Gizeh iron revisited

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Abstract

Further examination of the iron plate from the Great Pyramid at Gizeh failed to detect any gold as previously reported. The authors of this paper confirm the metallographic structure but suggest this can be better explained in terms of known post-medieval iron fining technology rather than invoking unknown techniques from the remote past.

In 1989 an article by El Sayed El Gayar and M P Jones on the iron plate from the Great Pyramid at Gizeh, Egypt, appeared in this journal suggesting on the basis of metallurgical examination that it was of great antiquity[1]. The present authors published a letter in the same issue expressing reservations over some of the principal conclusions of the article. We promised, somewhat optimistically as it turned out, to provide more information in the following issue of the Journal. For various reasons our work was delayed, but now that we have been able to examine the original section studied by El Gayar and Jones we can conclude our observations on the probable history of this artifact.

First, we will adumbrate the known facts; a plate of iron was found near an air passage high up on the side of the Great Pyramid in 1837. The original finders of the piece were at some pains to stress that it was apparently found deep within the masonry of the structure after blasting (!!) had removed the two outer tiers of stone, and thus it was likely to be contemporary with the construction of the pyramid in about 2750 BC. No less an authority than Petrie[2] seemed to have accepted this, making it the earliest substantial piece of iron known. Shortly after its discovery the piece entered the collections of the British Museum (Registration no EA 39 1-13 1). There it has remained ever since with no scientific examination beyond an analysis which showed that it was not of meteoritic origin[3], until El Gayar and Jones requested a section to be cut from a corner for metallographic examination.

Their analysis of the section revealed gold on the surface of both the corrosion and of the metal beneath. The iron itself was of high chemical purity, but contained many inclusions, although these were not of slag as might have been expected for early iron. On the basis of this examination they pronounced that the iron was likely to be of great antiquity[4].

We were sceptical about this, but were unable to obtain access to the section for a long time, and thus confined our attention to the remainder of the piece. The reported presence of gold would clearly suggest that this piece was of some importance and not just a piece of recent iron. However our analyses of surface of the plate, and of a new section cut adjacent to the original section, failed to detect gold at all either in the metal or in the corrosion. The examination began with micro-analysis in the scanning electron microscope with a detection limit of about 0.3%, both at the British Museum and also independently at the Ancient Monuments Laboratory, English Heritage by Dr G McDonnell. In addition analysis was carried out by X-ray fluorescence in the British Museum; this method has a detection limit of 0.05% for gold and once again no gold was detected anywhere. It was, and remains, highly suspicious that no gold could actually be seen in the microscope either by El Gayar and Jones or by us. In our experience surface gold is almost always visible, either as a thin sheet or as particles.

Since the last report the original section has been returned to the Museum and we have been able to carry out a thorough investigation. Once again we must report that despite extensive searches no trace of gold could be detected, and it is our firm opinion that the original report of gold is incorrect.

The structure of the iron in both of the sections is very similar and we are in broad agreement with El Gayar and Jones on its identification, if not interpretation. The structure of the iron is banded, mainly consisting of wrought iron (low carbon) with some areas containing more carbon. The unusual features are the absence of slag stringers and the very large numbers of other inclusions. These are unusual in that they contain large quantities of calcium (up to 60%), phosphorus (up to 15%), and some sodium, silicon and potassium. A number of chlorine-rich areas were also found. However, we do not agree with the view of El Gayar and Jones, that these inclusions indicate ancient primitive manufacture — careless maybe, but not primitive.

The structure is unfamiliar because the piece probably falls into the historical lacunae in published microstructures that presently exists between 'traditional' solid state bloomery iron, many examples of which have been extensively studied and published by archaeometallurgists, and 'modern' iron and steel from the late 19th century when metallography had become established. Little has so far been published on the microstructure of ordinary post-medieval fined iron.

El Gayar and Jones list the various origins of the iron, together with their reasons for dismissing them as possibilities for the plate, and we will summarize and comment on these here.

1. The metal is not meteoritic as the uncorroded metal has no detectable nickel.

2. It is most unlikely to be true native iron; this is of excessively rare occurrence in usable form and the iron plate has a very different structure from the only known examples of artifacts of telluric iron found on Disko Island, Greenland[5].

3. It is also most unlikely to be a by-product of copper smelting as no trace of copper could be detected.

4. It is not bloomery iron made by smelting iron minerals to produce iron in the solid state as it does not contain slag. Bloomery iron invariably contains some slag.

5. Cast iron made in a blast furnace in the liquid state was rejected because it usually contains inclusions of iron silicates, manganese sulphide and calcium phosphate, derived from the ore or the coke.

In the end El Gayar and Jones concluded that the plate was manufactured by welding together small pieces of iron, produced by direct reduction, which runs counter to their conclusion that the metal was not bloomery iron. We can think of no way in which iron minerals could be directly reduced to form coherent lumps of iron in the solid state without the medium of slag, or how this slag could be totally removed without melting the metal. So what is it? We agree that it is not modern cast iron smelted with fossil fuel, but may it not have been cast iron smelted with charcoal and then treated by the finery process to remove the carbon and produce a solid lump or bloom of wrought iron? The authoritative book on Islamic technology by al Hassan and Hill[6] states that this was the usual method of making iron in the post-medieval Islamic world, as it was of course in Europe until use of charcoal was superseded by coke and coal. Our examination revealed numerous calcareous inclusions in addition to those reported by El Gayar and Jones containing sodium and potassium from the fuel ash, and iron oxides. These mysterious inclusions can also be explained if the iron had been fined. Several post-medieval European descriptions of the process note that a variety of materials including crushed limestone, bone etc should be sprinkled onto the stiffening iron as it formed from the decarburized cast iron. Biringuccio[7] states that crushed marble was added to purify the iron. Percy[8], writing about the fining process, describes the addition of bone with salt and lime as a flux in the fining process. Percy notes John Payne's patent of 1728 was for the use of wood ashes, glass, sandiver (saline matter, *eg* alkaline chlorides and sulphates) common salt, clay, kelp and potashes. Lime was sometimes included in these recipes. Percy also quotes a patent granted to James Goodyear in 1771 which stated that 'common salt and other saline substances and animal charcoal dust improves steel'. If these additions were made at too late a stage in the fining process they could stick to the surface and become incorporated into the iron when forged into an ingot. The very few pieces of post-medieval fined iron that have been examined do not contain the level of inclusions encountered here, and we thus agree with El Gayar and Jones that this represents very crude workmanship, but without the need to invoke a hitherto unknown technology.

Conclusion

Gold was neither observed nor detected anywhere on the plate. The composition and structure of the iron rules out any form of natural iron. Similarly iron smelted in the solid state is precluded as some form of molten slag would be essential, which could only be eradicated by melting the iron. A more mundane but tenable explanation of the observed features is that the iron ore was smelted to cast iron in a blast furnace, using charcoal as the fuel, resulting in a chemically much purer iron than that smelted with coal or coke. This iron was then decarburized by the finery process to form solid wrought iron. The inclusions are likely to have originated either as deliberate additions during the fining, as specified in some European accounts, or inadvertently during the subsequent forging. The blast furnace process does not seem to have reached the Middle East until the post-medieval period, and this strongly suggests that the plate of iron from the Great Pyramid is of no great antiquity.

References

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2 Petrie, W M F, *The Pyramids and Temples of Gizeh* (London 1883), 275-7.

3 Performed by Professor W Flight of the Department of Mineralogy in the British Museum in the 1870's and reported in J. Newton Friend *Iron in Antiquity* (London 1926), 161.

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8 Percy, J, *Metallurgy*, Vol III (London 1864), 653.

The authors

Paul Craddock and Janet Lang have both researched early metallurgy in the British Museum Research Laboratory, latterly the Department of Scientific Research, for very many years, working on materials within the Museum's collections, as in this instance, and on related material from around the world. Paul Craddock's especial interests are in early extractive processes, and Janet Lang has specialised in metallographic structure and metalworking techniques.

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