based objects from Jebel Qa'aqir, and other sites like Jericho, are understood to reflect 'homogenisation' as the result of local recycling. Deliberate selection of arsenic-rich copper seems to have taken place for some of the daggers. The introduction and supply of tin for alloying was intermittent during the EB IV period, which accounts for the apparent relationship between composition and object type. There are clear local characteristics of the EB IV metalworking tradition. Copper containing high concentrations of arsenic was obviously the result of long distance trade; no such arsenic-rich ores are known to exist in the southern Levant. However, it is important to emphasise that during its transport and use, this material underwent considerable secondary selection, refining, mixing, alloying and recycling.

J. F. Merkel and W. G. Dever

Fig. 7. Dr John Merkel reconstructing casting metal ingots in one-sided flat moulds.

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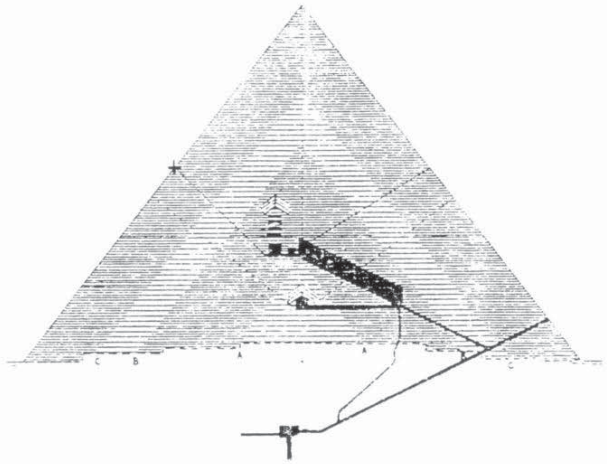
The Enigmatic Iron Object from the Great Pyramid – re-investigated

An iron plate was found by an excavation team in the Great Pyramid at Gizeh, Egypt, in 1837. This plate was said to have been found partly blocking an air passage high up on the south flank of the pyramid, but located *within* an undisturbed portion of the structure (Fig. 1).

The plate was not examined in any detail at the time and it has since been in the safe keeping of the British Museum in London. A small fragment of the plate has now been subjected to detailed examination by modern metallographic techniques. These techniques have shown, conclusively, that the plate consists of numerous laminates of wrought iron that have been inexpertly welded together by hammering (Fig. 2). The various laminates differ from each other in their grain sizes, carbon contents, non-metallic inclusions, and thicknesses. Some of the non-metallic inclusions consist of un-reacted (or incompletely reacted) fragments of the iron ore that was used to produce the iron metal. Other iron oxide 'inclusions' consist of the iron 'scale' that had formed between the inexpertly welded laminates. Yet other non-metallic inclusions are sodium- and potassium-rich 'ashy' remnants of the charcoal fuel.

The iron grains in all the laminates are equi-axial whilst the inclusions within the metal are all markedly elongated. These features show that the welding process was carried out at modest temperatures that allowed only the iron grains to recrystallise. It is signifi-

Fig. 1. Section of the Great Pyramid looking west. The find spot of the iron plate is marked by a cross on the upper left (south) side of the casing by the air hole entrance. Scale 1:2500.



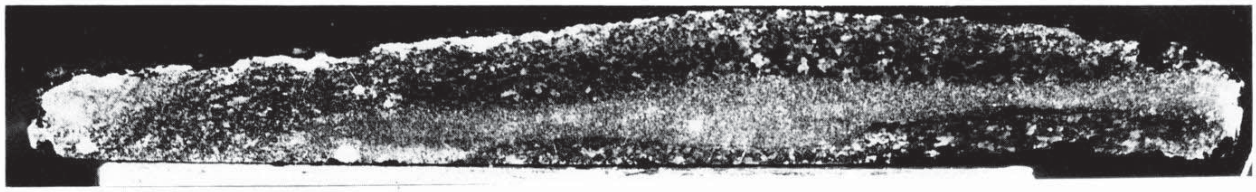


Fig. 2. Cross section of the iron plate (×13) found in The Great Pyramid of Gizeh. It shows a number of laminates that have been inexpertly welded together. The grain sizes, carbon contents and non-metallic inclusions are different in each laminate.

cant that the examined specimen contains no siliceous, slaggy, inclusions, nor does it contain more than a small trace of copper. Thus, it is most unlikely that the iron was produced as a by-product of a copper smelting operation.

The outer layers of the iron have been badly corroded and now form banded iron oxides. Significant proportions of gold were found in one of the oxidised layers and the plate may, originally, have been gold-plated.

The new data, coupled with the original, archaeological information, strongly suggest that the iron plate is contemporary with the building of the pyramid and that it is, therefore, one of the oldest known pieces of iron.

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[The Great Pyramid of Gizeh was built by the pharaoh Cheops (Khufu) of the Fourth Dynasty, c. 2560 BC. A fuller report of this investigation is to appear in *The Journal of the Historical Metallurgy Society*, vol. 23, pt. 2 (1989). Editor.]

Crucible smelting in Prehistoric Thailand

In the neighbourhood of Khao Phu Kha mountain, an ancient copper mine near Lopburi town, in Central Thailand, there are extensive mounds of ancient slag at Non Mak La (NML), Non Pawai (NP), Nil Kam Haeng (NKH), Tha Khae (TK) and Khao Sam Yoi (KSY) (Fig. 1). These were visited in 1984 and 1985 in order to assemble samples of past metallurgical activities.

Although only a very small amount of copper metal was recovered from any of the smelting sites investigated, the large quantities of slag indicated that the area around Lopburi had been an important industrial complex and that smelting had been carried out on a large scale.

The metallurgists were using an efficient and standardised process, employing a crucible smelting technology rather than the more usual method of smelting in shaft and bowl furnaces. Large numbers of fragments of thick-walled, organically tempered crucibles were recovered at the smelting sites of Non Mak La and Non Pawai. Unfortunately, no complete crucibles were found and the fragments were all quite small, often only 10% of the rim remained. Because of the absence of complete profiles the proportions of the crucibles cannot be established with any degree of certainty, but the internal diameter seems usually to have been between 12 and 24cms. The thickness varied from about one centimetre at the rim, through 1–1.5cm. for the wall, to 4cm. at the base, and while the rim thicknesses could be accurately assesed, considerable thinning had occurred in some wall and base areas due to the internal

Fig. 1. Map of the prehistoric copper casting and smelting sites in the neighbourhood of Khao Phu Kha mountain.