possible are:

1 The account of the victorious side (Assyrian) versus that of the defeated side (Judah) (Machinist 1983; Russell 1993; Grabbe 2003).

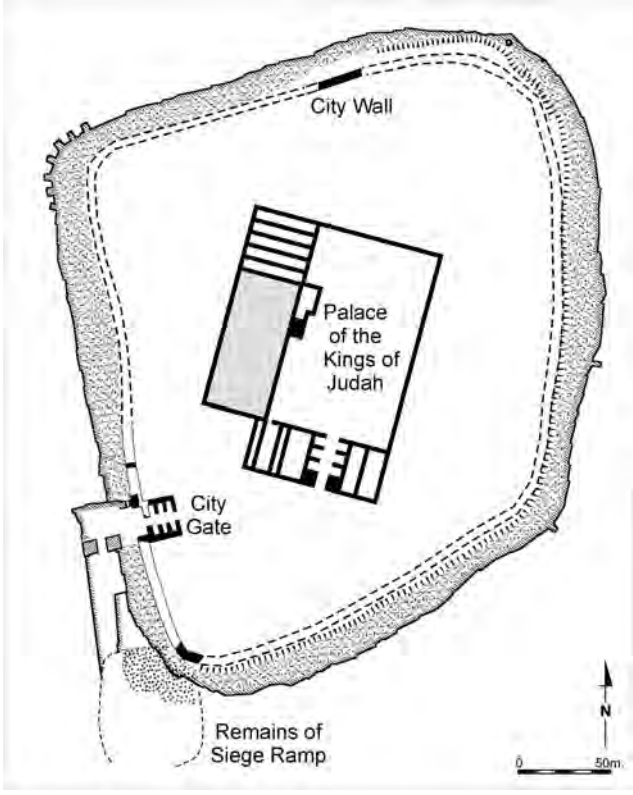

FIGURE 3
The site of Lachish with the distribution of the siege ramp remains in the south-west corner of the mound (Ussishkin 2004, fig. 13.6).

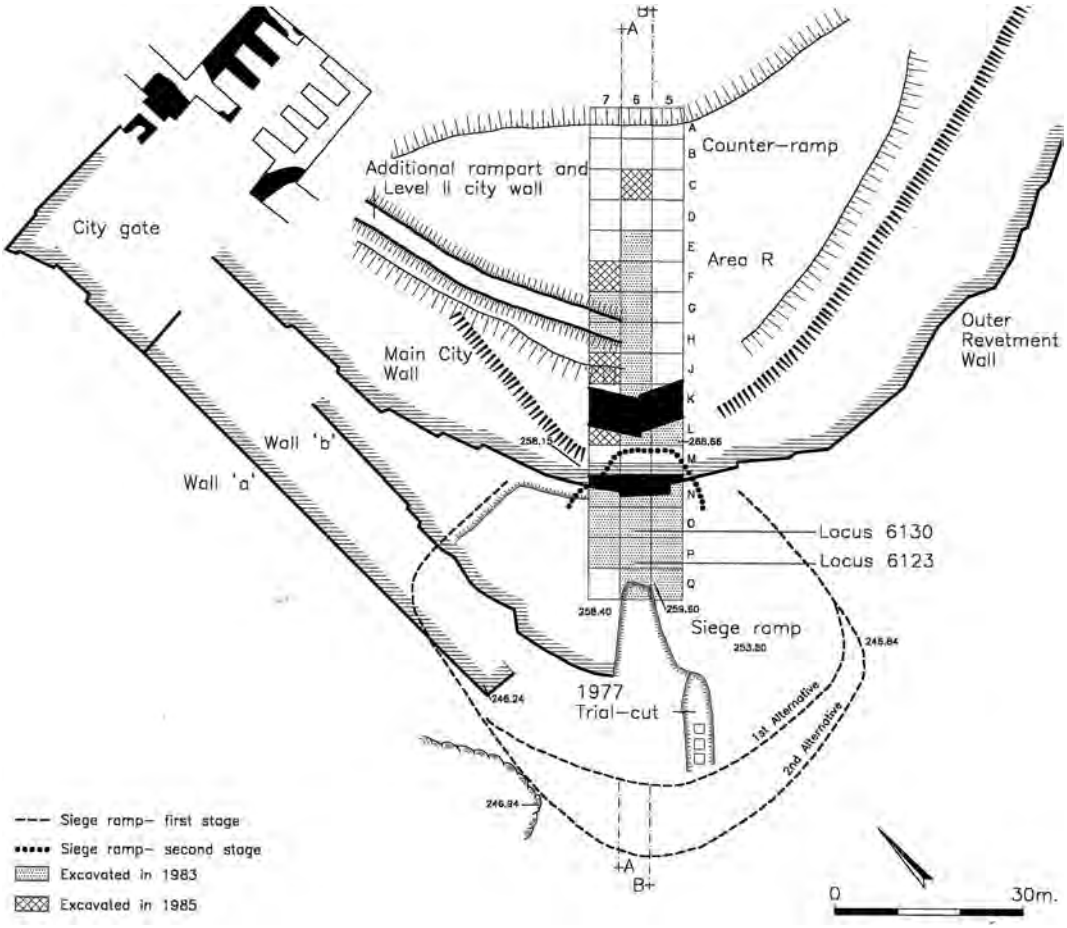

FIGURE 4
The south-west corner of the mound of Lachish with the remains of the Assyrian siege ramp and two different reconstructions of its length (Ussishkin 2004, figs. 13.6).

2 The Biblical tradition, a secondary historical source that has undergone a complex editing process, versus the primary historical sources of the Assyrians (Tadmor 1985; 1997; Aster 2007).
3 Archaeological data versus historical data (Eph'al 1984).
4 Pictorial representation versus archaeological data (Barnett 1958; Ussishkin 1982; Jacoby 1991; Uehlinger 2003).
5 Pictorial representation versus historical data (Dougherty 1930; Ussishkin 1982).

Here we will use this compound approach to examine one aspect of this complex issue: the construction of the siege ramp at Lachish. We have organized the analysis in several stages. First, by creating an ideal model of how a ramp can be constructed in the most efficient way; this enables us to achieve a better understanding of the problems encountered by the Assyrian army and their possible solutions. Second, by testing the archaeological data; instead of a simple description of the finds, we examine the data against the model. An important aspect that has been overlooked

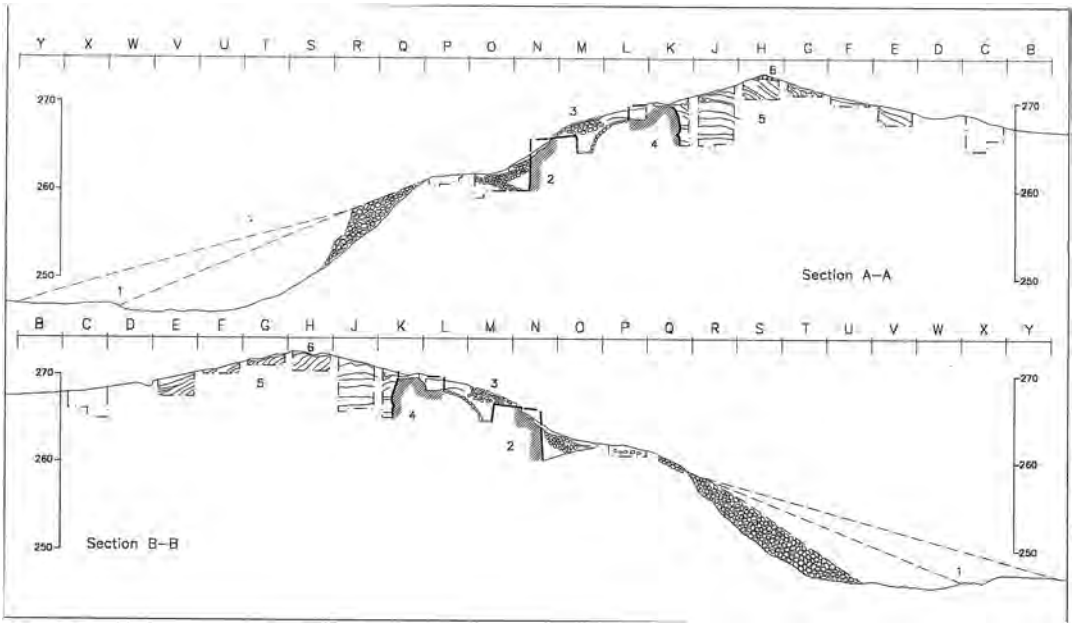

FIGURE 5
North-south section of the Assyrian siege ramp remains, with two different reconstructions of its length (Ussishkin 2004, fig. 13.7).

TABLE 1
Constructing the Assyrian siege ramp: the ideal model and the data

Model	Data	Type of data
Stones as raw material	The ramp is constructed from stones with an average weight of 6.4 kg each	Archaeological observations
Quarrying the stones	A quarry is located at the southern end of the ramp	Archaeological observations
Constructing the ramp 24 hours a day	'None of them asleep or drowsy'	Biblical text
Dumping stones from the southern end until the city wall is reached	The work is described as 'dumping' (2 Kings 19:32); no levels are observed within the ramp	Biblical text and archaeological observations
Protecting the work	Heavy shields are depicted on Assyrian reliefs; shields are mentioned by Isaiah	Iconography and biblical text
Paving the top of the ramp	The battering rams are depicted with a 'paved' roadway for each of them	Iconography

in previous studies is the complex site-formation processes that have affected the original shape of the siege ramp. Table 1 presents the model and the available data that support it. All of these aspects are presented and discussed below. Finally, we may test both the iconographic sources and the historical sources and ask whether they support the model.

THE MOST EFFICIENT WAY OF CONSTRUCTING A SIEGE RAMP

The construction of a siege ramp involves five basic components.

Collecting the raw materials

A ramp can be constructed from soil, stones, timber or a combination of the three. Since the area around Lachish is not characterized by forests, the city's use of timber was very limited; hence the readily available raw materials are stones and soil. The moving of soil requires baskets or carts, which will need to be carried back and forth, slowing the work. As baskets are made from branches or straw they quickly wear out, and pushing carts up and down the rough surface of the ramp will quickly wear out the wheels. If stones are used for construction, they can be transported by hand and there is no need for baskets or carts. Some empty space will remain between the stones; thus, while the specific gravity of stones in a building is 2.36–2.75, the estimated gravity of the ramp is *c*.2 (Ussishkin 2004, 717). Finally, when a heavy siege machine is pushed up the ramp, it may sink in soil, whereas stones can bear its weight.

Constructing the ramp requires many hundreds of thousands of stones, perhaps over a million. So far, scholars have assumed that the stones were simply collected from the surrounding land (Ussishkin 1982, fig. 42; Eph'al 1984, 63). It is clear that the supply of stones is the weakest point in the efficiency of the work. Collecting available stones from the ground will exhaust the nearby territory very quickly and require long lines of supply. The only way to keep up the supply of stones in large quantities is by intensive quarrying on the spot. Hundreds of labourers need to be involved in quarrying the stones, 24 hours a day, in two or three shifts a day.

Transporting the stones

The stones can be carried by porters who go back and forth from the quarry to the ramp. This was suggested by Eph'al (1984), based on data related to public works in Assyria. A military operation, however, requires maximum efficiency and a faster way of transporting the stones. This can be achieved by a human chain, passing the stones from hand to hand from the quarry and up the ramp. The labourers remain standing and only the stones move.

Depending on the width of the ramp, two, three or more chains can operate simultaneously. For a smooth operation the stones should be medium-sized and hence easily shifted. If a person can move one stone every two seconds, a human chain can move 30 stones per minute, 1,800 stones per hour and 43,200 stones per 24 hours. Two such chains can move about 80,000 stones per day, and four chains can move 160,000 stones. Even if the work is not carried out with the greatest efficiency, three human chains can move about 100,000 stones a day.

The workers need to be supplied with food and water, either during official breaks from time to time or by replacing the workers every few hours. For maximum efficiency, the workers should work in shifts, 24 hours a day.

Constructing the ramp

Starting the construction of the ramp at the base of the city-mound will place the attackers in an inferior tactical position, since they can easily be injured by arrows or by stones dropped from

the city wall directly above. Constructing the ramp in successive superimposed levels will repeatedly bring the attackers to the foot of the city, making them vulnerable repeatedly. All of this can be avoided by starting the construction of the ramp far away from the city, here at its southern end. The ramp has a diagonal profile, rising as it gets closer to the city. At the beginning, the ramp is quite low and hence the segment constructed each day is longer. As the ramp becomes higher, a shorter segment is constructed each day. When the ramp reaches the mound, it rests on its slope and a smaller volume needs to be constructed; from this point onwards, the work once again progresses quickly. No masonry construction, such as walls, is needed; the human chain simply stands on top of the already constructed ramp and dumps an enormous number of stones per hour down toward the city.

The length of the ramp is dictated by two factors: the height of the mound above the local surroundings and the angle of the ramp. This angle is in turn dictated by the weight of the siege engine that is to be pushed up to the city wall. Lighter engines can be pushed up a steeper and shorter slope, while heavier engines will need a more moderate slope and consequently a longer ramp.

The ramp is basically a road bringing the Assyrian army into direct contact with the city wall. Most of the ramp can be a relative narrow passageway, but adjacent to the city wall a larger space is needed to accommodate several battering rams and additional soldiers.

Protecting the work

The inhabitants of the besieged city on top of the mound will do their best to obstruct the work by shooting arrows and throwing sling stones from their higher position. Clearly, the attackers need to protect the people working at the northern end of the ramp, who are lower down than the city and thus need protection from the front and from above. This can be achieved with massive L-shaped wooden or wicker shields (Fig. 6). These are not the light shields used by individual soldiers in combat (Yadin 1963, 13–14, 293–4; Ussishkin 1982, fig. 67 lower levels; Dezső 2012, figs. 98–101, 104–5, 110–17; De Backer 2016) but heavy, static installations (Yadin 1963, 295; Ussishkin 1982, fig. 67 upper level; Kern 1999, 46–51; Dezső 2012, figs. 95–6, 102–3). They probably looked like the heavy L-shaped shields seen in Fig. 4, each held there by a soldier to protect a nearby archer.

It is even possible to protect labourers constructing a siege ramp by a third type of shield, wider, heavier and with openings in its lower part through which stones can be dumped. As the ramp construction advances, the heavy shield will be moved forward. Such extraordinarily massive shields are not depicted in Assyrian reliefs (De Backer 2016), but this is probably because the artists concentrated on the final stages of the battle rather than the logistics.

In addition to the passive protection by shields, archers shot arrows and slingers stones at the city. Anyone who exposed himself on the city wall was put in immediate mortal danger.

Smoothing the top of the ramp

Since the top of a stony ramp is uneven and rough, the surface must be smoothed and made level so that heavy siege engines can be pushed up the ramp until they face the city wall. The ramp's top surface could be covered with soil, but if too deep this might not bear the great weight of the

FIGURE 6
Siege scene with two massive L-shaped shields protecting Assyrian soldiers, in a relief from the palace of Tiglath-Pileser III at Nimrud (courtesy of the British Museum). The shields are made up of short sections with diagonal lines in each. This may indicate that they were wickerwork items, woven from light but strong plant fibres.

engines. Ussishkin (2004, 557) suggested, admittedly on the basis of very problematic data, that the top was covered with stones and plaster. The remains he quoted had in fact already been dated by their original excavators to the later city of Level II, destroyed in 586 BC by the Babylonians (Tufnell 1953, pls. 13.3, 14.5).

Plastering the entire ramp would require enormous amounts of material to be produced in high-temperature lime kilns. This will require large quantities of wood as fuel, and will take weeks to produce the amount needed. Hence plastering the ramp is not a sensible option. Dumping just enough earth on top of the stones to level and stabilize the top, and placing large wooden planks on that in turn, can quickly produce an even enough surface on the ramp. The wooden planks will not even need to be laid all over the ramp, but can be placed *ad hoc* in front of the battering ram and repositioned once it has passed over them.

Fig. 7 presents the most efficient way of constructing a ramp. The work starts at the southern end, well away from the city. In this way, the attackers are safe from objects aimed at them from the city, as they are not situated at the foot of the mound during the construction. The ramp

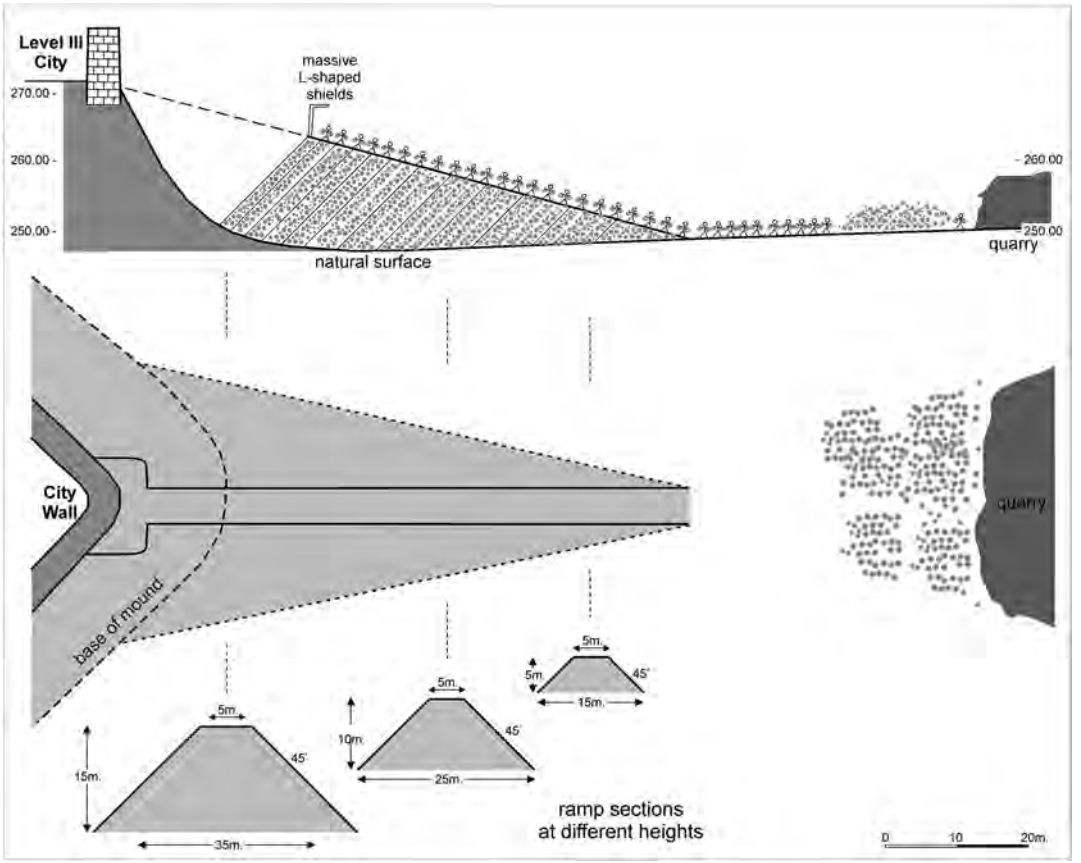

FIGURE 7
Our reconstruction of the construction of the siege ramp, starting from the far end with a stone quarry nearby.

gradually rises, creating a sloping path leading towards the city wall. As the attackers get closer, they are also higher up, and the height advantage of the defenders diminishes.

It is clear that the construction of the massive shields, the siege engines and the postulated wooden planks requires a large number of professional carpenters. Most probably Assyrian carpenters were involved in the most complex work, the construction of the siege engines, while prisoners of war and forced labour from the population of nearby areas provided carpenters for the simpler tasks.

THE ASSYRIAN SIEGE RAMP AT LACHISH: THE ARCHAEOLOGICAL DATA

The earliest documentation of the ramp is a photograph taken in November 1932. In it a steep hill can be seen, located adjacent to the main mound near the south-west corner of the site (Fig. 8). The ramp, however, was not recognized as such by the excavators of the site, and it was

FIGURE 8
The earliest photograph of the Assyrian ramp in the south-west corner of the site, view to the north (courtesy of the Wellcome Trust, London).

Yadin, an expert on warfare in the ancient Near East, who was the first to suggest its identification (Ussishkin 2004, 699). Ussishkin finally excavated the ramp in the late 1970s, and his investigations were published in great detail (Ussishkin 1982; 2004).

Ussishkin understood the ramp as a very wide installation, 50–75 m across at its base, 25 m on top, 50–60 m long and 6,500–9,000 m^3 in volume (Ussishkin 2004, 716–17, fig. 13.6). His account was accompanied by an artist's reconstruction that shows wide, short and steep siege ramps (Ussishkin 1982, 123–4). This concept was probably derived from both the state of the remains at Lachish and the depiction of steep ramps in the Assyrian reliefs. Both of these sources, however, are problematic. The ramp has undergone severe post-depositional processes and is no longer in its original shape. Moreover, the Assyrian relief is not a realistic representation but a schematic artwork executed according to artistic conventions and aesthetic values. For the Assyrian artist the accurate depiction of the size and shape of a ramp was not important, as the main goal of the relief was to present the great power of the Assyrian king and his army.

Ussishkin's reconstruction thus assumes that the current state of the remains reflects the original ramp as left by the Assyrians and ignores the complex site-formation processes that have taken place since 701 BC. Some of the contributing factors to the ramp's dissolution are listed here below.

At some time after the destruction of Level III, the city of Level II was constructed. Would the builders of the new city have left the siege ramp in place, making the city easy prey for any attack? Clearly they removed large segments of the ramp. The current distribution of the remains, adjacent to the mound, indicates that they concentrated their efforts on the lower southern end and removed most of the southern part. As for the part close to the mound, the stones were probably simply dispersed to the left and right. In this way, instead of a long and moderately sloping ramp, the current steep fan-shaped hill was created. The prominent Assyrian siege ramp was largely erased from the local landscape; indeed, in Area 7000 a few houses of Level II were actually built on the location of the southern end of the Assyrian ramp (Tufnell 1953, pl. 130). Removing the siege ramp also had a psychological effect, as a manifestation of the restoration of the Kingdom of Judah.

It is possible that during their assault on the city of Level II the Babylonians also constructed a siege installation in this area. If so, the builders of Level I may have removed such remains and perhaps even further dismantled remains of the earlier Assyrian ramp.

The local Arab villagers formerly quarried stones from the lower part of the ramp for the production of lime, thus damaging its southern end. The 1932 photograph of the ramp shows three whitish piles, the results of such activity (Fig. 8). The production of lime and the camels used for taking away the final products are visually documented as well (Ussishkin 2004, 717, fig. 13.26).

FIGURE 9
The six locations on the Assyrian siege ramp where stones were retrieved and weighed (photograph by Dr. M. Pytlik).

FIGURE 10
The stones collected from location No. 6 (Photograph by Dr. M. Pytlik, with Oakland University students: N. Vandenheuvel, L. Schaaf and A. Babjack).

The first archaeological expedition dismantled large parts of what remained of the ramp without understanding its identity. Further damage to the ramp occurred when the expedition camp was sited in this location and when the light railway that went up from the camp to the site was constructed here (Garfinkel 2016). The third expedition also removed parts of the original ramp by clearing a section with a mechanical backhoe (Ussishkin 2004, fig. 13.5).

Despite the damage that has occurred, much information on the ramp can yet be gathered. The ramp is constructed from medium-sized lumps of the local *nari* limestone. No levels can be

observed in the cross-section of the ramp (Ussishkin 2004, figs. 13.5, 13.8). The stones are not organized in any way in its building, but were dumped at random. The stones used in the construction are described as 'all relatively small, easily transportable boulders' (Ussishkin 2004, 716). In 2017, they were examined by Dr. Michael Pytlik and his students from Oakland University. A total sample of 200 stones was taken from six different locations in the siege ramp and the weight of the individual stones was recorded (Figs. 9–10). Table 2 presents the relevant data. The average stone weighed about 6.5 kg and hence could easily be carried manually to construct the ramp.

Ussishkin assumed that the ramp's top was covered with 'stone-and-mortar conglomerate presently estimated to be about one meter or less thick', and that the top 'was consolidated with large quantities of mortar'. This is based on remains uncovered in the 1930s (Ussishkin 1982, 52–3, fig. 44; 2004, 557) and is commonly accepted in the literature (Eph'al 1984, 64; Melville and Melville 2008, 150). Close examination below of the data, however, indicates that this hypothesis cannot be accepted.

The nature of the plaster phenomenon shows it as but an isolated patch, no more than a few metres wide. How can such a small phenomenon be representative of the entire siege ramp? Moreover, its location is on the western side of Lachish, beyond the original limits of the siege ramp.

The patch is actually on a steep accumulation of sediment that does not conform with the moderate slope needed for the heavy siege machine to be pushed up the ramp.

In the photograph, the 'stone-and-mortar conglomerate' is visible immediately below the topsoil (Ussishkin 1982, fig. 44; 2004, fig. 11.34). Can this phenomenon be specifically dated to Level III? These remains were in fact dated by their excavators to the later city of Level II, destroyed in 586 BC (Tufnell 1953, 97, figs. 13.3, 14.5). Tufnell clearly stated that this sediment covers a well-built glacis retaining the western side of the mound, adjacent to the road leading to the Level II city gate (Starkey's Wall B). Ussishkin himself refers to the problematic stratigraphic situation of these remains: 'It thus remains unexplained why, at this point, the lime plaster layer of the siege ramp appears to cover the wall, which otherwise seems to be late in date' (2004, 557). Nevertheless, 160 pages later, it is taken for granted that the 'stones of the upper layer of the ramp were cemented together by hard mortar' (Ussishkin 2004, 717).

Ussishkin observed two phases (A and B) in the development of the siege ramp (Fig. 5). While the earlier phase is presented with a very wide outline, the top of the second phase is quite narrow, only 20 m across (Ussishkin 2004, 719–23, fig. 13.6).

When large parts of the lower part of the ramp were removed by the first and the third expeditions, no significant artefacts were found. Given that this was a battleground, it would not

TABLE 2
Locations and the average weight of stones in the Assyrian siege ramp at Lachish

Point	Location in the ramp	Sample size	Average weight in kg
1	Base of ramp	25	5.86
2	Upper part, southern portion	25	5.25
3	Upper part, mid slope	25	5.66
4	Upper part, just below mud-brick wall	25	7.12
5	Upper SE side, above Ussishkin's trench, near top of mound	50	7.61
6	Upper SW side, above Ussishkin's trench, near top of mound	50	6.12
Total	Average weight of entire sample	200	6.42

be surprising to find arrowheads or sling stones, which are known from other parts of the site. Thus, the top of the ramp, near the city wall, did yield evidence of the battle in the form of arrowheads, sling stones, large drilled stones with remnants of cords, and an iron chain (Ussishkin 1982; 2004; Yadin 1984; Gottlieb 2004). It is thus clear that this upper part of the ramp was not removed by the Level II inhabitants.

About 120 m south of the site is a rocky hill with prominent cliffs. A photograph taken in 1933 documents the landscape before later interventions (Fig. 11). Close examination of the cliff showed chisel marks. These cliffs are exceptional, as they are not found on other hills in the region. If they were cut by a river, they should be located in its valley. Quarries for stone used in the construction of city walls and buildings were noticed inside the city, in the area known as the 'Great Shaft' (Ussishkin 2014, 263–6). Intensive quarrying was also observed in various locations at the foot of the mound, such as Area 100 (Starkey 1936, 179). We argue that this artificial cliff is the result of Assyrian stone quarrying for the ramp.

PHOTOGRAMMETRY AND RECONSTRUCTION OF THE RAMP

Ussishkin reconstructed the ramp as a short, wide fan shape (Fig. 4), based on the current distribution of the ramp's remains. He did not take into account the later activities that had altered

FIGURE 11
The cliff south of the site, as documented by the first expedition to Lachish. The photo was taken from site in 1932, with the Assyrian ramp shown as the whitish area in the lower right corner (Courtesy of the Wellcome Trust, London).

the original shape of the ramp. The original siege ramp is better understood as a long, narrow construction leading up with a moderate slope from the ground level near the stone quarry in the south to the city wall in the north. East-west cross-sections of the ramp are trapezoidal in shape, with a flat top and a much wider base. Three basic dimensions are required to calculate the volume of the ramp and how many stones were needed to construct it:

Height: This dimension is relatively easily ascertained, as we know the local topography, including the ground level outside the mound and the height of the city wall above the ground. Ussishkin's excavations of the battlefield added significant information about both the height and the width of the ramp.

Length: A shorter and steeper ramp would require less raw material and a shorter construction time. However, a moderate slope was necessary for the heavy siege engines to be pushed up the ramp.

Width: The width of the ramp is of two aspects, that of the upper part, where the road leading to the city wall was placed, and that of the lower part. If the ramp had been constructed with retaining walls it could have been steeper, but it was constructed in haste in battle conditions and the stones were simply dumped. The lower base was thus created by gravity. The angle of the sides of the ramp could be as steep as 45°degrees.

To achieve a better understanding of the site's topography, the shape of the ramp, the amount of stones needed and the location of the quarries supplying the stones, the south-west corner of the site was surveyed in high resolution. We deployed a SenseFly Ebee small Unmanned Aerial System (UAS) – a fixed-wing drone – to fly linear transects and gather overlapping georeferenced imagery averaging 2.5 cm in pixel resolution. Emotion 3.5 (SenseFly 2018) was used to program the flight transects, monitor in-flight mission performance and download/pre-process the imagery. A digital point cloud was created in Pix4D Mapper 4.5.6 (Pix4D 2020), and a visual band (RGB) orthomosaic and a 1-m contour map generated from a Digital Terrain Model (DTM) were then produced (Figs. 12–13). ArcGIS 10.7.1 (ESRI 2019) was used to conduct slope analysis and for cartographic visualization.

Table 3 presents various simulations of the geometry of the ramp. Ussishkin offers two alternatives for where the ramp begins (Figs. 4–5). Alternative 1 results in a slope of 28.51° degrees and an overall trip distance of 56.58 m from the ramp's base to the top of the mound. Alternative 2 results in a slope of 25.18°degrees and an overall distance of 68.38 m.

We propose a third option, in which the slope was 23.11° degrees, ramp length was 80 m long and its width on top was 5 m (Fig. 13), before it reached the expanded end by the city wall. The volume of such a ramp would be 9728 m^3 and it would require about 19,456 tons of stones.

A fourth possibility that we considered is that the ramp actually originated much farther away from the city and closer to the quarry that supplied the stones. An arbitrary starting point for the ramp was placed in ArcGIS at what is now the edge of the site's parking area, but it could have been located much closer to the quarry, further reducing the overall slope. This version results in a slope of 21.73° degrees with a total trip distance of approximately 97.88 m (Figs. 12–13). The additional distance, and resulting decreased slope, would provide greater degree of protection from the opposition inside the city and would have also made it easier to move a siege engine up the ramp. This possibility, however, would require a huge amount of stones and presumably too much time and labour.

Our preferred reconstruction of the geometry of the ramp, Alternative 3, took into consideration the following dimensions.

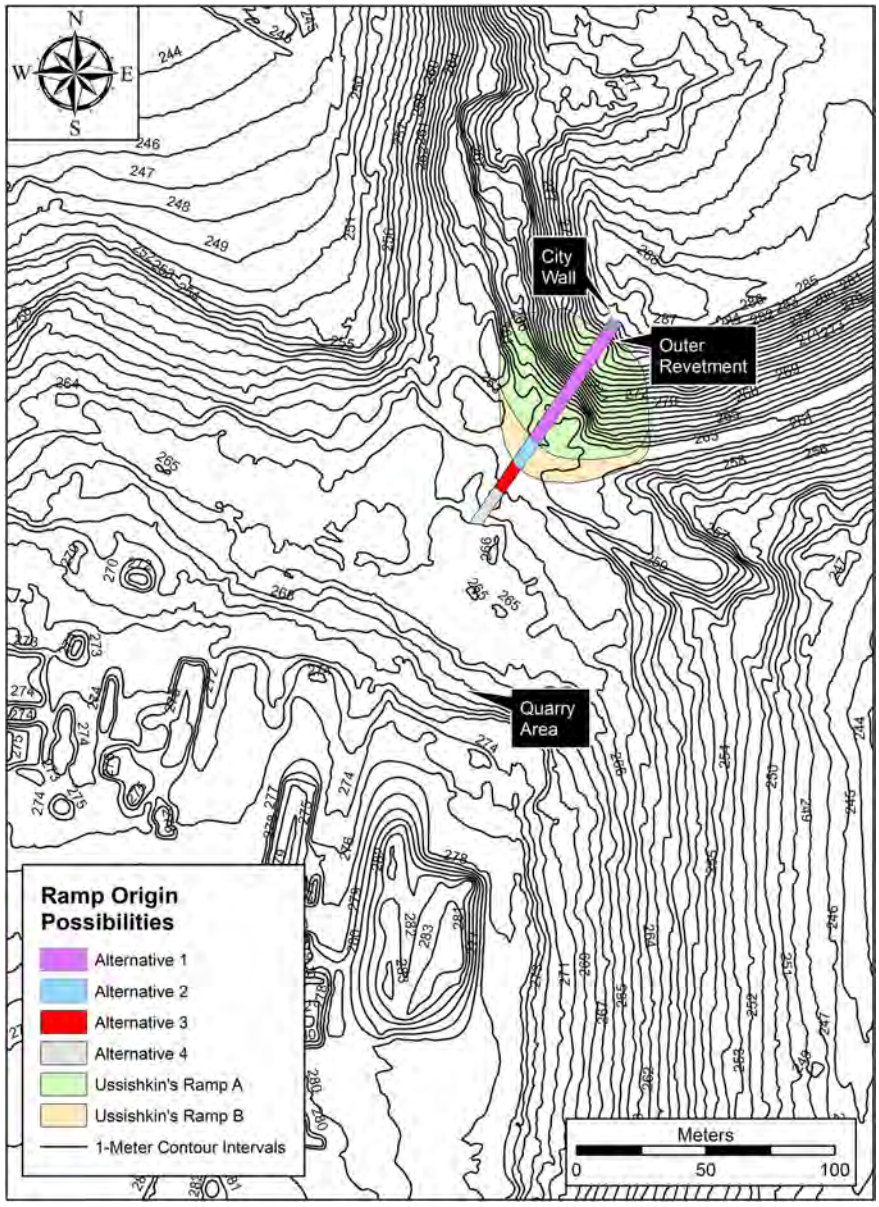

FIGURE 12
Small Unmanned Aerial System (sUAS) orthophoto imagery of Tel Lachish, July 2019. The three possible reconstructions of the ramp are marked in different colours.

Height: the local topography is basically the same as it was in 701 BC, and thus the Level III city was some 20 m above the base of the mound in its south-west corner; Length: from the starting point near the quarry, the distance to the city wall was *c*.81 m; and Width: a width of about

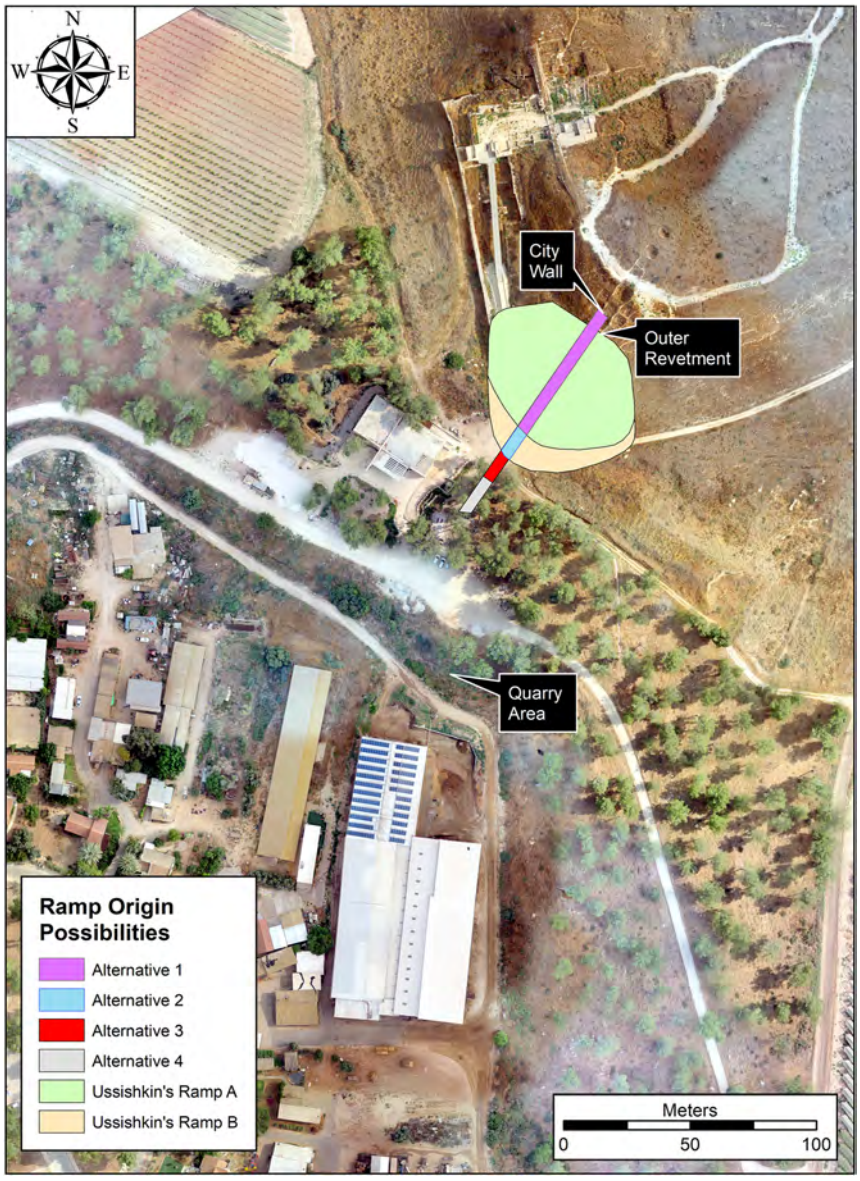

FIGURE 13
Topographic contour map of Tel Lachish. The three possible reconstructions of the ramp are marked in different colours.

5 m on the top surface would have enabled two siege machines to be pushed up in succession, while providing space for archers and slingers. The width at the base increased as the ramp approached the city; halfway along, at 40 m, the base width would be *c*.15 m.

TABLE 3
Slope, distance, volume and weight dimensions for the Lachish ramp

Alternative	Slope (°)	Distance (m)	Volume (m^3)	Weight (tons)	Reference
1	28.51	56.58	6500	13,000	Ussishkin 2004, 716–17
2	25.18	68.38	9500	19,000	Ussishkin 2004, 716–17
3	23.11	80.73	9728	19,456	Our estimation
4	21.73	97.88	12,727	25,454	Our estimation

The volume of the ramp in cubic meters was calculated from the photogrammetry data. This gives a volume of *c.*9728 m^3 and 19,456 tons of stones for Alternative 3 (Table 3). As calculated above, three human chains could move some 100,000 stones a day. With an average weight of 6.4 kg per stone, 640 tons of stones could be moved in a day. At this rate, about 25 days were needed to complete the ramp. Four human chains could move 160,000 stones a day, about 1000 tons, and complete the work in about 20 days.

THE ICONOGRAPHIC SOURCES: DO THEY SUPPORT THE MODEL?

The Assyrian artists were not interested in the earlier phase of the siege, which was occupied by the tedious construction process of the ramp. Instead, they presented a dramatic attack with siege engines and various units of the Assyrian army. Some scholars (e.g. Petrie 1891, 37–8; Ussishkin 1982) have taken the relief as an accurate representation of the battle. Petrie wrote: 'This testing of a sculpture excavated in Assyria, hundreds of miles distant from the place, is of great interest, as it shows that some sketches and notes were actually made, probably by a royal designer attached to the court, one of the secretaries.' Some scholars, however, emphasize the artistic aspect of the reliefs, their role in royal propaganda and the various difficulties posed in their interpretation (Jacoby 1991; Winter 1997; Uehlinger 2003; Smoak 2008). Nevertheless, the relief conveys important information with regard to the paving of the top surface of the ramp. This paving is portrayed as three rows of elongated objects (Fig. 2). It seems to us that these are wooden planks placed side by side to create a convenient surface for pushing the heavy siege engine up the ramp, from the ground level near the foot of the mound to the base of the city wall.

Another matter arising from the Assyrian iconography concerns the iron chain that was uncovered at the top of the siege ramp (Ussishkin 2004, 734). Yadin (1984) noticed that in one of the Assyrian reliefs the defenders used a chain to deflect the battering ram. He concluded: 'Here is a rare case of ancient reliefs and archaeological discoveries complementing each other, thus explaining the chain found at Lachish.' We will discuss this chain below.

THE ANCIENT SOURCES: DO THEY SUPPORT THE MODEL?

The Assyrian sources provide no information on the logistics involved in the construction of siege ramps. The historical inscriptions concentrate on political aspects and on the booty taken from the relevant cities rather than how much time and manpower were needed for the construction of siege ramps.

While these aspects were of no importance to the Assyrians, they seem to have had a deep impact on the people of Judah. The prophet Isaiah, who lived at the end of the eighth century BC and

was an eyewitness to the events, mentioned the Assyrian army in some of his prophecies. He relates to the Assyrians as a mighty, supernatural power: 'None of them tired, none of them stumbling, none of them asleep or drowsy, none of them with belt unfastened, none of them with broken sandal-strap' (Isaiah 5:27, online New Jerusalem Bible). How did the Assyrian army function day and night without sleeping?

Another prophecy declares that the city of Jerusalem will be saved from the Assyrians: 'This, then, is what Yahweh says about the king of Assyria: He will not enter this city, will shoot no arrow at it, confront it with no shield, throw up no earthwork against it' (2 Kings 19:32, online New Jerusalem Bible). In view of the Hebrew verb used in connection with the shield (יקדמנה), however, the phrase would be better translated as 'he will not advance a shield towards her [the city].' The order of the Assyrian actions here is shooting arrows, advancing a shield and constructing a siege ramp. While shooting arrows and constructing a ramp are aggressive actions, why is a shield, a defensive object, mentioned here?

Here and in other cases (2 Samuel 2:15; Jeremiah 6:6; Ezekiel 4:2, 17:17, 21:27, 26:8; Daniel 11:15), the verb used for the construction of the ramp is *spk* (Eph'al 1984, 64). The same verb is used for pouring liquids such as water (1 Samuel 7:6) or blood (Leviticus 4:7; Deuteronomy 12:27). Why does the description of a ramp's construction include a verb used for pouring materials?

It seems that Isaiah's words can be better understood in the light of our model. The shield mentioned by the prophet is the large and heavy one that protected the builders of the ramp and was advanced closer and closer to the city every day. The shield prevented the Judean warriors from disrupting the construction of the ramp, and thus became a symbol of the Assyrian supremacy. Since it was built from the southern end, the ramp at Lachish was constructed by dumping the building material, an action that can be likened to the pouring of liquids. The mighty Assyrian army was active day and night during the construction of the siege ramp.

THE BATTERING RAM AND ITS IRON CHAINS

The use of a battering ram is recorded as early as the third millennium BC (Steinkeller 1987; Nadali 2009). This military technique has been discussed by various scholars (Yadin 1963, 16–18, 313–16, 400–1; Madhloum 1965; Scurlock 1989; Kern 1999, 46–51; Ussishkin 2004, 765–7; De Backer 2014). In Assyrian texts and reliefs, the construction of siege ramps and the shattering of city walls by battering rams commonly feature in portrayals of the conquest of cities.

The battering ram was a large, heavy wooden beam with a metal tip on the active end. Its main effect was to deliver a repeated impact on the city wall, until the wall crumbled and collapsed. The ram's operation required a mechanical device, probably a suspension frame, to swing the heavy beam back and forth. The ram and its operating device were placed inside a siege engine, a large wheeled wooden box covered with metal sheets to protect the attackers from objects hurled from the city above. The machine could carry additional military equipment, which in the case of Lachish seems to have included a water tank (Ussishkin 2004, fig. 13.59). When all these functions were incorporated in a single siege engine, the result was a very heavy installation, which could easily weigh between 500 kg and 1000 kg (a ton). The wheels enabled this massive device to be propelled up the siege ramp to the city wall. It is likely that the siege engine was moved by both pushing and pulling, and that this was probably therefore done by night. The soldiers operating the ram entered the siege engine only when it was in its final position against the city wall.

The smooth operation of the battering ram required a suspension device to create a pendulum action. How was this achieved? Yadin (1963, 314) suggested that the wooden beam was suspended from a rope attached to its upper front part. Such an arrangement, however, would allow the heavy wooden beam to swing not only back and forth but also to the sides; the beam would have needed to be attached at two points at least (Scurlock 1989, 131). Linguistic analysis of the Akkadian terms used to describe the siege machine and the battering ram points to the use of the word *umāšu*, (clamp), referring to the use of clamps and chains for suspending the heavy wooden beam (Scurlock 1989). The constant swinging of the heavy wooden beam would quickly wear out any rope made from organic fibres, and so metal chains are better for this task.

An iron chain was found on top of the siege ramp at Lachish. On the basis of Assyrian reliefs, Yadin (1984) suggested that the chain had a hook at its end and was used by the defenders to snare and deflect the battering ram. Ussishkin, however, based on the siege of Palataea in 429 BC, suggested that the iron chains were used for suspending heavy beams that the defenders used to drop on and snap off the head of the battering ram (Ussishkin 2004, 734). Both suggestions link the chain to the Judean defenders. Such an iron chain, however, has never been found inside Lachish or any other Judean city. Thus, the iron chain found on the ramp is more likely to have originated from an Assyrian siege engine, an advanced piece of Assyrian military technology.

CONCLUSIONS

The case study of Lachish has presented a unique opportunity in combining diverse sources: Assyrian texts (primary sources), the Biblical text (secondary sources), iconography and archaeology. Our analysis has shown that the combination of all these sources can add up to a better understanding of the construction of the ramp at Lachish (Table 1).

A major problem faced by the Assyrian army was the supply of stones: over one million stones were needed. Where did these stones come from? Collecting natural field stones from the surface around the site would require a great deal of time and would slow the construction of the ramp. A better solution would be to quarry the stones as close as possible to the southern end of the ramp. At Lachish there is indeed an exposed cliff of the local bedrock exactly at the point where one would expect it to be.

The Assyrian ramp was constructed from south to north, from the point furthest from the city walls. The raw material was quarried on the spot or a few hundred metres away from the southern end of the ramp. The stones were medium-sized and hence not too heavy to handle.

Time was the main concern of the Assyrian army. Hundreds of labourers worked day and night carrying stones, possibly in two shifts of 12 hours each. The manpower was probably supplied by prisoners of war and forced labour of the local population. The labourers were likely protected by massive shields placed at the northern end of the ramp, and advanced towards the city by a few metres each day.

At the end of the construction the top surface of the ramp was uneven and very rough. Earth and wooden planks were laid to create a smooth passageway on top of the stones, up which the heavy siege engines were pushed. The battering rams were suspended inside the siege engines on iron chains, which enabled them to swing back and forth without cease and eventually shatter the city wall.

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REFERENCES

AHARONI, Y. 1975: *Investigations at Lachish: the Sanctuary and the Residency (Lachish V)* (Tel Aviv).
ASTER, S.Z. 2007: The image of Assyria in Isaiah 2:5–22: the campaign motif reversed. *Journal of the American Oriental Society* 127, 249–78.
BARNETT, R.D. 1958: The siege of Lachish. *Israel Exploration Journal* 8, 161–4.
CHILDS, B.S. 1967: *Isaiah and the Assyrian Crisis* (London).
DE BACKER, F. 2009: Some basic tactics of Neo-Assyrian warfare. 2. Siege battles. *State Archives of Assyria Bulletin* 18, 265–86.
DE BACKER, F. 2014: Notes sur les machines de siège néo-assyriennes. In NEUMANN, H. (ed.), *Krieg und Frieden im Alten Vorderasien* (Münster, *Alter Orient und Alter Testament* 401), 69–86.
DE BACKER, F. 2016: *The Neo-Assyrian Shield: Evolution, Heraldry, and Associated Tactics* (Atlanta).
DEZSŐ, T. 2012: *The Assyrian Army. I. The Structure of the Neo-Assyrian Army* (Budapest).
DOUGHERTY, R.P. 1930: Sennacherib and the walled cities of Judah. *Journal of Biblical Literature* 49, 160–71.
EPH'AL, I. 1984: The Assyrian siege ramp at Lachish: military and lexical aspects. *Tel Aviv* 11, 60–70.
ESRI 2019: *ArcGIS Desktop 10.7.1* (Environmental Systems Research Institute, Redlands, CA).
FAGAN, G.G. 2010. 'I fell upon him like a furious arrow': toward a reconstruction of the Assyrian tactical system. In FAGAN, G.G. and TRUNDLE, M.F. (eds.), *New Perspectives on Ancient Warfare* (Leiden), 81–100.
GALLAGHER, W.R. 1999: *Sennacherib's Campaign to Judah: New Studies* (Leiden, *Studies in the History and Culture of the Ancient Near East* 18).
GARFINKEL, Y. 2016: The Decauville light train at Lachish (1933–1938). *Strata* 34, 165–90.
GARFINKEL, Y., HASEL, M.G. and KLINGBEIL, M.G. 2013: An ending and a beginning: why we're leaving Qeiyafa and going to Lachish. *Biblical Archaeology Review* 39(6), 44–51.
GARFINKEL, Y., HASEL, M.G., KLINGBEIL, M.G., KANG, H.-G., CHOI, G., CHANG, S.-Y., HONG, S., GANOR, S., KREIMERMAN, I. and RAMSEY, C.B. 2019: Lachish fortifications and state formation in the biblical Kingdom of Judah in light of radiometric datings. *Radiocarbon* 61(3), 695–714.
GARFINKEL, Y., HASEL, M.G., KLINGBEIL, M.G., KREIMERMAN, I., PYTLIK, M., CARROLL, J.W., WAYBRIGHT, J.W.B., KANG, H.-G., CHOI, G., CHANG, S.-Y., HONG, S., DAVID, A., WEISSBEIN, I., and SILVERBERG, N. 2021: The Canaanite and Judean cities of Lachish, Israel: preliminary report of the Fourth Expedition 2013–2017. *American Journal of Archaeology* 125(3), 419–59.
GONÇALVES, F.J. 1986: *L'expédition de Sennachérib en Palestine dans la littérature hébraïque ancienne* (Louvain).
GOTTLIEB, Y. 2004: The weaponry of the Assyrian attack. Section A: The arrowheads and selected aspects of the siege battle. In USSISHKIN, D. (ed.), *The Renewed Archaeological Excavations at Lachish (1973–1994)* (Tel Aviv), 1907–69.
GRABBE, L. 2003: *'Like a Bird in a Cage': The Invasion of Sennacherib in 701 BCE* (Sheffield, *JSOT Supplement* 363).
GRAYSON, A.K. and NOVOTNY, J. 2012: *The Royal Inscriptions of Sennacherib, King of Assyria (704–681 BC)* (Winona Lake).

JACOBY, R. 1991: The representation and identification of cities on Assyrian reliefs. *Israel Exploration Journal* 41, 112–31.
KERN, P.B. 1999: *Ancient Siege Warfare* (Bloomington).
LAATO, A. 1995: Assyrian propaganda and the falsification of history in the royal inscriptions of Sennacherib. *Vetus Testamentum* 45, 198–226.
LAYARD, A.H. 1849: *Nineveh and its Remains* (London).
LUCKENBILL, D.D. 1924: *The Annals of Sennacherib* (Chicago).
MACHINIST, P. 1983: Assyria and its image in the First Isaiah. *Journal of the American Oriental Society* 103, 719–37.
MADHLOUM, T. 1965: Assyrian siege-engines. *Sumer* 21, 9–15.
MELVILLE, S.C. and MELVILLE, D.J. 2008: Observations on the diffusion of military technology: siege warfare in the Near East and Greece. In ROSS, M. (ed.), *From the Banks of the Euphrates: Studies in Honor of Alice Louise Slotsky* (Winona Lake), 145–68.
NA'AMAN, N. 1974: Sennacherib's 'Letter to God' on his campaign to Judah. *Bulletin of the American Schools of Oriental Research* 214, 25–39.
NADALI, D. 2009: Representations of battering rams and siege towers in Early Bronze Age glyptic art. *Historiae* 6, 39–52.
PETRIE, W.M.F. 1891: *Tell el Hesy (Lachish)* (London).
Pix4D 2020: *Pix4D Mapper 4.5.6* (Lausanne).
RUSSELL, J.M. 1991: *Sennacherib's 'Palace without Rival' at Nineveh* (Chicago).
RUSSELL, J.M. 1993: Sennacherib's Lachish narratives. In HOLLIDAY, P.J. (ed.), *Narrative and Event in Ancient Art* (Cambridge), 55–73.
SCURLOCK, J.A. 1989: Assyrian battering rams revisited. *State Archives of Assyria Bulletin* 3(2), 129–31.
SCURLOCK, J.A. 1997: Neo-Assyrian battle tactics. In YOUNG, D.G., CHAVALAS, M.W. and AVERBECK, R.E. (eds.), *Crossing Boundaries and Linking Horizons: Studies in Honour of Michael C. Astour on His 80th Birthday* (Bethesda), 491–517.
SenseFly 2018: *Emotion 3.5* (Lausanne).
SMOAK, J.D. 2008: Assyrian siege warfare imagery and the background of a biblical curse. In KELLE, B.E. and AMES, F.R. (eds.), *Writing and Reading War: Rhetoric, Gender, and Ethics in Biblical and Modern Contexts* (Atlanta), 83–91.
STARKEY, J.L. 1936: Excavations at Tell el Duweir, 1935–6. *Palestine Exploration Quarterly* 68, 178–89.
STEINKELLER, P. 1987: Battering rams and siege engines at Ebla. *NABU* 1987, 14.
TADMOR, H. 1985: Sennacherib's campaign to Judah, historical and historiographical considerations. *Zion* 50, 65–80 (Hebrew).
TADMOR, H. 1997: Propaganda, literature, historiography: cracking the code of the Assyrian royal inscriptions. In PARPÓLA, S. and WHITING, R.M. (eds.), *Assyria 1995: Proceedings of the 10th Anniversary Symposium of the Neo-Assyrian Text Corpus Project, Helsinki, September 7–11, 1995* (Helsinki), 325–38.
TUFNELL, O. 1953: *Lachish III: The Iron Age* (London).
UEHLINGER, C. 2003: Clio in a world of pictures – another look at the Lachish reliefs from Sennacherib's Southwest Palace at Nineveh. In GRABBE, L.L. (ed.), *'Like a Bird in a Cage': The Invasion of Sennacherib in 701 BCE* (Sheffield, *JSOT Supplement* 363), 221–307.
USSISHKIN, D. 1982: *The Conquest of Lachish by Sennacherib* (Tel Aviv).
USSISHKIN, D. 2004: *The Renewed Archaeological Excavations at Lachish (1973–1994)* (Tel Aviv).
USSISHKIN, D. 2014: Biblical Lachish. *A Tale of Construction, Destruction, Excavation and Restoration* (Jerusalem).
WINTER, I.J. 1997: Art in Empire: the royal image and the visual dimensions of Assyrian ideology. In PARPÓLA, S. and WHITING, R.M. (eds.), *Assyria 1995: Proceedings of the 10th Anniversary Symposium of the Neo-Assyrian Text Corpus Project, Helsinki, September 7–11, 1995* (Helsinki), 359–81.
WRIGHT, G.E. 1955: Judean Lachish. *Biblical Archaeologist* 18, 9–17.
YADIN, Y. 1963: *The Art of Warfare in Biblical Lands: In the Light of Archaeological Study* (London).
YADIN, Y. 1984: The mystery of the unexplained chain. *Biblical Archaeology Review* 10(4), 65–7.