

# A Unique Assyrian Iron Smithy in the Northern Negev (Israel)

In 1978 Beno Rothenberg was invited by the Director of the Tel esh-Shari'a excavation, to investigate an unusual metallurgical installation which had begun to show up in the excavation of the Citadel's courtyard. A small IAMS team excavated the iron-working installation, the metallurgical investigation of the finds was undertaken by Ronnie Tylecote. Although originally written for the final report on the excavations at Tel esh-Shari'a (still in preparation) it was considered appropriate to publish it in the present issue of IAMS Newsletter, which is dedicated to the memory of Ronnie Tylecote.<sup>1</sup>

## An Assyrian Citadel at Tel esh-Shari'a

Tel esh-Shari'a<sup>2</sup> is situated in the north-western Negev of Israel. It has been identified with the Biblical city of Ziklag (1 Samuel 27: 6-7), a town in the 'country of the Philistines'. It was under the political patronage of Philistine Gath and was given to David by Achish, king

of Gath, as a refuge during his flight from Saul. It remained David's headquarters until he became king of Israel.

Tel esh-Shari'a has been excavated since 1972 under the direction of Professor E. D. Oren, Ben Gurion University of the Negev, Beersheba. Twelve archaeological strata were exposed, dating from the Late Bronze Age

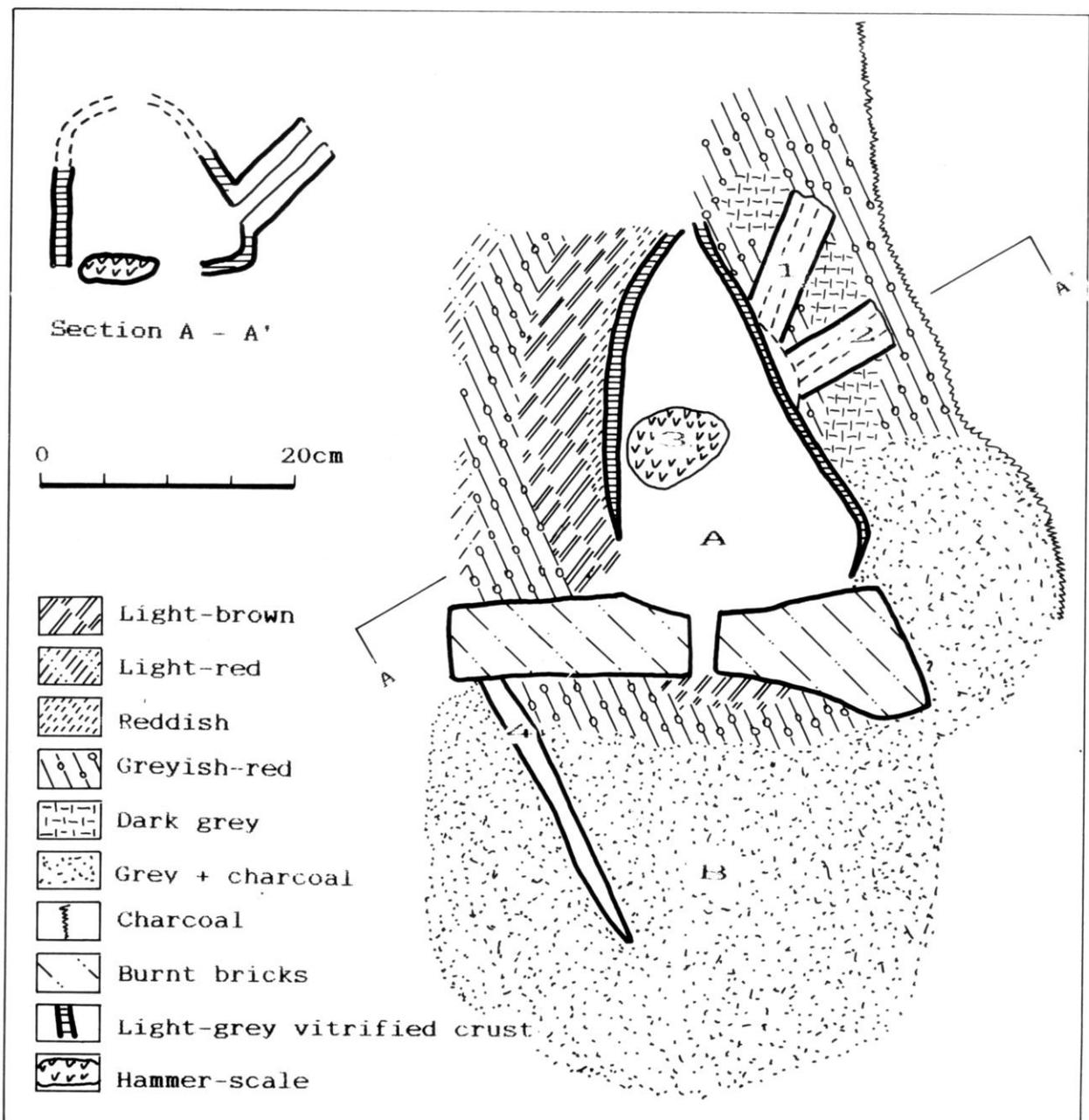


Fig. 1. Plan and section of excavated smithy. 1 and 2—two tuyeres found in situ; 3—piece of furnace bottom; 4—iron spike.



Fig. 2. Locus 2785. Assyrian iron smithy before its complete excavation. Note the iron spike in front of the hearth.

(16th–15th century B.C.) to Early Islamic times (7th century A.D.) and later. There was also evidence for Chalcolithic and Middle Bronze Age occupation of the tell before a city was built on it.

In stratum VI (7th–6th century B.C.), on the northern tip of the hillside, a citadel with unusually thick walls (4m wide) was excavated, which was part of the defensive system of the city in Assyrian times. Among the archaeological finds in the citadel was pottery of typical 'Assyrian palace ware' as well as a crescent-shaped bronze standard and a socketed bronze spearhead of the type often depicted on Assyrian reliefs.

According to the ceramic evidence, the Assyrian citadel was destroyed in the late seventh or early sixth century B.C., perhaps during one of the Babylonian military campaigns to southern Palestine or by an Egyptian military expedition of the Twenty-sixth Saite Dynasty. It was the last fortified city at Tel esh-Shari'a.

In 1978 the courtyard of the citadel was excavated and the installation, described in the following report, was uncovered and subsequently investigated by the present authors.

#### An iron working furnace (Locus 2785) in the citadel's courtyard.

Excavating Locus 2785 (on the Tel esh-Shari'a excavation plan) turned out to be a small furnace, roughly triangular, formed in a shallow depression in the floor of the courtyard (Figs. 1 and 2). It was possible to establish the method of its construction. First, a shallow, egg-shaped pit was dug into the hard floor of solidly cemented crushed limestone and brick fragments, 20cm deep, 75cm long and 30cm(A) to 40cm(B) wide. Then the narrow half of the pit (A) was filled with a mass of highly silicious clay and the actual hearth, shaped as an isosceles triangle, was roughly hand-shaped into this clay mass. Numerous fingerprints were found preserved in its hard-baked inner surface.

Two bricks were used to close the triangular hearth at its base, but care was taken to leave a narrow opening between them. Whilst these bricks showed the typical

light-red discolouration of burned brick material, the two other sides of the hearth showed a fairly uniform, 1–2cm thick, light-grey layer of highly vitrified silicious clay, behind which typical grey-to-red heat discolouration penetrated the surroundings for about 15cm. At first this grey layer appeared to be furnace lining, as is often found in metallurgical installations, but closer investigation revealed that it was not a proper, intentionally applied refractory lining, the result of a fettling operation, but a heavily vitrified crust created by the effect of intense heat on the sandy walls of the hearth.<sup>3</sup>

Two tuyeres were found in situ (Figs. 3 and 4), penetrating the furnace wall at an angle of about 35°, without, however, protruding into the actual hearth. Strangely enough, the two tuyeres, located close together and obviously acting as protective nozzles for 'twin-bellows', were of quite different shapes and method of manufacture. Tuyere 1 was round in section, slightly conical, with an inner diameter of 11mm, its length about 8cm, and its outer diameter, at the furnace end, 4.3cm. Tuyere 2 was rectangular, 4 x 3 cm, with an inner diameter of 10mm, its length more than 10cm. Tuyere 1

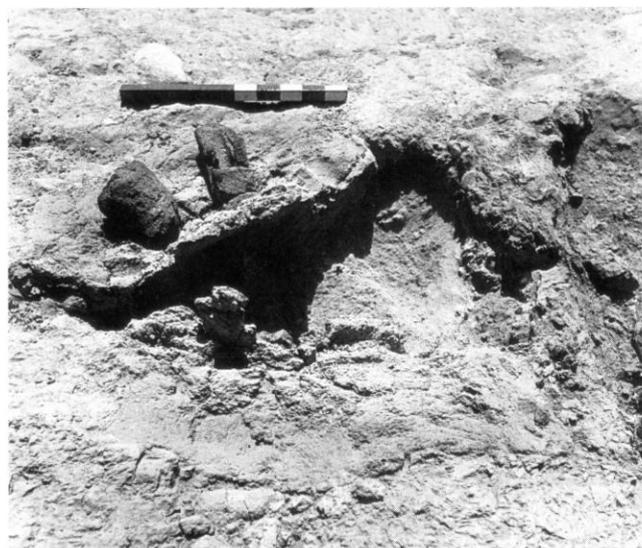


Fig. 3. The excavated hearth with the two clay tuyeres in situ. In front, a fragment of furnace wall shows the curvature of the arched top.

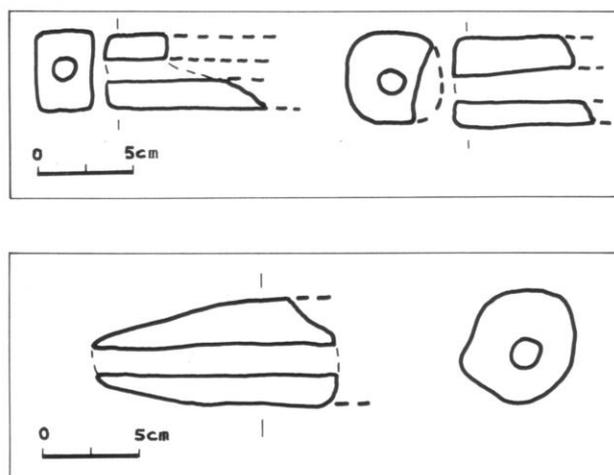


Fig. 4. Drawing of the two tuyeres found in situ in Furnace A.



Fig. 5. Furnace A with tuyeres in situ and cinder-like 'furnace bottom' at conclusion of its excavation.

was apparently made by rolling the clay mass around a cylindrical rod, the removal of which left a perfectly regular tubular hole for the airstream. Tuyere 2 was made in a mould and its 'seams' were still discernible. Both tuyeres, which were found damaged and seemingly in secondary use, were made of the same reddish-brown clay used for making the hearth, and both showed light-grey discolouration at the end nearest to the fire. In fact, the tuyere ends (at the left side on the drawings in Fig. 4) and the hard 'crust' of the hearth wall were found cemented together by the intense heat inside the furnace.

It was very informative to study in detail the heat discolouration visible around the hearth. The relatively deep penetration into the furnace wall and fill behind the tuyeres showed, as would be expected, that the hottest area of the hearth must have been right in front and above the air-blast of the tuyeres. The bottom of the hearth was charred to whitish-grey, typical for metallurgical furnace bottoms. Near the tuyeres, and also further up in the narrowing end of the hearth, a thick layer of cinder-like, slaggy material had formed at the bottom of the hearth (Fig. 5).

The upper part of the furnace structure was found to have been damaged during the excavation of the fill layers above. However, a number of curved furnace fragments found in the vicinity, and the shape of the preserved parts of the walls, provided the evidence for the reconstruction of a furnace with an arched top, probably with an opening for the escape of the exhaust gases. Its inner total height, when reconstructed with the arched top, was 15–20cm (see section in Fig. 1).

The wider part of the pit (B), in front of the hearth (A), was a semi-circular working space, also used as a store for charcoal. Here an iron spike was found, 25cm long, and 2cm diameter (see Figs. 1 and 6).

Hearth A, as found in the excavation, was not the first metallurgical installation built into the shallow pit, as was shown by the thin layer of charcoal and charred soil cropping out from underneath the clay mass on both sides of the preserved furnace structure. We may therefore assume that this spot had been previously used as a smithy and the furnace was repeatedly repaired or even reconstructed when rendered unserviceable by use.

### Metallurgical examination of the metallurgical finds.

1. A friable 'cake' of typical smithy furnace bottom material (Sample No. 1134, basket No. 8528, Locus 2785) consisting mostly of sand and charcoal, but here and there were pieces of crystalline material which were found to be hammer-scale.<sup>4</sup> This sample was found in situ at the bottom of hearth A, near the tuyere. Microscopically two main phases could be identified: a light phase which was mostly wustite with some iron and magnetite precipitated due to the eutectoidal decomposition  $4\text{FeO} - \text{Fe} + \text{Fe}_3\text{O}_4$ . A dark phase was anorthite glass.

2. Four pieces of magnetic slag (Sample No. 1132, basket No. 7869, Area D, Locus 2755).

3. A heavy piece of vesicular magnetic slag, greenish with holes on one side only.

Samples 2 and 3 were virtually the same. They were not found in Locus 2785 (the installation excavated by our team) but elsewhere in the courtyard of the Assyrian citadel indicating that further metallurgical operations were taking place in other installations in the courtyard.

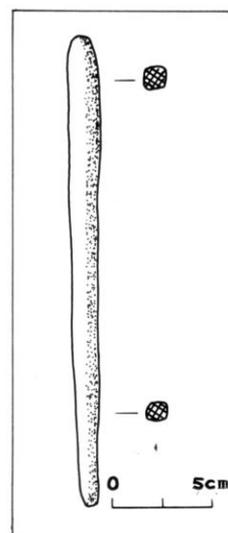


Fig. 6. The iron spike found in the pit (B) in front of the hearth (A).

These pieces of slag looked more like smithing than smelting slag<sup>5</sup>. Microstructural examination showed that the hammer-scale had been virtually absorbed into the vitrified wood-ash producing a slag with relatively low iron content. Some of the dissolved iron had been precipitated out of the dendrites of wustite and some of the hammer scale had not been completely absorbed.

The matrix consisted of thin, lathy, crystals which were certainly not fayalite but probably one of the wollastonites, wollastonite-beta (CaFe)O.SiO<sub>2</sub> or pseudo-wollastonite-alpha CaO.SiO<sub>2</sub>. The lime would be derived from the wood ash and some of this would be replaced by Na or K. The vesicles in sample 3 would come from the decomposition of the alkali carbonates.

Slag samples 2 and 3 were completely vitrified and must have been raised to a temperature of the order of 1110–1200°C by means of bellows.

4. A fully rusted magnetic iron spike.(Sample No. 1137, basket No. 8539, Locus 2785). (Fig. 6).

5. A piece of completely rusted magnetic iron, weighing 60g. Its size was about 5 x 4cm, 1cm thick. Its original shape or function could not be established. (Sample No. 1133, basket No. 7828, Locus 2785).

Since samples 4 and 5 contained no residual metal, not much could be done with them. Residual 'relict' structures are only met with when corrosion has just been completed and residual metal is present somewhere in the specimen.

6. A round tuyere made of yellowish clay, 12cm long, its inner diameter 1.4cm. (Sample No. TSA 10142, Locus 2783–Fig. 7). Although found in the vicinity of the excavated smithy at Locus 2785, it did not seem to be related to this installation, especially as it was unused. The tuyere, tapered at its active tip, was typical of a crucible furnace or smithy.

## Discussion

Although Furnace A was the only metallurgical installation found in the courtyard of the Assyrian citadel, there was evidence for additional metal working in the area. The very fact that two quite different types of tuyeres were used in Hearth A for one and the same set of 'twin-bellows' was a clear indication of the existence nearby of other installations serving pyro-technological purposes. The builder of Furnace A just used available tuyeres, which had been used before and were damaged. Furnace A would not have been suitable for smelting, it was obviously a smithing furnace for the repair of iron weapons and tools.

There was, however, a basic problem. Furnace A was not built at all like an ordinary smithy because its builder took the trouble to carefully construct his furnace with an arched top. A blacksmith would not need highly reducing conditions in his forge, which would best be achieved by such an arched hearth. In fact, a smith does not really need a special furnace installation but could do just as well with a pair of bellows attached to a tuyere and a pile of charcoal. The smith would place his iron

implement in the pile of charcoal in front of the tuyere where a high enough temperature (above 800°C) was easily obtainable. If he dealt with wrought iron, most of the work could have been done by cold hammering and annealing at 700°C. Many primitive smiths still work this way quite satisfactorily<sup>6</sup>. So why the arched and triangular shaped hearth?

Furnace A would be quite suitable for an intentional carburization process used to substantially improve the quality of iron weapons and tools.<sup>7</sup> Iron packed in red-hot charcoal (above 920° C) in the reducing zone of the hearth, i.e. at some distance from the oxidizing zone right in front of the tuyere, would convert to its austenite state and absorb carbon extremely easily. At a temperature of 1150°C, easily reached in Furnace A, as much as 1.0% carbon could dissolve in the iron and diffuse. By this process wrought iron, low in carbon, would be converted into steel.

It is rather unfortunate that we have no information on iron objects with residual iron from Tel esh-Shari'a to verify that intentional carburization<sup>8</sup> was already known there in Assyrian times, but the furnace at Locus 2785, difficult to understand as simply a smithing hearth, could well have had such a purpose.

Since hitherto no iron forge or smithing installation has been found at Assyrian sites<sup>9</sup> – in fact no smithy of any period especially constructed for a carburization operation – the Tel esh-Shari'a smithy is a welcome addition to archaeo-metallurgical knowledge.

Beno Rothenburg and R. F. Tylecote†

## Notes

1. In the following report we have retained loci, sample and basket numbers as given by the excavators of Tel esh-Shari'a in order to make it possible to relate our results with the details of the general report of the excavation. For the same reason, the metallurgical investigation of the finds from Locus 1785, by R. F. Tylecote, also includes a few metallurgical finds not directly connected with the smithy excavated by our team.
2. On the excavations at Tel esh-Shari'a see E. D. Oren, in M. Avi-Yonah and E. Stern (ed.), *Encyclopedia of Archaeological Excavations in the Holy Land*, Jerusalem, 1978, Vol. IV, 1059–69; plan of the Assyrian citadel (as excavated by 1976) is on p. 1069. The courtyard of the citadel was further excavated in 1978.
3. See Rothenburg, B., *The Ancient Metallurgy of Copper*, 1990, Chapter 1. The smelting experiments by John Merkel, M. Bamberger and P. Wincierz, reported in chapters 2 and 3 of this volume showed that a very hard, heavily vitrified crust, looking very much like proper furnace lining, was formed on the sand-built walls of an unlined smelting furnace by the intense heat of the smelting process. Similar findings were reported by Kingery, W. D. and Gourdin, W. H., Examination of Furnace Linings from Rothenburg Site No. 590 in Wadi Zaghra (Sinai), in *Journal of Field Archaeology*, Vol. 3, 351–3.
4. Compare R. F. Tylecote, *Metallurgy in Archaeology*, London, 1962, 254, plate 26c.
5. On the difference between smelting and smithing slag see H. G. Bachmann, *The Identification of Slags from Archaeological Sites*, London, 1982, 30–33, plates 16–27.
6. R. F. Tylecote, *A History of Metallurgy*, London, 1976, 42; idem, From Pot Bellows to Tuyeres, *Levant*, Vol. 13, 1981, 107–18.
7. R. F. Tylecote, *Metallurgy in Archaeology*, 1962, 244–5; W. K. V. Gale, *Iron and Steel*, London, 1969, 70; T. S. Wheeler and R. Maddin, in The. A. Wertime and J. D. Muhly (eds), *The Coming of the Age of Iron*, New Haven, 1980, 116–25.
8. On the problem of intentional carburization see Wheeler-Maddin (n. 7) and Cyril Smith, quoted by V. C. Piggott, *ibid* (n. 7), 432–3.
9. R. Pleiner and J. K. Bjorkman, The Assyrian Iron Age: The History of Iron in the Assyrian Civilisations, *Proc. Amer. Anthropol. Soc.*, Vol. 118, 1974, 305.