

# Scrutinizing copper and bronze slag on Gotland

## On the making and dismantling of a category of archaeometallurgical finds

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The aim of this paper is to introduce a relatively unknown and sadly misinterpreted type of archaeological find. Finds of copper and bronze slag have been reported at various settlements on Gotland since the 1930s at least, and from early on this slag was provided with a legend of its own – that it was derived from a little-known local industry producing copper. During the last 30 years the number of finds of this type has risen considerably due to the organized use of metal detectors for investigating ploughed-over settlements. Contrary to the earlier assumptions, examination of a number of these finds has shown that they are by no means slag but fragments of refractorised hearth lining from ploughed-over workshop areas. Rather than copper production, they point to other disciplines associated with non-ferrous metalworking – presumably casting.

*Keywords:* Gotland, non-ferrous metalworking, Iron Age, Early Medieval, copper alloy, slag

### Introduction

This investigation of a certain category of metallurgical debris found on Gotland aims to address an issue which has prevailed latently in published works concerned with archaeometallurgy on that island published from the 1920s onwards – namely the claim that the fragments of “copper slag” or “bronze slag” discovered there indicate the existence of local copper extraction on the island during the Iron Age and Early Medieval Period. This production is assumed to have been based on the use of local ores, imported ores or unrefined “raw copper”. The main goal here is to establish whether this was the case or whether a different explanation has to be sought in order to interpret these finds correctly.

### Background

In the course of the 19<sup>th</sup> and early 20<sup>th</sup> centuries rich remains of ironworking came to light in Visby, the provincial capital of Gotland, Sweden’s largest island,

situated about 90 km east of the mainland. During the 1920s the archaeologist John Nihlén undertook the first basic in-depth survey of these finds in order to establish what processes had been carried out and how they were distributed spatially in the town. His report, published in 1927 (Nihlén 1927), also included a discussion of early iron production in the countryside of Gotland. To accomplish this, Nihlén had employed the network of semi-official local liaison representatives contracted by the Swedish National Heritage Board from most of Gotland’s 92 church parishes. At Eskelhem, about 20 km south of Visby, for instance, he was aided by Gabriel and Erik Bohlin of the Simonarve farm. They were father and son and occupied the position as parish representatives consecutively in the 1920s and 1930s.

In 1932 Erik Bohlin reported the recent discovery of some concentrations of slag in a field to the northwest of his farm, which is variably referred to as Sinnare, Simnare, Sinnarve and Simonarve in written accounts. Since John Nihlén was the authority on the archaeometallurgy of Gotland at that time, he was



Figure 1. Eleven pieces of metal-soaked hearth lining from Binge 1:6 in the parish of Alva, all originally reported and catalogued as “bronze slag”.

sent by the Board to inspect the site. There were three concentrations of finds – one with iron slag close to a drained bog and two with a considerable amount of copper spillages, scrap metal and what Nihlén interpreted as fragmented copper slag. According to his report (Nihlén 1932), he collected some samples of this slag and scrap metal. Erik Bohlin had previously found a hammered-out metal ingot and an incomplete box brooch, both of copper alloys, in the same area. These two artefacts were later bought by the National Historical Museum (inventory no. SHM 20246), while Nihlén’s samples – according to his report – went to a Dr. G. A. Granström for analysis. In a later addition in the margin of the report Dr. Granström dismissed Nihlén’s statement as pure nonsense – and the samples from Simonarve were never seen again. They left one lasting impression, though, in that they established Gotlandic copper slag as an archaeological find category in its own right. Nihlén interpreted the finds as possible debris left by local copper production, remnants from the smelting of copper ore and/or the re-smelting of “raw copper”.

For unknown reasons, Nihlén never elaborated any further on the hypothesis regarding local copper smelt-

ing, but copper and bronze slag was found and reported in a few other settlement deposits over the following decades. The situation changed in the late 1970s, when the local branch of the National Heritage Board on Gotland launched the Hoard Project (Östergren 1989), an organized metal detection programme that stepped up the general find rate on Gotland considerably and yielded a wealth of settlement-related artefacts from all over the island. Finds evidently resulting from metalworking were collected at a number of sites, and these included an increasing number of fragments reported as “copper slag” or “bronze slag” (cf. Östergren 1984; Zerpe 1985; Ström 2001) (Fig. 1). After a long hiatus, Nihlén’s ideas of local copper production on Gotland surfaced again in the doctoral thesis of Majvor Östergren (1989), in which a note on the traces of metalworking acknowledged the presence of this enigmatic slag, although by then it had come to be called “bronze slag” or occasionally “crucible slag”. Like Nihlén, Östergren connected it with possible copper production on the island, but she explicitly stated that there was no scientific evidence to support such an interpretation (Östergren 1989:187).



Figure 2. Map of Gotland with key sites marked. 1: Binge 1:6 in Alva; 2: Smiss 1:14 in Linde; 3: Stora Sojdeby 2:7

## Investigations

Modern archaeometallurgical research has rendered Nihlén's ideas of copper extraction on Gotland quite obsolete. The island has no naturally occurring rock ores, since the bedrock consists of sedimentary limestone and sandstone. Even the local ferrous bog ores are not indigenous to Gotland, since it has been established that the iron was originally eluviated from ferrous rocks brought to the island by the ice sheet during the last glaciation (Rydén 1979). It is clear that there were large imports of both ferrous and non-ferrous metals into Gotland during the Iron Age, but there is nothing to imply that the local metalworkers were forced to import unprocessed ores in order to obtain their metal. Later, in the 16<sup>th</sup> and 17<sup>th</sup> centuries both rock and bog ores were indeed imported to the island, but that took place within a social frame-

work which was entirely different from that which prevailed in the first millennium AD.

By consulting Östergren's thesis and all the archived survey reports mentioning copper or bronze slag it was possible to identify 22 sites where such fragments had been found. Examination by eye sufficed to establish that none of the fragments could be said to consist of copper slag – or indeed any slag at all. Instead they consisted of highly tempered clay in various stages of vitrification. Most samples also displayed visible patches of verdigris, which was obviously what had originally triggered the metal detectors. Five fragments representing three sites, Binge in the parish of Alva, Smiss in Linde and Stora Sojdeby in Fole (see Fig. 2), were brought to the Archaeological Research Laboratory for further analysis to establish the basic elements contained in the verdigris by means of SEM-guided Energy Dispersive Spectroscopy (SEM-EDS). The analyses showed that the verdigris patches consisted of copper with inclusions of zinc, lead and tin, i.e. the basic elements of copper alloy (Table 1). As stated above, Nihlén's finds are unfortunately no longer available for examination, but an important clue as to the nature of the Simonarve "slags" fortuitously came to light in 2011 in the form of a small box of samples stored in the Gotland County Museum. They had been collected in 1930 by the physician Dr. Kurt Bergström from a 2 m<sup>2</sup> patch of "copper slag" in the field of Bryeäkern, close to the area which was surveyed by Nihlén in 1932. Although none of these samples has been analysed by SEM-EDS, they all show the same basic features as the fragments found through the metal detector surveys, i.e. heavily fired tempered clay with inclusions of clearly visible verdigris.

## Discussion

Both visual inspection and the SEM-EDS analyses showed beyond doubt that the fragments were *not* slag – but what were they? Based on finds from better preserved contexts such as a workshop at Bottarve in the parish of Fröjel (Söderberg & Gustafsson 2006, Gustafsson & Söderberg 2007), recently excavated hearth bottoms at Artilleriet in Visby and other contemporary metalworking sites outside Gotland (see Willim & Grandin 2008:9), it can be established quite firmly that the fragments of copper and bronze "slag" are actually refractorised hearth lining. It has long been evident from finds and experiments that casting hearths in the late Scandinavian Iron Age were generally of a simple design, mainly consisting of a relatively small pit filled with charcoal and lined

Table 1 : SEM-EDS analyses of five fragments of hearth lining, results in atomic % with a precision of  $\pm 1\%$ .

Site	Al	Si	K	P	Ca	Fe	Cu	As	Sn	Sb	Ag	Hg	Au	Zn	Pb
Binge, Alva (SHM 31674)	-	-	-	-	5	-	88	-	-	-	-	-	-	5	2
Binge, Alva (SHM 34075:33)	-	-	-	-	2	-	86	5	-	-	-	-	2	1	3
Linde, Smiss (SHM 34067:69)	1	4	-	4	1	1	85	1	-	-	1	tr	-	-	tr
Linde, Smiss (SHM 34067:70)	2	2	-	3	tr	-	90	tr	tr	tr	-	1	1	-	1
St. Sojdeby, Fole (SHM 34300)	-	15	2	-	2	1	72	tr	-	-	tr	-	-	-	6

with stones and refractorised clay, or exclusively the latter at some find sites (Söderberg 2002:256–257). Clay tempered with quartz or grog, for example, was the only sufficiently refractory material readily available to Iron Age craftsmen. Most of the fragments of hearth lining from Gotland considered here have been recovered through metal detector surveys of ploughed-over settlements. This simple fact partly explains why there are so few finds, for Gotland was a veritable centre for metalworking during the late Iron Age and well into the Medieval period and hundreds of thousands of copper alloy and silver artefacts were produced all over the island. Very little is known today, however, about how this production was organized and controlled, and not least about how it was carried out. Most earlier studies have focused on depositional patterns (e.g. Carlsson 1983; Thunmark-Nylén 1983), and such an approach can be useful to some extent, but all too often these patterns are equated with those left by production. Since present-day Gotland is a rural province that is seldom touched upon by large-scale excavations, metal detector surveys of settlement areas is often the only way of gathering more information about earlier periods. As stated above, fragments of metal-impregnated hearth lining have been recovered from at least 22 sites on Gotland, some of which yielded just one or two stray fragments, but some are represented by as many as 15–20 fragments. Regardless of the number of fragments, however, it should be remembered that *one* single fragment of this hearth lining most probably equals twenty or more non-detectable fragments with no traces of metal.

Some attention should also be paid to how these fragments were formed. As mentioned above, Iron Age casting hearths generally consisted of pits lined with refractorised clay. The metalworkers made the charcoal in the pit burn at a sufficiently high temperature by ensuring a steady flow of air from a set of bellows at one side of the pit. The metal was then heated in a crucible, likewise of refractorised clay

and, depending on the metal being cast, the temperature was increased to and held at between 1000 and 1200°C until the metal had melted sufficiently to be poured from the crucible into a pre-heated mould. The furnace lining was expected to withstand the heat for the necessary length of time, for example, 8–15 minutes for up to 100 grammes of copper alloy (Söderberg 2002:263). One particularly exposed area was where the air entered the hearth (Gustafsson 2009), as the combination of the jet of air and heat from the charcoal often caused the point of entry of the airstream – the tuyere – to vitrify so completely that it is rather simple to identify pieces of it, even for a person with little experience in the field of archaeometallurgy. Naturally the crucibles, too, were – for obvious reasons – severely exposed to the heat on their outer faces. Modern experiments have shown that the life of an Iron Age crucible must generally have been short (see Lönborg 1998:24) and could end suddenly with it cracking open and spilling its molten contents into the hearth. It is here, at least in part, that the origins of the hearth lining impregnated with copper alloy ought to be sought. In a hearth-pit the molten metal from a wrecked crucible would not have solidified in the same fashion as that left to solidify outside the hearth, as it would have run down to the bottom of the hearth along the surface of the lining and would either stay there or, as often seen in extant fragments, follow natural cracks deeper into the lining and eventually solidify when the temperature dropped. Thus varying quantities of metal would have been preserved inside the hearth lining, serving to hold the clay together when it was exposed to erosion or more active mechanical forces, whether it was the pick of a contemporary craftsman cleaning out the hearth-pit or a modern day plough displacing a whole settlement deposit. Spillage when molten metal is poured from crucibles into moulds is another possible explanation for copper alloy in the hearth lining, as solidified drops and spillages are generally to be found in and around hearths both

in regular archaeological contexts and after modern experiments (Söderberg 2002:259–260). Spillages of this kind could also be used to identify possible sites of metalworking, although preferably not on their own, since spillages and droplets from metal casting are indistinguishable from those caused by jewellery melting away in funeral pyres. However, if a number of spillages are found in close proximity to other key metallurgical finds such as casting jets or metal-impregnated hearth lining material they should be seen as strong indicators of non-ferrous metalworking, even in cases where the vast majority of the cultural deposits at the site have been ploughed away.

## Conclusions

In short, “copper slag” or “bronze slag” can be ruled out as a category of archaeological finds, as can theories that presuppose the existence of local copper extraction on Gotland. Instead, it can be clearly shown that these finds are fragments of metal-impregnated hearth linings. As such, they still signal that metalworking has indeed occurred on the find sites – just as the fabled copper slag did.

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