
IRON ARTEFACTS FROM THE DGB-1 SITE, NORTHERN CAMEROON:
CONSERVATION, METALLURGICAL ANALYSIS AND
ETHNOARCHAEOLOGICAL ANALOGIES



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Abstract


In 2008, a number of iron artefacts were recovered from an interior courtyard on the DGB-1 site during fieldwork in 2008. DGB-1 is a large multi-function site located in the northeastern Mandara Mountains of Cameroon, and dating to the mid-second millennium AD. The iron artefacts recovered included a cache of spear/arrow points found buried under a living floor; as well as a local hoe and a chain and a 'barrette' probably not of local provenance. This discovery has a number of points of interest: (1) ethnoarchaeological reenactments of iron smelts in the 1980s in the same region provide a rare opportunity for comparison of iron-working techniques over about five centuries in sub-Saharan Africa; (2) the variability in different forms of iron (including eutectoid steel) used in these artefacts; and (3) the welding of different forms of iron to produce composite artefacts.

Résumé

En 2008, des objets en fer ont été mis au jour dans une cour intérieure de DGB-1, un très grand site multifonctionnel se trouvant dans le nord des monts Mandara camerounais et datant du milieu du deuxième millénaire après J-C. Ces objets comprenaient un ensemble de pointes de lance/flèche constituant un dépôt enterré sous un niveau d'occupation, ainsi qu'une chaîne à maillons et une barrette, probablement allochtone ainsi qu'une houe de provenance locale. Cette découverte présente plusieurs intérêts : (1) l'occasion rare de comparer, sur cinq siècles environ, des techniques sidérurgiques en Afrique sub-saharienne grâce aux réactivations de la réduction de fer réalisées en contexte ethnoarchéologique dans les années 1980 dans la même région, (2) la variabilité des différentes qualités de fer (y compris l'acier eutectoïde) utilisées dans ces objets, et (3) l'utilisation de la soudure de ces fers de différentes qualités pour produire des objets composites.

Keywords: Mandara Mountains, blacksmithing, iron technology, DGB sites, ethnoarchaeology


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Introduction

During 2008 excavations, a number of iron artefacts were recovered from an interior sunken courtyard on the DGB-1 site, located in the northeastern Mandara Mountains of Cameroon. DGB-1, with the smaller, neighbouring DGB-2 site, forms a complex of dry-stone walls, terraces, platforms and associated archaeological features on the slopes of the northern Mandara Mountains of Cameroon, in Central Africa. DGB-1 and DGB-2 are only 100 m apart, and are partially contemporary with an occupation spanning the period from the 13th to the 17th centuries AD (see below). In total, sixteen DGB sites have been identified to this point (*Fig. 1*), but the DGB-1/DGB-2 complex is significantly larger than any of the other DGB sites (DAVID 2008; MACEachern 2012b). DGB stands for ‘diy-geδ-bay’, or ‘ruins of chiefly residence’ in the Chadic language, Mafa, spoken across this region.

The DGB-1/DGB-2 complex covers approximately four hectares (*Figs. 2 and 3*), and is perhaps the largest example of indigenous stone architecture in Africa between Ethiopia and Great Zimbabwe. The functioning of the site complex is at present unclear, or at least incompletely known: there is evidence for domestic occupation on DGB-1 and between the two sites, and ritual activities were carried out on the summit of both and in different places on both sites. DGB-1/-2 appears to have been utilised most intensively in the mid-15th century AD, in a period of (probably interrelated) environmental and political crises south of Lake Chad (MACEachern 2012a). Chronologically, the site complex’s development dates to a period when slave-raiding and the irruption of predatory states into the southern Lake Chad Basin were transforming social and political relations between Mandara Mountain populations and the communities living on the plains around the mountains. Until recently, almost all of the archaeological investigations in the region were undertaken on sites in the plains around the Mandara Mountains, because of a lack of well-preserved archaeological sites known from the mountains themselves. Excavations on the DGB sites by Nicholas David and colleagues began in 2002, and have continued from 2008 until 2011 under the direction of the first author (DAVID & MACEachern 1988; DAVID 2008; MacEachern *et al.* 2010; MACEachern 2012b).

Communities of Chadic-speaking Mafa terrace farmers now occupy the area of the DGB sites. There is no explicit historical relationship between the builders of the DGB sites and the Mafa (STERNER 2008), whose oral histories of the region go back 200–300 years and who profess ignorance of the history of these structures. However, there are important continuities between

some aspects of DGB material culture (especially ceramics) and that of modern Mafa populations, and some domestic features excavated at DGB-1 in 2008 were interpretable in Mafa terms, according to Mafa men working as excavators there. This is of course not an unusual situation: such claims of cultural affiliation or disaffiliation need to be thought of as social charters in the present as much as they are historical accounts of the past, and they will have played important social roles through the whole period of coexistence between the DGB-1/-2 site complex and the humans for whom that complex would have formed an impressive feature of the mountain landscape.

The question of potential cultural continuities between the builders and users of DGB-1/-2 and the Mafa people who live in the region today is significant for our interpretation of the iron artefacts found on DGB-1 in 2008. Two ethnoarchaeological reconstructions of traditional Mafa smelts, and one smelt associated with the neighbouring Plata group in the northeastern Mandara Mountains, were undertaken by members of the Mandara Archaeological Project in the late 1980s (DAVID & LE BLÉIS 1988; DAVID *et al.* 1989; KILLICK 1991; DAVID 2012a). The results of those smelts (and especially of the 1986 Mafa smelt [DAVID *et al.* 1989]) can be compared with the characteristics of the iron artefacts recovered from DGB-1.

The examination of iron artefacts from DGB-1 thus allows researchers a very rare opportunity to compare iron-working techniques in one narrowly delimited area of sub-Saharan Africa over a period of five centuries. In this article, the iron artefacts recovered from the DGB-1 site are therefore referred to as ‘DGB artefacts’, while the products of modern Mafa ethnoarchaeological smelts are referred to as ‘Mafa artefacts’. We recognise, of course, that comparison of the results of an ethnographically known iron-smelting episode (bloom fragments) with finished tools recovered archaeologically is not a straightforward issue. The latter can, for example, shed no light upon processes of decarburization which would probably be different for the different types of furnaces ethnographically known from the area (DAVID 2012b). The spatial and cultural proximity in this case nevertheless make the comparison worthwhile, if such limitations are kept in mind.

Archaeological context

During work on the DGB-1 site in June–July, 2008, researchers under the direction of Datouang Djousou excavated a sunken interior courtyard, the Central Courtyard Area (CCA), on the summit of the site (MACEachern *et al.* 2010) (*Fig. 3*). Although relatively

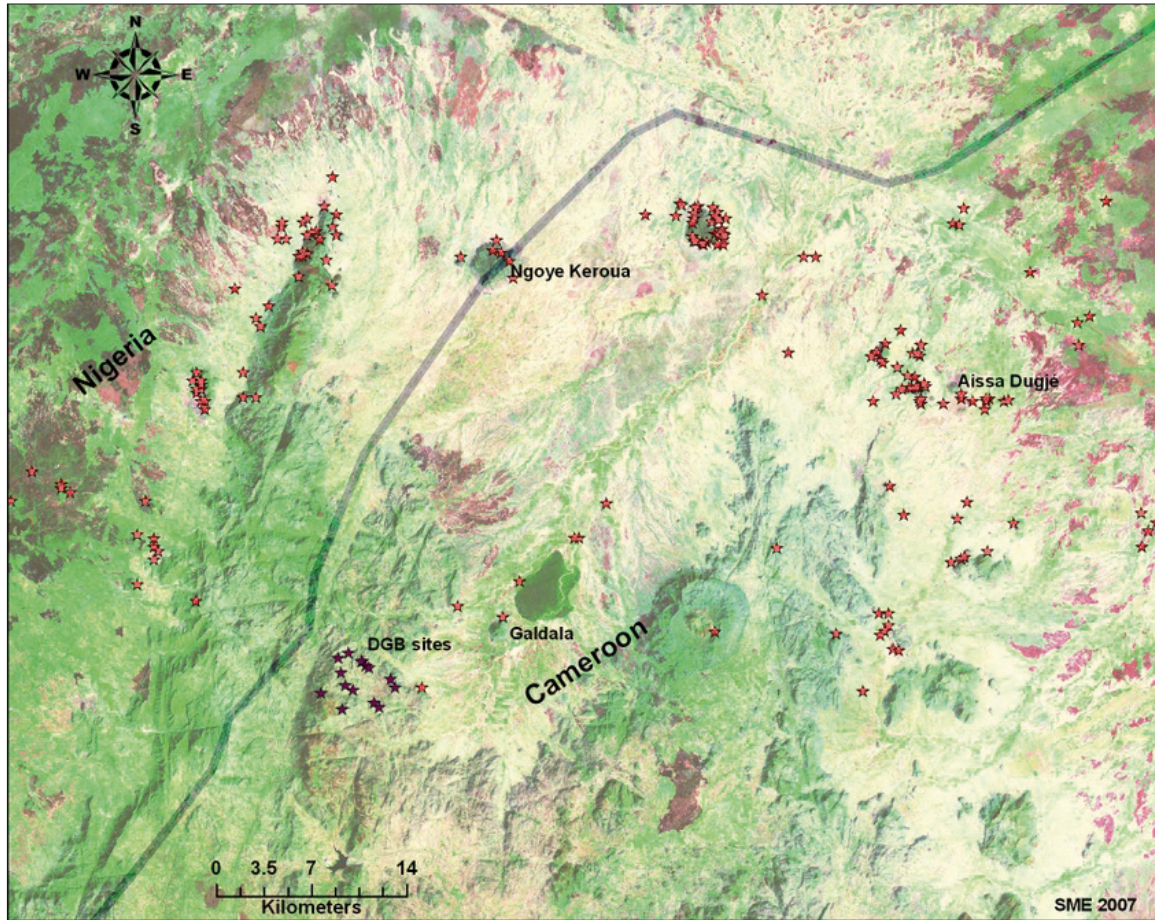


Fig. 1. The DGB archaeological sites (purple stars) in the Mandara Mountains of Northern Cameroon, Africa, with other known archaeological sites in the area (red stars).



Fig. 2. The DGB-1 site from the northeast.

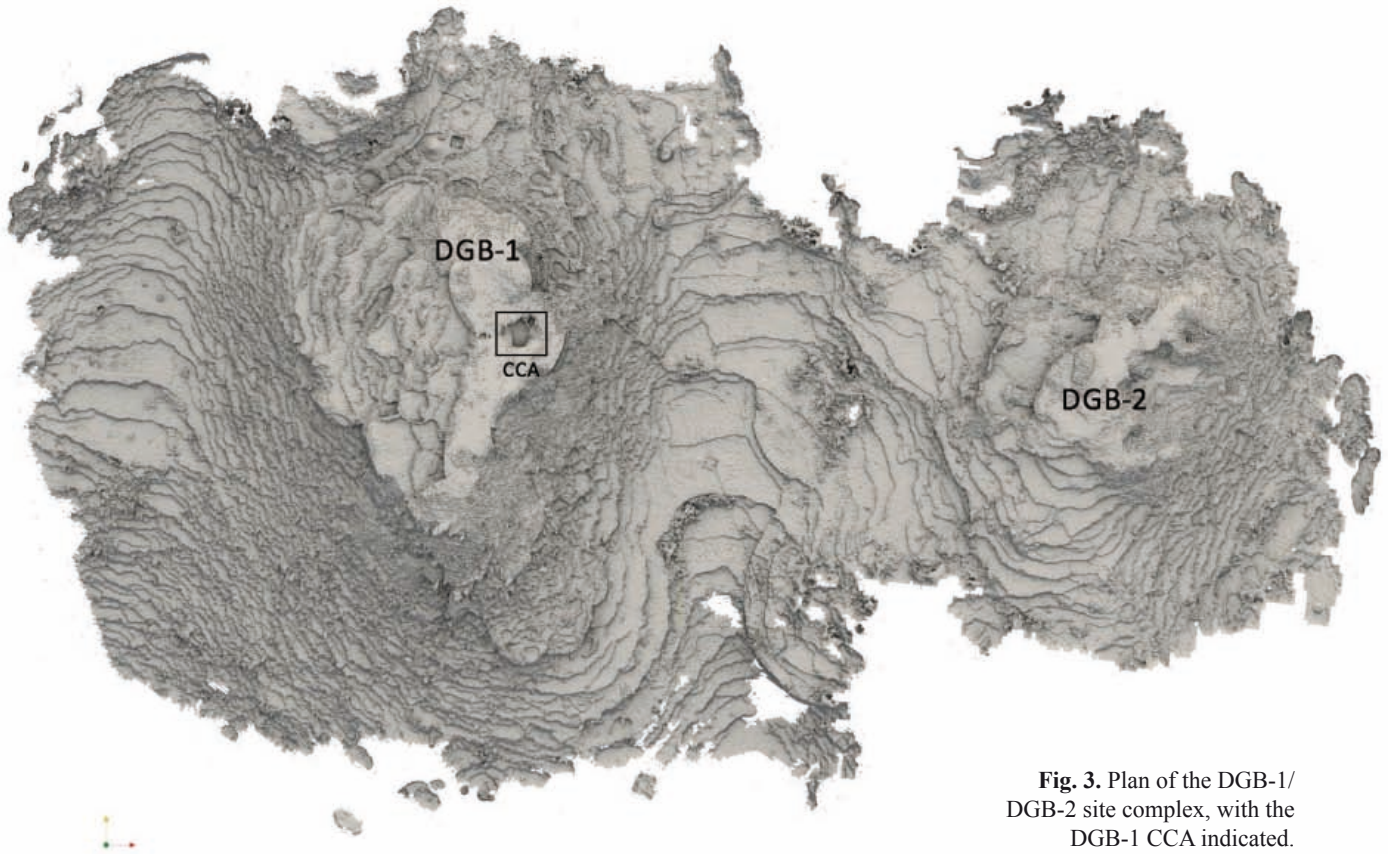


Fig. 3. Plan of the DGB-1/DGB-2 site complex, with the DGB-1 CCA indicated.

small (approximately 3x4x4.5 m deep), this trapezoidal sunken courtyard was articulated with a number of other significant architectural features, including two subsurface stone passageways on the western and northeastern sides and a staircase on the east side of the CCA that was carefully built, used for some time, and then equally carefully blocked off behind a courtyard wall. Excavation of the CCA revealed a complex stratigraphic sequence, including multiple occupation surfaces over a 30–40 cm horizon, at approximately 3–3.5 m below the level of the surrounding platforms. These occupation surfaces had been either cleaned or swept at various points during their use, and included a set of stone niches along the south wall of the courtyard. Significant amounts of charcoal, burned and unburned animal bone, and burned earth were found in and around these niches. Our interpretation is thus that these niches were hearth enclosures, used at least for the cooking of meat. Meat preparation and consumption are an important element in Mafa ceremonial and sacrificial activities, and it seems quite likely that the evidence of meat preparation in the CCA reflects similar ritual activities.

Distinctive DGB-type ceramics were found through virtually all levels of excavation in the CCA, although in upper levels (well above the levels of the occupation surfaces, and mixed with architectural deb-

ris) they were probably washed in from the platform surfaces above the courtyard after abandonment of the CCA. Other materials found in primary context and associated with the occupation surfaces included iron artefacts, two artefacts made of copper alloy, stone and (probably) glass beads, and two very small fragments of what appears to be tin-glazed earthenware. Some of these artefacts are certainly foreign to the region around the DGB sites, and probably to the Lake Chad Basin more generally. Four radiocarbon dates were obtained from the CCA, one from architectural fill at approximately 1.5 m depth and three others from the occupation levels between 3–3.5 m below the level of the surrounding platforms (MACEachern *et al.* 2010: 43). The latter three indicate an occupation in the 16th century AD although, given indications that the floors were swept clean periodically, this is quite likely to have marked only the latest part of the period of use for the CCA.

In the course of excavation of the CCA, a group of iron artefacts was located in the northwest corner of the courtyard, just adjacent to the West Passage and 5–10 cm below an occupation surface. Six artefacts were recovered as part of this group: they are labelled Cons 1 to Cons 6 in the outline drawings in **Figure 4**, with the areas from which metallographic samples were extracted shown in black. These artefacts were

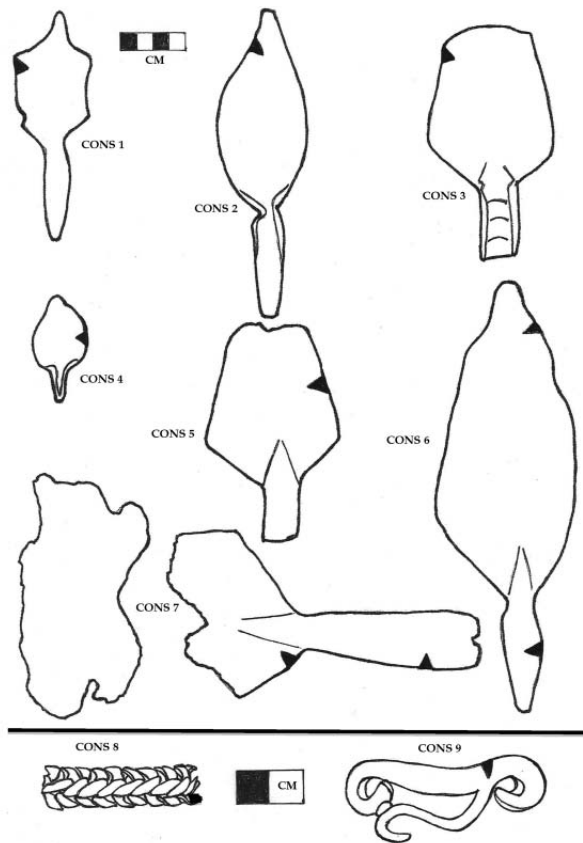


Fig. 4. Outline drawings of the DGB-1 artefacts, with the metallurgical sampling areas indicated as black triangles.

laid flat and in contact with one another, and it seems extremely likely that they were deliberately cached at that location. The precise significance of these deposits is unknown, although a group of iron objects (an arrowhead, a knife blade, a possible awl and a closely associated sickle blade) was found in a probable cache under a stairway lintel during earlier excavations at DGB-2 (DAVID 2008: 94). Given the value of iron in the area (DAVID 2012b) and the care with which these iron artefacts were arranged, it is likely that their burial was an occasion of some significance for the people then making use of the site.

Four of the artefacts recovered from this cache were tanged, while two were socketed. Large tanged iron artefacts are rarely found in this area. The tanged objects have the general form of spear points (one is small enough to possibly be a large arrowhead), while the socketed pieces have an unusual shovel-shaped head. The function of the latter artefacts is unclear; in *Figures 5* and *6*, these artefacts are referred to as 'hoes', but in fact the thinness of the blade, the shape of the head, and the angle between blade and socket make it unlikely that they were used for that purpose. It is notable as well that on the three larger tanged artefacts

(Cons 1, 2 and 6), the distal end — that is, the 'point' — does not appear to be fully finished, in that the metal has not actually been formed into a point. Our interpretation is that these three artefacts are weapon points, but not (yet) fully functional ones. Two iron artefacts recovered by a Mafa informant near the DGB-5 site (DAVID 2008: 106) have some characteristics in common with these large tanged artefacts, especially the blunted distal ends and the constriction at the proximal end of the blade visible especially in Cons 2.

In addition to the six objects in the cache, two other iron artefacts were found in association with the CCA occupation surface, sampled and conserved. One of these, labelled Cons 8, was a piece of loop-in-loop chain of unusual design: it is, first, a single loop-in-loop chain and is extremely tightly woven, to the extent that it is difficult to see how the links were put together (Jean Stark, pers. comm. to Carlson; see also STARK & SMITH [1999: 23–27]). Cons 9 has the general morphology of a barrette, with a clasp formed by a shaped arm separated from the main body of the artefact. In contrast to the artefacts found in the cache, Cons 8 is on the basis of form and production technique unlikely to be of Mandara manufacture; Cons 9 would be within the technical capacities of modern Mafa smiths at least, but in form the piece does not resemble modern Mafa iron artefacts. Finally, Cons 7, a socketed iron hoe of a form very similar to those of modern Mafa hoes was recovered from a depth of approximately 1.5 m below the surface of the CCA, and thus probably dates after the period of use of the occupation surface below which the cache was found. Although it is included with the DGB artefacts, it needs to be borne in mind that Cons 7 may post-date the DGB period on the site, and may in fact be associated with an early Mafa occupation, possibly having been lost or discarded in the course of farming activities.

Thus, in total, nine artefacts from the CCA were sampled for metallographic analysis. In the following account, these are labelled Cons 1 – Cons 9, with their characteristics noted in *Table 1*.

Conservation

When first received for conservation, the artefacts were photographed while encased in excavation soils and taken to Mid-Coast Hospital in Brunswick, Maine, for digital radiology using a Phillips Digital Diagnost machine. Digital x-ray images were converted to JPEG picture format and guided the mechanical removal of the gross overburden of the soil matrix from the objects. The x-ray images, one of which (Cons 2) is shown here in *Figure 8*, also revealed white ridges of higher density metal left by the smithing process and

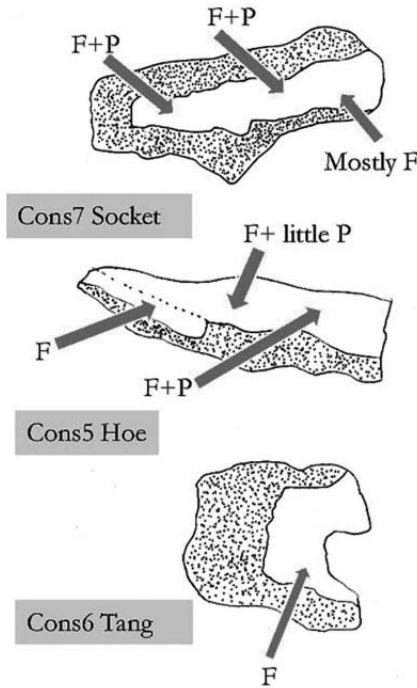


Fig. 5. Drawing showing remaining iron content in Cons 5, 6 and 7. The letters added to the sections indicate the following: P = pearlite; F = ferrite, W = Widmanstätten morphology, F+P = ferrite areas with some pearlite. Areas of corrosion are shown in stippled dots.

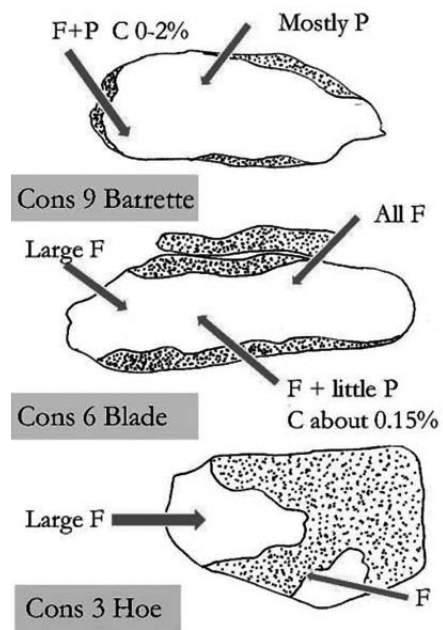


Fig. 6. Drawings of the remaining metallic areas for Cons 3, 6 and 9. The letters added to the sections indicate the following: P = pearlite; F = ferrite, W = Widmanstätten morphology, F+P = ferrite areas with some pearlite. Areas of corrosion are shown in stippled dots.

Artefact	Descriptor	Location	Samples
Cons 1	Tanged point-spear	CCA-NW-313-317bd	Cons 1 Blade
Cons 2	Tanged point-spear	CCA-NW-313-318bd	Cons 2 Point
Cons 3	Socketed artefact with blade	CCA-NW-313-319bd	Cons 3 Head
Cons 4	Tanged point-arrow	CCA-NW-313-320bd	Cons 4 Point
Cons 5	Socketed artefact with blade	CCA-NW-313-320bd	Cons 5 Blade
Cons 6	Tanged point-spear	CCA-NW-313-321bd	Cons 6 Tang
Cons 7	Mafa-style hoe	CCA-160bd	Cons 7 Socket Cons 7 Blade
Cons 8	Loop-in-loop chain	CCA-EWall-290bd	Cons 8 Chain
Cons 9	'Barrette'	CCA-NE-302bd	Cons 9 Barrette

Tab. 1. Artefacts included in the analysis, with locations in the Central Courtyard Area and sample designation.

dark areas, originally thought to be holes or losses, which were actually glassy slags incorporated into the artefact. It is notable that the variations in density are probably due to the use of a ridged boulder hammer in the forging process, a tool still used by Mandara montagnard blacksmiths (ROBERTSON 2012).

A sampling scheme for metallurgical and composition analysis was designed by Carlson and Scott, and reviewed/approved by MacEachern. Sampling spots were chosen to contrast blade edges with handles on the DGB artefacts. Initially, attempts were made to remove samples from the object using a jeweller's hand-saw

and size 00 blades, but the DGB iron proved too hard to be cut this way. A rotary dremel tool with separation discs was successfully used to remove triangular samples that were 3–5 mm per side in length. Sample sites were fully documented with digital photography before, during and after sampling, and again when the white fills were in place. Final mechanical cleaning was done using a variety of techniques, including hand cleaning, compressed air driven micro-abrasive cleaning using dolomite and aluminium oxide particulate (17.5–28 micron particle size, 10–80 psi), and a Paleo Tool® #3 vibrating needle. All cleaning was done under stereomicroscopy. The sandy quartz grains

from the local soil could not totally be removed from the objects, as it is this corrosion layer that retains the shape of the object. Over-zealous cleaning could risk the loss of the artefact's form and, after consultation with MacEachern, the decision was made to leave the sandy corrosion matrix *in situ* when its removal would risk the object.

All iron objects except Cons 7 were placed into separate 0.5M sodium hydroxide solutions for one month to determine chloride (Cl⁻) ion loads. Artefacts that returned 10 ppm Cl⁻ or less in a month's time were cleared from chloride extraction treatment. Objects with over 10 ppm Cl⁻ were left to soak another month and tested again. Testing of the solution was done using an Orion 407A analyzer and chloride ion electrode calibrated to reference standards. The chloride ion load in these iron objects was very small, on average less than 30 ppm extracted in 2 months time. Objects were washed of the sodium hydroxide solution in boiled and cooled deionised water until pH of 7.0 was constant, and air-dried.

Areas of loose chips of iron were reattached using 10–20 % B-72 ® (chemically an ethyl methacrylate co-polymer) dissolved in acetone. Metallurgical sampling voids had their inner edges sealed with 10 % B-72 ® in acetone before fills made of a conservation grade 2-part epoxy called Milliput ® (fine grade) were set into the voids. When this putty dried 24 hours later, it was sanded and carved into the final shape and painted with acrylic artist's paints to blend the repair to the colour of the surrounding object. These fills are removable by wetting the fills with acetone, which then releases the B-72 ® polymer and allows for the fill to be removed. Each object's Milliput® fill areas were photographed before in-painting to document the location of the fills.

Several coats of a 5 % w/v tannic acid surface stabilizing treatment were used to protect the iron surface from renewed corrosion. This left the metallic iron object's surface colour black. Where the surface still retained corrosion products, the color with tannic acid was an orange-black.

Metallographic examination

Scott analyzed the composition and microstructure of the samples. Most contained some residual iron, even if heavily corroded, and most of the artefacts preserved substantial amounts of the original metallic constituents while a few were completely corroded and preserved none of the original microstructure of the artefacts. Samples were prepared, mounted, ground and polished

following by etching (SCOTT 1991, 2011), examined using a Nikon Epiphot metallograph and photographed using a Nikon D300 digital camera mounted on the F mount of the metallograph.

In sketches of some of the samples mounted for study (**Figs. 5 and 6**), the letters added to the sections indicate the following: P = pearlite¹; F = ferrite²; W = Widmanstätten morphology³; while F+P indicates areas of ferrite with some pearlite, the eutectoid constituent of the steel, at which the carbon content rises to 0.8%. Areas of corrosion are shown in stippled dots: in the iron artefacts from this site, there is no pseudomorphic retention of shape of the iron grains within the corrosion crust.

Descriptions of individual artefacts

Cons 1 Blade

This blade section shows an interesting microstructure, consisting of a low-carbon blade onto which a carbon steel has been welded. The line of the weld is delineated by a series of darker slag inclusions. The overall view at low magnification is shown in **Figure 7**, etched in 2 % nital to reveal the grain structure. The grain structure in the region of the steel is very variable, and suggests that heavy forging has been undertaken here to weld the two parts together. The etched microstructure in **Figure 7** shows the pearlite and ferrite grains in the welded-on carbon steel. The extent of the pearlite shows that the carbon content

- 1 Pearlite: A common constituent of bloomery iron, pearlite is a fine mixture of ferrite and cementite (the hard intermetallic compound Fe₃C). Pearlite is produced through a eutectoid solid-to-solid transition from austenite, which in iron metallurgy is what the blacksmith produces by heating the iron to red heat before striking. In etched sections, the pearlite appears as a dark phase or darker cluster of very small particles, and may etch a straw-yellow colour in nital. The amount of pearlite present is a good indication of the carbon content. An eutectoid steel has about 0.8 % carbon and consists entirely of pearlite. If half of the microstructure is composed of pearlite and the other half ferrite, then the carbon content is about 0.4 % overall.
- 2 Ferrite: Wrought iron, or otherwise iron with no alloying elements present. Ferrite is soft and easily worked, by heating in the forge and hammering. In the photomicrographs, ferrite generally appears white or lightly coloured, without internal components visible in the crystals.
- 3 Widmanstätten morphology: In low-carbon steels, needles of ferrite grow on former austenite grain boundaries, as the iron or steel cooled down. This Widmanstätten precipitation is quite common in early iron and steels because of heating and cooling cycles. In DAVID & LE BLEIS (1988), Dokwaza is shown quickly cooling his iron hoe in water. If very quickly cooled, this could create martensite, a very hard phase in steels, but if cooled less rapidly a Widmanstätten structure could result.

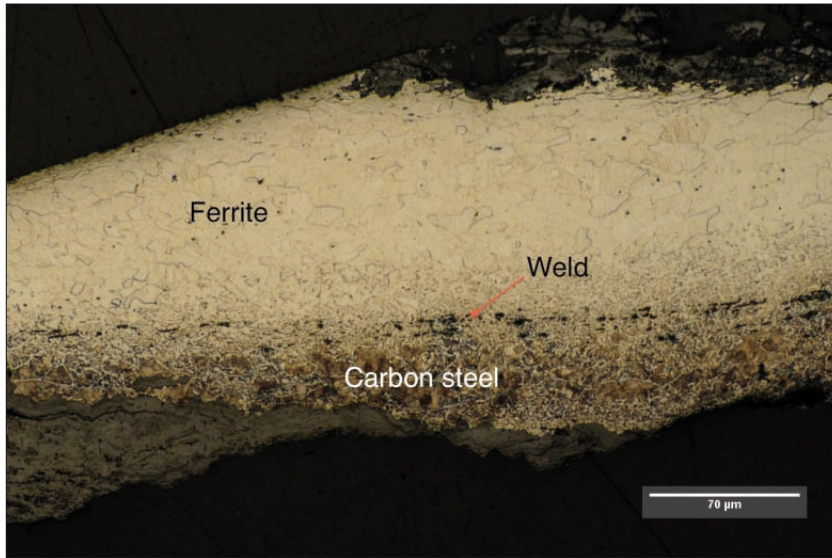


Fig. 7. Cons 1 tanged point, etched in 2 % nital, showing the carbon steel edge, which has been welded to the principally ferrite back.

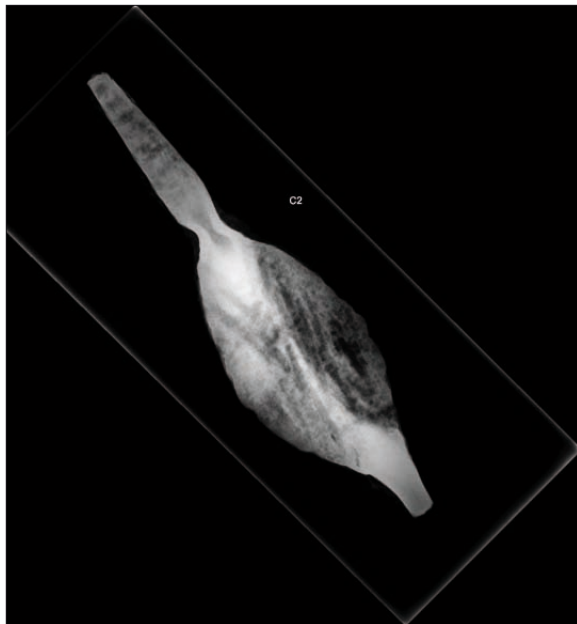


Fig. 8. Cons 2 tanged point: the x-radiograph shows the striated microstructure of the blade with elongated features along the length. The iron is very inhomogeneous, differentially corroded and contains glassy slags in the dark area of the upper blade.

rises to about 0.6 % in this area of the blade. The ferrite area of the blade is free of carbon and has a relatively low slag content, suggesting that a quite pure ferrite was selected for this purpose. This contrasts with the carbon steel welded along the edge, where the carbon content is about 0.6 %. The welding-on of a steel edge along the back of a blade is a commonly used method to create a steel blade on a soft ferritic back.

Cons 2 Blade

An x-radiograph of the spear point is shown in **Figure 8** and reveals the heavily striated iron used to make the spear. A representative photomicrograph is shown in **Figure 9**. In one region of the artefact, very fine pearlite with acicular ferrite at the grain boundaries can be seen, showing that a carbon steel has been used in part of the spear. This pro-eutectoid ferrite is jagged and has a smaller volume than the pearlite. The carbon content here is about 0.6 %. The overall picture of the section in **Figure 9** shows, towards one end of the section, a ferrite and pearlite structure with a Widmanstätten precipitation. Towards the other side of the section, there is more ferrite and less pearlite. Passing along to the mid-point of the section, the grains become very fine pearlite. The other side of the section contains more ferrite laths and a little less carbon. The section therefore shows a quite heterogeneous iron with some areas of eutectoid steel and others of more ferrite and less pearlite, the carbon content dropping to about 0.3 %. There is a substantial amount of a glassy slag elongated along the length of the spear, as visible in **Figure 10**. In some of the iron, a two-phase slag can be seen, but most of the slag is a rather jagged single-phase glassy slag. The carbon content rises in some areas to close to 0.8 %. The characteristics of this section may indicate a weld between areas of eutectoid steel and low-carbon iron, as in Cons 1.

Cons 3 Socketed artefact

There are only two areas of metal remaining in this rather heavily corroded section, but it is enough to show that this artefact was made in a quite pure ferrite, a wrought iron with no carbon content as shown in **Figure 11**. The slag inclusions are glassy and rather rounded. Ferrite grains are large and clear, with no inclusions.

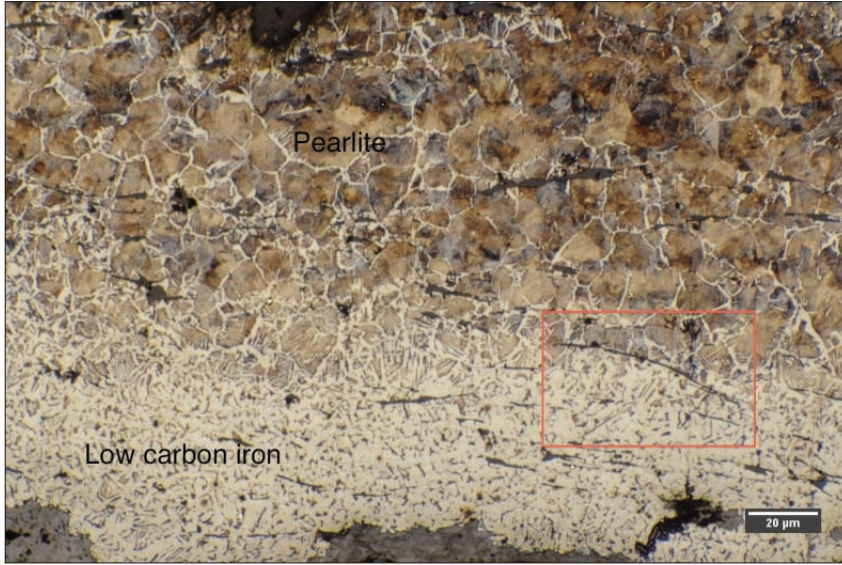


Fig. 9. Cons 2 tanged point, etched in 2 % nital. The pearlitic area to the upper part of the photomicrograph shows that the alloy here is nearly a eutectoid steel, and the lower part is a different piece of iron, with low carbon content. The red rectangle indicates the location of *Figure 10*.

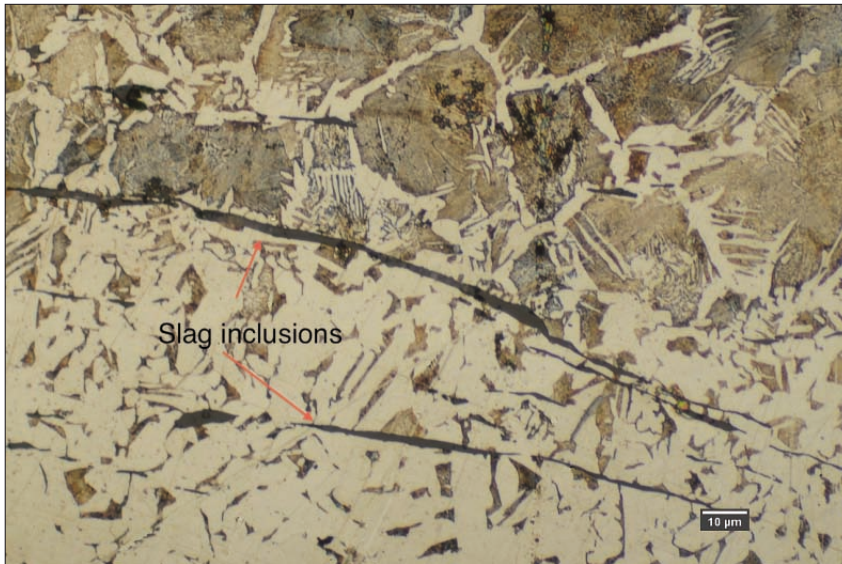


Fig. 10. Cons 2 tanged point, etched in 2 % nital. In this higher-magnification image, the long slag inclusions across a possible weld can be seen. The carbon content of the grains rapidly decreases in the lower part of the photomicrograph.

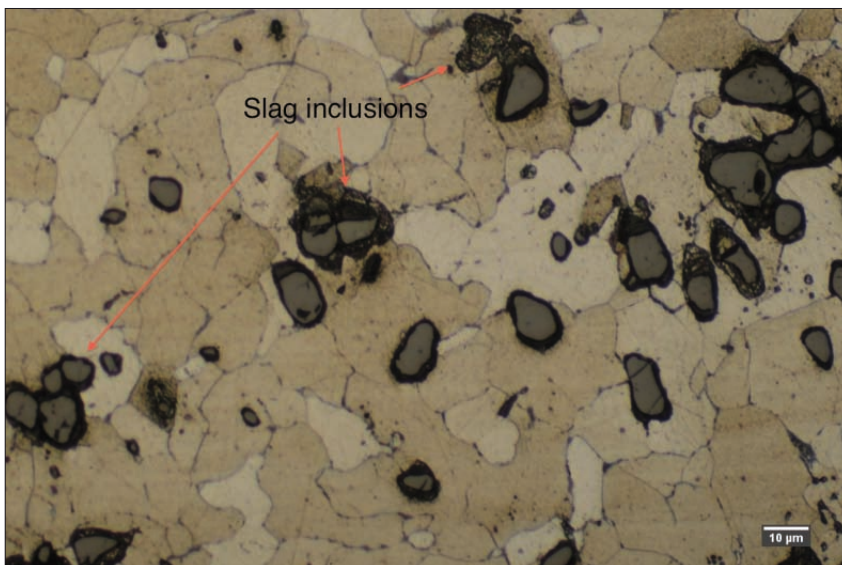


Fig. 11. Cons 3 socketed artefact, etched in 2 % nital, showing scatter of glassy slag inclusions and a grain structure of ferrite with no carbon content.

Cons 4 Arrow point

This sample is totally corroded, with only a few tiny flakes of metallic iron remaining. It is quite difficult, on the basis of this section, to decide what the microstructure of the original iron that constituted this arrowhead consisted of. From the few remaining clues, the inference would be that the arrowhead was made in a ferritic iron with no carbon content. This would be quite likely if the metalsmiths were selecting the carbon steel bits of the bloom for blades and knives, as there is no reason for an arrowhead to be made of a low-carbon steel.

Cons 5 Socketed artefact

The section shows long, heavily elongated thin slag inclusions. In one end of the section, the grains are predominantly of ferrite. The slag here is of a common type seen in much ancient iron: a two-phase mixture

of a glassy matrix with wüstite particles within it. The carbon content in the central region of the section increases but is not even, and the grain size and carbon content fluctuate. In some areas, the carbon content rises to 0.5 %, as seen in **Figure 12**, while the pure ferrite grains are revealed in **Figure 13**. There is a typically Widmanstätten precipitation of the pro-eutectoid ferrite grains on former austenite grain boundaries. The evidence shows that this artefact has been heavily hot-forged to shape and that it has been made of a low-carbon steel component, with some ferrite and little carbon in some areas.

Cons 6 Tang

The microstructure shows that the tang is composed of quite clean ferrite, with little slag content, as illustrated in **Figure 14**. The slag is comprised of a two-phased glass and wüstite mixture, as in Cons 5. From the extent of deformation of the tang, we can infer that the amount of hot-forging of this part of the tang was moderate. The ferrite grains are very large, and there is no carbon content at all. The size of the grains may possibly



Fig. 12. Cons 5 socketed artefact, etched in 2 % nital. In this area, the Widmanstätten structure of the low-carbon steel is seen. The carbon content is about 0.4 % and there is little slag content. Contrast with **Figure 13**, from the same artefact but in a region where the carbon content is much lower.

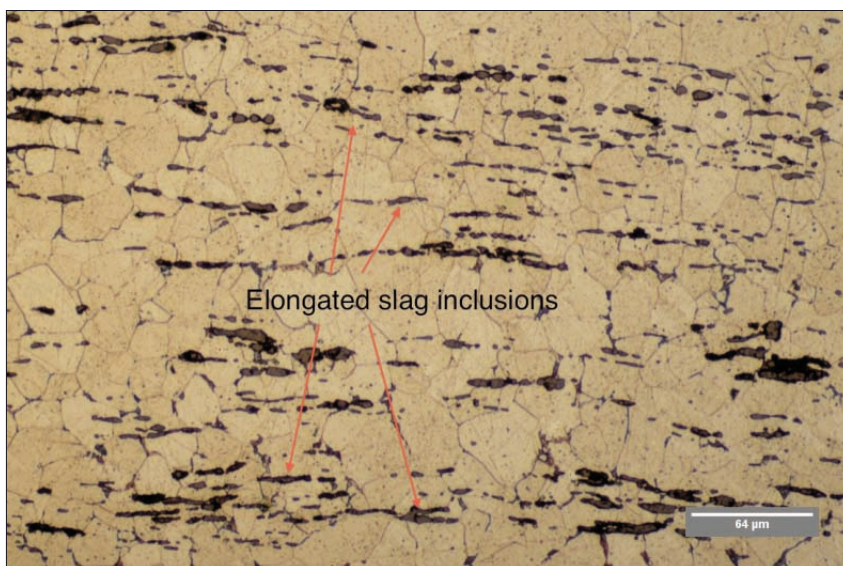


Fig. 13. Cons 5 socketed artefact, etched in 2 % nital. The carbon content is low in this area, and slag content shows extensive elongation as a result of hot-forging.

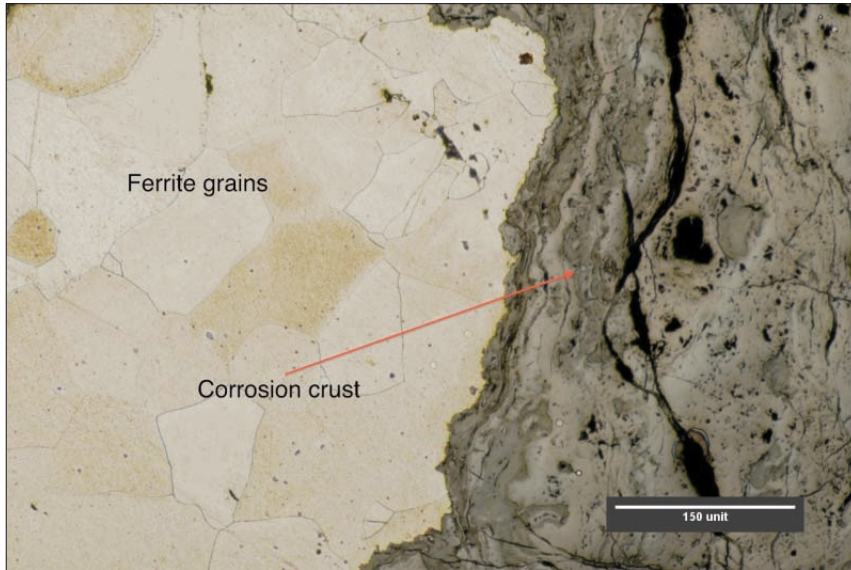


Fig. 14. Cons 6 tanged point (tang), etched in 2 % nital, x280. The grains are large and of quite pure ferrite. The junction with the corrosion crust is evident.

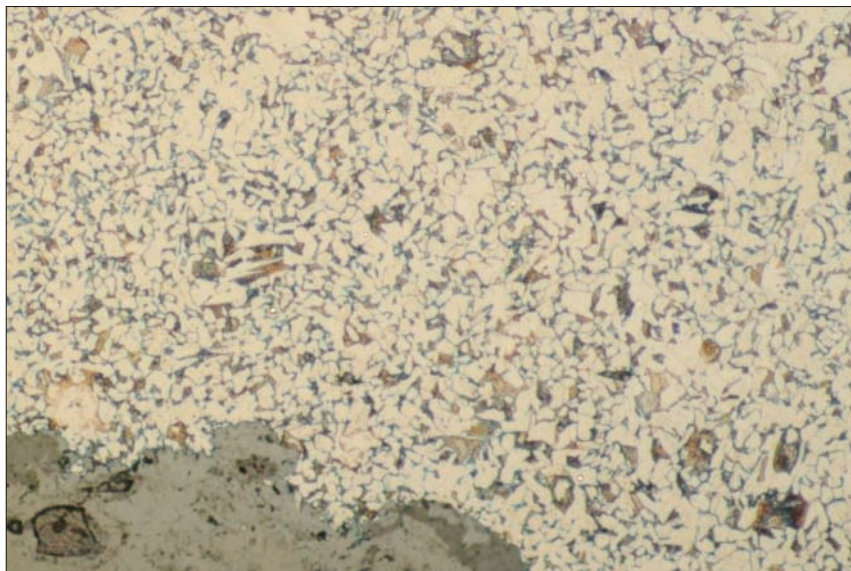


Fig. 15. Cons 6 tanged point (blade), etched in 2 % nital. The structure is that of a low-carbon steel, with little slag content in this area of the artefact.

be due to other alloying elements such as phosphorus, but no sign of any ‘ghosting’ often associated with phosphorus can be seen.

Cons 6 Blade

Towards the edge of the blade, the carbon content rises to about 0.1–0.2 %. This low-carbon steel is illustrated in *Figure 15*. The investigation shows that the tang is made in a quite soft ferrite, while the blade has been heavily hot-forged to shape, is considerably harder, and has some carbon content to one side. The gradual transition to the low-carbon steel region suggests inhomogeneous distribution in the bloomery product rather than the welding of another piece of steel, as is obvious from *Figure 7* in the case of the Cons 1 tanged point.

Cons 7 Socket

This socket has an interesting microstructure, due to considerable variations in the amount of carbon present in different areas. As seen in *Figure 16*, there is one area of low carbon, mostly ferrite with a large scatter of small slag inclusions. The carbon content slowly increases along the length of the section, gradually rising along one side to about 0.3 % carbon, the other side of the section being practically ferrite with no obvious weld between the two, although there is a thick slag inclusion of the two-phased glassy slag present, close to the boundary of the change in carbon content. There are unusual and numerous small slag stringers in this iron. The ferrite-pearlite continues along the length of the section in a fairly uniform manner, with the ferrite

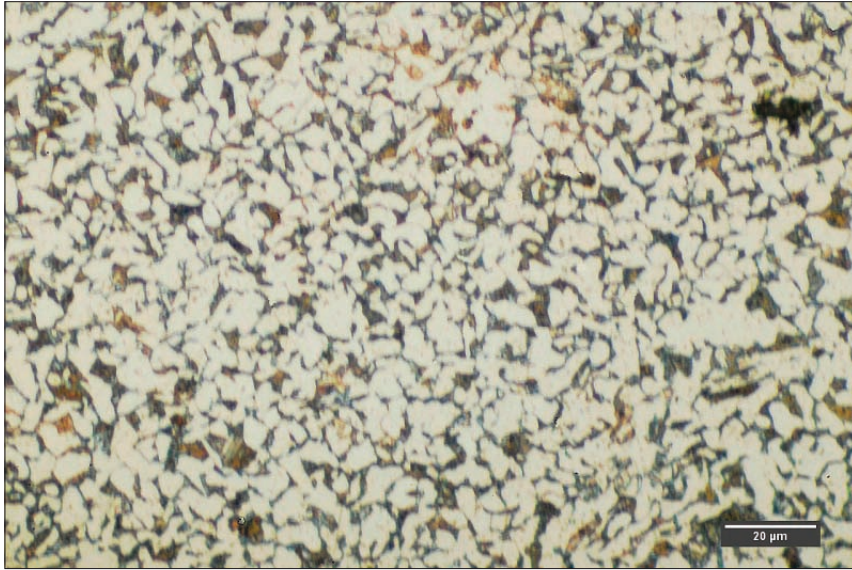


Fig. 16. Cons 7 hoe (socket), etched in 2 % nital, showing the low-carbon steel with about 0.2 % carbon content and a moderated refined grain size.

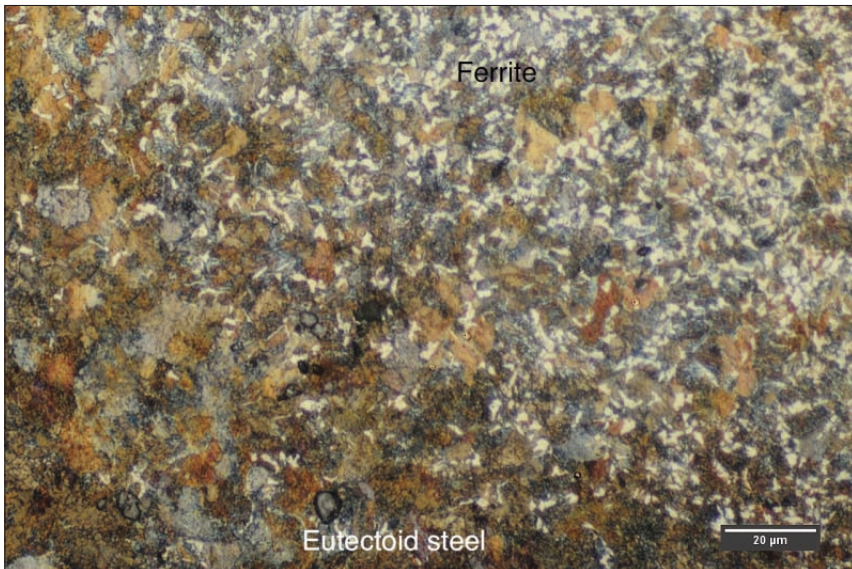


Fig. 17. Cons 7 hoe (blade), etched in 2 % nital, showing the transition from the lower carbon ferrite to the eutectoid steel that is located in the lower region of the photomicrograph. x80.

area being confined to one of the sides of the section towards the thicker part of the section.

Cons 7 Blade

The photomicrograph of the blade section, shown in **Figure 17**, indicates that a medium carbon steel has been selected for this part of the artefact. The end of the section shows a fine pearlite eutectoid, of 0.8 % carbon content and moving back from this edge, the grains are of pearlite and ferrite with about 0.4–0.5 % carbon. Towards one edge, the carbon content falls back to being mostly ferrite and further back still, to pure ferrite. A small amount of the two-phased glassy and wüstite slag is present. The evidence suggests that a steel edge has been selected for this blade, with ferrite towards the back of the blade.

Cons 8 Loop-in-loop chain

The section is very corroded, and only a small region of remnant metal is exposed on polishing. The carbon content is very low, and the grains are essentially of pure ferrite, of even size and polygonal with a little sub-structure within the grains, possibly from internal grain nitrides or carbides. The microstructure is shown in **Figure 18**. There is a small scatter of the two-phase glassy and wüstite slag. The grains and their size and shape show that a soft iron has been selected to make this loop-in-loop chain, which is a good use for soft wrought iron. Forming the loops would be much more difficult in a high- or moderate-carbon steel than with a soft wrought iron, with less carbon content than used in some of the other artefacts from the DGB-1 site.

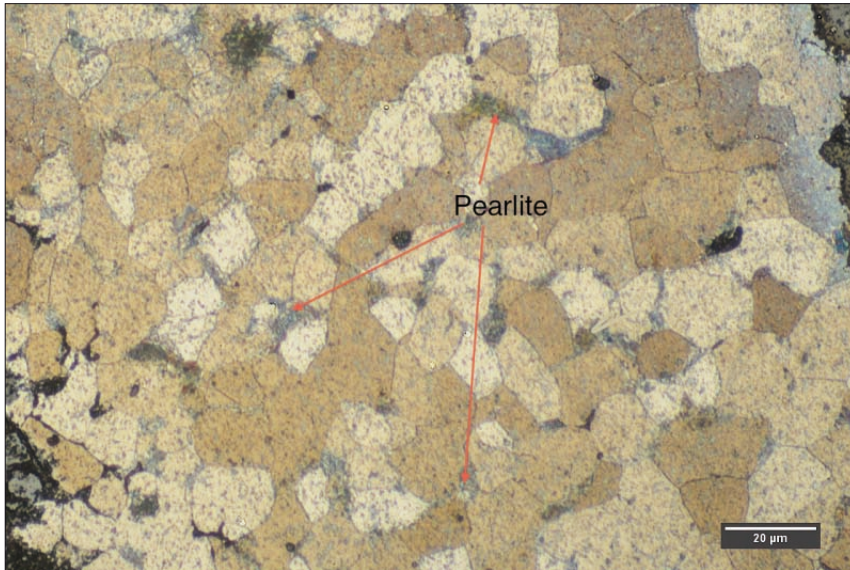


Fig. 18. Cons 8 loop-in-loop chain, etched in 2 % nital, showing small islands of grey pearlite among the ferrite grains. The overall carbon content is about 0.1-0.2 %. x130

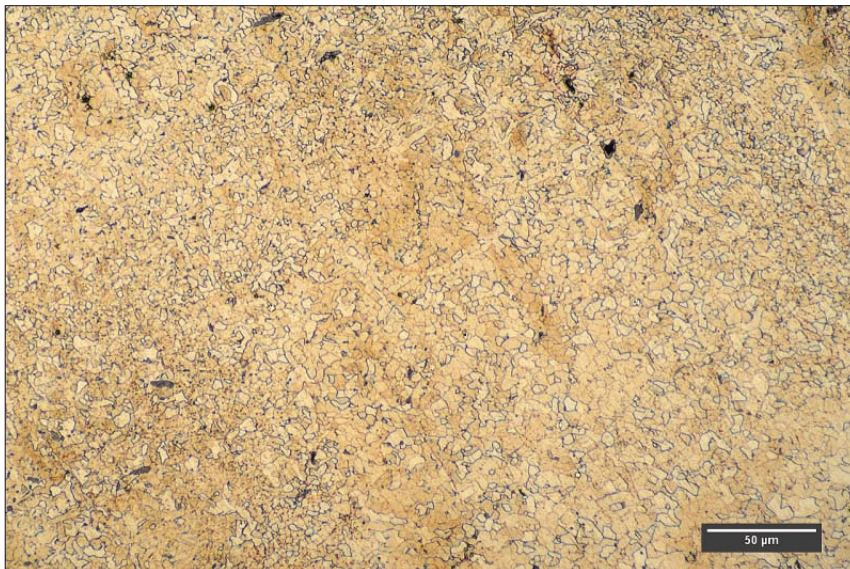


Fig. 19. Cons 9 'Barrette', etched in 2 % nital, showing ferrite grains with relatively little slag content. The ferrite grains are small and even in size.

Cons 9 Barrette

This artefact is principally made of a low-carbon steel. In one area towards the outer surface, the section is mostly ferrite, which grades into a region of ferrite with a little pearlite, as shown in **Figure 19**. Towards the other side, the structure is more Widmanstätten in morphology and has ferrite and pearlite, with about 0.2 % carbon. The slag inclusions are small, two-phase glassy slags with wüstite.

Metallographic conclusions

Research on this group of iron artefacts from the DGB-1 site reveals similarities between the artefacts assumed to have been produced in the Mandara region (Cons 1–7) and those that on stylistic grounds

are hypothesised to have been produced outside the region (Cons 8–9), especially in the appearance of two-phase glassy slags with wüstite in both groups (see below). The DGB-1 metalsmiths had eutectoid steel available to them with about 0.8 % carbon, and a variety of materials of lesser carbon content, typically 0.2–0.4 % carbon with Widmanstätten ferrite. The selective use of low-carbon steel components applied to welded ferritic iron shows the sophisticated use of steel for making harder components of blades used for cutting, such as on the Cons 1 and Cons 7 blades, and possibly on Cons 2. (As noted above, Cons 7 may come from a post-DGB use of the site.) The use of welding of different elements, some with no carbon and others with variable carbon content, is demonstrated in this group of artefacts. For those objects where the presence of steel would be unnecessary or counterproductive,

such as the Cons 8 loop-in-loop chain, the smiths who produced the artefacts selected softer iron with very low carbon content. The variable carbon content of the socketed artefacts is striking, especially in contrast to the Cons 1 and 7 blades; Cons 3 is almost pure ferrite, while Cons 5 has a highly variable carbon content. This suggests that edge hardness may not have been such a high priority for the socketed artefacts as it was for the tanged blades, presumably because of some (unknown) difference in their function.

Variation in carbon content across some of the objects shows the heterogeneous nature of the iron bloom, in which some regions were of low-carbon steel and others of relatively pure iron. The slag content is generally comparable to that of typical European bloomery iron products and the slags are either glassy or a two-phased glass and wüstite type slag, very commonly encountered in bloomery iron production. However, the ferrous materials overall are typically of higher quality than those produced in Medieval Europe, with less slag content (SCOTT 1991). Some of the low-carbon steels have practically no slag inclusions, as in the blades of Cons 7 and Cons 1, showing that some high-quality materials were available for selected purposes. The examination has confirmed that steels of eutectoid composition were not only produced, but were selectively utilised by the DGB-1 people in their iron technology. The hammering of small prills removed or broken off from the iron bloom would reveal themselves to the skilled blacksmith as noticeably harder. These parts could then be used for specific purposes in the making of high-quality steel blades.

Comparison of DGB-1 artefacts with ethnoarchaeological Mafa examples

The sophistication of the many different indigenous African iron-smelting technologies is well known (VAN DER MERWE 1980; AREMU 2004; KILLICK 2009). The present paper describes the metallurgical characteristics of some iron artefacts from northern Cameroon, in an area where colonial and post-colonial iron working is well attested. Iron working by blacksmiths of the Mafa group is particularly well known, but observations were also made among Sukur, Marghi and Plata smiths (SASSOON 1964; VAUGHAN 1973; DAVID 1995). Mafa iron smelting has been observed by HINDERLING (1955) and GARDI (1954). The Mafa smith Dokwaza was documented reenacting a traditional smelt in 1986 that became the subject of a film (DAVID & LE BLÉIS 1988), with a second smelt in 1989 and with further analysis of the products of the 1986 smelt by DAVID *et al.* (1989). The Mafa iron-smelting furnaces are remarkable for their construction, with a long tuyère that is suspended from the roof of the furnace, going downwards into the furnace and oper-

ated by hand bellows by the smith, who is effectively sitting over the furnace.

The documented ferrous materials produced in the 1986 Dokwaza smelt were: (1) wrought iron (ferrite) with less than 0.05 % carbon; (2) low-carbon steel, with about 0.2 % carbon; (3) high-carbon steel, with about 1 % of carbon; and (4) mixed areas of white and grey cast iron, representing a carbon content over 2 %. This heterogeneity is closely comparable with the variety of iron/steel found in the DGB-1 artefacts some 500 years earlier. In the smithing of such heterogeneous iron, those pieces from the bloom that are effectively cast iron would have to become decarburised in order to fabricate an iron artefact from them by hammering and welding. The high quality of the iron and steel components used by the Mafa is well illustrated by the range of microstructures found in the ethnoarchaeological examples, and is associated with the skill of the Mafa smiths in selecting different types of iron for specific purposes. A hoe made by Dokwaza, for example, as a finished product had a carbon content varying from 0.2 % to 0.8 % (DAVID *et al.* 1989: 199), while a locally made older example from iron also smelted in the region had a carbon content of below 0.1 % to about 0.1 %.

One of the socketed artefacts (Cons 3) from DGB-1 was determined to be made of wrought iron, while the hoe (Cons 7) was of a medium-carbon steel. The blades from the DGB-1 artefacts all made use of steel. The Cons 7 blade is uniform and made of steel throughout, with about 0.8 % carbon content, confirming the similarity between some of the Dokwaza iron products and those observed here. This would be significantly interesting if Cons 7 turned out to be from an earlier phase of Mafa use of the site. The use of a 0.5–0.6 % carbon steel as a welded edge (Cons 1) revealed that value was placed on the selective use of this high-quality product and that it was both recognised and appreciated for its practical utility. Analysis of the DGB-1 artefacts also revealed the use of softer iron for tangs and arrowheads, areas where hardness would not be at such a premium (for example Cons 4 and 6), in the socketed artefacts (Cons 3 and 5), and in the possibly imported artefacts (Cons 8 and 9) where softer iron was required for their fabrication.

Conclusion

This study provides insights into the quality and selection of ferrous materials utilised by the prehistoric occupants of the DGB sites approximately 500 years ago, and allows for comparison between their metallurgical techniques and those of Mafa blacksmiths in modern times. Examination of the artefacts recovered from excavations at DGB-1 suggests that their iron-working

techniques produced ferrous materials similar to those produced by Mafa smiths reconstructing traditional smelting procedures, with blooms yielding eutectoid steel, various forms of lower-carbon steel, and wrought iron. It is quite likely that cast iron would also have been produced in these blooms, as they were in the 1980s Mafa smelts, but that this cast iron was then decarburised for use. The DGB smiths demonstrated impressive technological sophistication: in selecting and processing these different forms of iron and steel; in making use of them in artefacts where their different qualities would be most appropriate; and in combining different kinds of iron and steel through welding in areas of the artefacts — especially blades — where the varying qualities of these materials would be most useful. Mafa and other Mandara peoples claim that their iron products were superior to Western tools in strength and hardness, just as the hardness of the DGB artefacts made sampling difficult during the conservation process. It is also notable that the two artefacts that, based on morphology, are quite likely foreign to the region cannot easily be distinguished from DGB artefacts based on their metallurgy, since their very low carbon content could easily be due to selection of soft iron for artefacts in which malleability was important.

We cannot, on the sole basis of these comparisons, make a claim for direct technological or cultural continuity between the DGB and modern Mafa iron-working traditions. The similarities that we have identified are ones that might also hold for other iron-working traditions in this part of Central Africa, making use of generally similar smelting and forging techniques. On the other hand, the general similarities that we have identified establish themselves as another strand of cultural connection between the prehistoric inhabitants of the DGB sites and the modern populations that now inhabit the same area, one of a number of such connections that appear in technological and material contexts in these different cases. They thus make it more likely that, although modern Mafa people do not incorporate the DGB sites within their own historical narratives, some degree of cultural and historical continuity exists between these past and present inhabitants of the Mandara Mountains.

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