The Early Islamic crucible steel industry at Merv

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In 1993 dramatic new evidence for early crucible steel production was discovered at the ancient city of Merv in the Central Asian state of Turkmenistan. The preliminary analyses of archaeometallurgical remains from an Early Islamic workshop at this site were first reported in this Newsletter (Merkel, Feuerbach and Griffiths 1995). These remains are the subject of doctoral research by Ann Feuerbach at the Institute of Archaeology, University College London. Further preliminary analyses of the archaeometallurgical and other finds and the excavations themselves have been published (Feuerbach, Merkel and Griffiths 1997, 1998; Feuerbach, Griffiths and Merkel in press; Herrmann, Kurbansakhatov and Simpson *et al*. 1997, 10-13). The purpose of this short report is to update readers of IAMS and place the excavated remains into a wider context.

The ancient city of Merv is situated in the heart of the fertile alluvial delta created by the river Murghab that flows north from Afghanistan. Surrounded on all sides by steppe and desert, this delta resembles a huge oasis that has been continuously occupied since the 3rd millennium BC. During the 5th or 6th century BC a city was founded on the site known today as Erk-Kala; this became the citadel of the sprawling Hellenistic city of Antioch Margiana, occupied thereafter for a thousand years throughout the Parthian and Sasanian periods and surviving today as the deserted city-site of Gyaur-Kala. The ruins of Merv were described by 19th century British and Russian travellers and explorers, and first excavated in 1890. Later Soviet archaeologists based in Tashkent made some significant discoveries between the late 1940s and 1980s, including the western-most known ancient Buddhist monastery and richly decorated houses in the nearby medieval city-site of Sultan-Kala.

The Soviet teams also paid particular attention to the investigation of industrial areas or so-called "craftsmens quarters". Extensive fired brick and pottery-producing areas were identified within and to the south of Gyaur-Kala, and immediately outside the west wall of Sultan-Kala. All of the published remains date to the 8th century AD or later; the single so-called "Parthian" pottery kiln identified in YuTAKE Trench 5 on a low mound in the north-east corner of Gyaur-Kala was later recognised to be an Early Islamic construction on an earlier part of the site (Zaurova 1958). Similar Sasanian and earlier industrial suburbs must have existed to support the ancient city of Merv but these appear to have been either buried below later occupation in Sultan-Kala or destroyed in agricultural redevelopment. Nevertheless, the identified remains offer important insights into developments of medieval technology at an important urban centre on the interface of Iran and Central Asia.

In AD 651 the last Sasanian king, Yazdigird III, was murdered a short distance outside the city-walls of Merv to which he had been refused entry by the governor. An Arab army entered the city soon afterwards and Merv became a military headquarters for the Arab conquest of Central Asia. Large numbers of people from Iraq and Transoxiana settled in the vicinity and a very large mosque with a spiral minaret of the same type as at Samarra and Abu Dulaf was constructed at the town of Khurmuzfarrah [present-day Kishman-tepe West or Uly Kishman], on the main road leading north from Merv to Khorezm. At Merv itself, Arabic ostraca from a Late Sasanian building on the summit of the citadel, and sporadic finds of Arab-Sasanian bronze coins from other trenches suggest a continuing administration within the 7th or 8th centuries yet by the 9th century most of Erk-Kala and Gyaur-Kala appear to have been abandoned in favour of new locations closer to the Razik canal that ran along the western side of Gyaur-Kala. One possible reason for this urban drift was social tension between Muslim immigrants and the indigenous population, probably exacerbated by the relative difficulty of gaining access or fresh water.

The previously inhabited areas of Gyaur-Kala now became extramural industrial suburbs. Surface surveys and detailed observation of the micro-topography suggest that the new industrial activity was based in separate workshops, some clustered near tracks running between the east and west gates or from the centre of the site to the position of the south gate; other workshops were separated by large open spaces. Many, if not all, of these workshops were engaged in pyrotechnology. Although there is little evidence for the organisation of the industry, two distinct types of pottery kiln have been excavated. One consists of a deep subterranean firepit, square in plan, with a perforated grate supported on transverse arches; the firing-chambers do not survive. Two examples of this type have been excavated by the International Merv Project (Herrmann, Kurbansakhatov and Simpson *et al*. 1999, 13-15, pl. III). The second type is smaller and consists of a circular kiln, between 2.1-2.9 m across, heated by means of a flue leading from an external firepit. Associated pottery and coins recovered by Soviet teams suggest an 8th century date for this type (Zaurova 1958).

In 1993 the first remains of crucible-steel furnaces were found in the same industrial quarter. The plan of these somewhat resembles that of the second type of kiln found by the Soviet teams, suggesting a common technological source. A total of four crucible-steel furnaces have now been excavated, constructed with clay walls reinforced along the inside with reused fragments of vitrified crucible. The floors of the furnaces were sunk below the level of the surrounding deposit; the tops were destroyed but they are likely to have been domed originally. Each had a single ceramic tuyere, with a diameter of c. 8 cm, that entered the base of the furnace through the centre of the floor; the opposite end of the tuyere was presumably attached to a bellows placed within a pit (Fig. X). In one case, the collapsed remains of a mudbrick shield wall was found along one side of the bellows-pit where it had probably served to protect the operator from the heat of the nearby furnace as the exit flues for the furnaces were at ground level. Charcoal residues from nearby refuse pits suggests that a combination of high-calorie narrow roundwood, particularly imported pistachio but also members of the *Chenopodiaceae* and other species, was employed (Gale forthcoming).

After each firing the upper part of the furnace was partly dismantled in order to gain access to the contents. Examination of broken crucibles found within nearby refuse pits provides a glimpse of the firing process. The crucibles were made of a high refractory clay that was thrown on the wheel to produce a flat-based cylinder c. 20 cm high with a diameter of 8 cm. These were covered with a circular perforated lid, 8 cm across, sealed with wet clay and placed on top of separate circular pads of refractory clay positioned on the furnace floor. It is estimated that a single furnace would have held some twenty crucibles during a single firing. Refiring experiments indicate that the furnaces were fired at temperatures of up to 1500 ^{0}C, fusing the crucibles to their lids and pads and necessitating force to extract the small steel ingots within. The presence of cast iron droplets and steel prills within the glassy slag adhering to the crucible walls is interpreted as evidence for a co-fusion process as described by the contemporary writer al-Biruni; these ingots were either sold or re-

Merv, Turkmenistan: view of half-sectioned circular crucible steel furnace with pottery tuyere at the base; 1 metre scale.

worked locally. The small quantity of steel produced within each firing underlines the high relative value of the final product. The furnaces were used repeatedly, although relined each time. The refractory properties of the vitrified clay was clearly recognised as broken furnace wall and crucibles were deliberately recycled within the construction or crushed as grog for adding to new crucibles. The latter proves the co-existence of this workshop with a local ceramic industry.

Each of the excavated furnaces lay within an open space at the rear of a mudbrick workshop with rooms arranged around a paved courtyard. The stratigraphy suggests a relatively short span of occupation, possibly no more than a generation, before the workshop was abandoned or relocated to a different spot. Associated slip-painted bowls belong to the earliest tradition of local glazed wares in this region; glassware paralleled from Nishapur, splashed wares and turquoise glazed wares support a 9th or early 10th century date for the complex. Other finds include jet gaming-pieces decorated with dotted circles, presumably imported from Tus in north-east Iran, which boasted a jet industry at this period, and fragmentary chlorite cooking pots, again imported from north-east Iran.

The discovery of a crucible steel industry at Merv confirms contemporary Early Islamic written sources. This evidence suggests that Khurasan was the second most important Iranian province for the manufacture of iron and steel, the towns of Herat, Tus, Nishapur and Ghur being specifically mentioned as manufacturing centres for iron arms, armour, knives and needles whereas a locksmithing industry is attested from Merv (Allan 1995). Specialised products were therefore available in some centres and iron ingots and finished goods were widely traded; steel was particularly valued for its hardness and strength: uses include swords, daggers, maces, axeheads, spear and arrow heads and armour (Allan 1979). This pattern of production was developed from the Sasanian period, if not earlier. The 3rd century author Zosimus of Alexandria described the production of crucible steel through direct carburisation as an Indian technique that had been exploited by the Persians. Iron and steel-workers and a variety of steel weapons are attested in Middle Persian (Pahlavi) sources, and the manufacture of sword-blades from crucible steel is now confirmed by analysis of an unpatterned Late Sasanian sword in the British Museum (Lang, Craddock and Simpson 1998).

The archaeological evidence for an Early Islamic crucible steel industry at Merv has added considerably to our understanding of early medieval ferrous technology. It is likely that the design of the excavated furnaces is traditional to this region and that earlier forebears will eventually be discovered in Iran or Central Asia. Technological continuity from the Sasanian to Early Islamic periods is also suggested by archaeobotanical evidence for a cotton industry at Merv and the gradual evolution of plainware ceramic forms from 5th or 6th century types to those used in the 9th century. However, the importance of local regional trade in ingots, fuel and possibly the technology itself should not be under-estimated and further surprises probably still lie in store.

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