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Craft production of large quantities of metal artifacts at the beginnings of industrialization: Application of SEM–EDS and multivariate analysis on sheathing tacks from a British transport sunk in 1813

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ABSTRACT

In June 1813, several ships from a combined fleet that unsuccessfully tried to liberate Tarragona from Napoleonic forces ran aground in the Ebro Delta (Catalonia coast, Spain). One, a British transport is currently the subject of research by the Catalan Centre for Underwater Archeology (Centre d'Arqueologia Subaquàtica de Catalunya). During the excavations at the stern area of the ship, hundreds of unused sheathing tacks were recovered, among other items of the cargo. A sample of these artifacts was subjected to characterization by means of energy dispersive X-ray spectroscopy, light microscopy and scanning electron microscopy. Based on the multivariate statistical analysis of the data obtained, an evaluation of the production of large quantities of artifacts was performed. The emphasis was on the control of chemical composition, thus providing novel information about the persistence of craft practices within the context of the remarkable growth at the beginnings of industrialization.

1. Introduction

In June 1813, a combined fleet of three ships of the line, three frigates, a brig, a schooner, six gunboats, and a hundred and thirty-two transports, led by Lieutenant General John Murray,[1] besieged Tarragona, key location for the strategic operations east of the Iberian Peninsula. But after the fruitless attempt to free the city from Napoleonic troops, several vessels ran aground in a storm at the mouth of the Ebro river (to South of Tarragona). Some of the ships finally sunk; sources are inconsistent regarding their number (Blanch, 1861:382; Suchet, 1829:22). A little over two-hundred years later, a local fisherman found the remains of a shipwreck at the area where the tragedy occurred. Archeological investigations at the site, named Deltebre I thereafter, began in 2008 and developed annually by the team of the Centre d'Arqueologia Subaquàtica de Catalunya (CASC), Museu d'Arqueologia de Catalunya (MAC).

The study of naval architecture and the objects found at the stern area indicated that this ship — of about thirty meters of length — is indeed among those that ran aground in 1813. The excavated areas revealed part of the cargo, consisting mainly of ammunition (e.g. musket balls; round shot and bombs; gunpowder and gunflint barrels) and artifacts related to navigation, personal hygiene, cooking, clothing and religious worship (Vivar et al., in press). Within the objects associated to the cargo, a discrete array of hundreds of sheathing tacks was located at the ship's hold, to the port and aft of the mizzen-mast step. No evidence of their original container was preserved in this area. Sheathing tacks are small nails, usually made of copper or copper alloy, used to fasten protective metal sheets to a ship's hull (McCarthy, 1996:185,186) (see Section 2). The vast majority of pieces from the Deltebre I site show no signs of use, as it is likely that they were destined for minor repairs both on the ship itself or other vessels of the convoy.

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[1] Murray commanded a fleet sailed by men of many different nationalities. A detailed account of their provenances was reported in an article from the newspaper *El Redactor General*, Cadiz, Spain, July 12th 1813, No. 758.

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In this study, the results of the physicochemical analyses performed on a sample of twenty five tacks are presented, paying particular attention to chemical composition variations and the manufacturing methods applied. Taking into consideration the high temporal and spatial definition of the pieces, the data obtained shed light on several aspects regarding the quality of serial production of such artifacts in early 19th century England. The significance of this work lies in the assessment of the dynamics of the transition from a craftsman production modality to an industrialized one, distinctive of the modern world, and in a case for which scant historical documentation is available.[2]

2. Metallic sheathing in navy ships

Anthropic material in seawater is affected by the action of wood-boring bivalve molluscs (Teredinidae and Pholadidae families, known as shipworms and piddocks) and isopod crustaceans (Limnoriidae and Sphareomatidae families, known as gribble and pill bug), as well as by biofouling (benthic micro and macro-organisms added to artificial substrata) (see Robinson, 1981; Grosso, 2014). For centuries, these organisms represented a serious problem for the operation of wooden ships, for example affecting speed, maneuverability and durability. Aiming to mitigate the difficulties caused by them, diverse protection methods began to be implemented, such as metal sheets or sacrificial wooden planks, and mixtures of pitch and tallow, among other compounds. However, it was not until the second half of the 18th century, after a process of experimentation, that copper sheathing was finally introduced (see Bingeman et al., 2000; Staniforth, 1985; US Naval Institute, 1952).

The first vessel thoroughly sheathed in copper (its hull, below the waterline) was the 32-gun frigate HMS *Alarm*, in 1761. The success of the trial led to the practices broader implementation in other Navy ships first, and in commercial vessels some time after that (see Harris, 1966; Harland, 1976; Wilkinson, 1842). In subsequent years, numerous innovations regarding materials and manufacturing methods appeared, for many of which patent registers were granted (e.g. Muntz metal, Cu 60% and Zn 40%, in 1832) (see Jones, 2004). This practice had great economic importance for the copper industry in Great Britain, and for Royal Navy contractors (e.g. Raby, Forbes, Collins, Westwood & Williams, and Roe & Co.), that also supplied other European powers (McCarthy, 2005:106,108; Staniforth, 1985:25–26).

The dimensions of the sheets had to meet certain specifications of size and shape. In places outside the Navy's scope, however, the pieces were less regular. Furthermore, their dimensions also depended on the sector of the hull they covered. On the other side, each sheet was manually bored using a special punch and fixed to the structure with copper or copper-alloy tacks, following a stipulated sequence (Bingeman et al., 2000:220–221; Boudriot and Berti, 2004:14–15; Staniforth, 1985:28). The rudder from the Deltebre I site is illustrated in Fig. 1. This, as the hull's bottom, was sheathed in copper, with the exception of its back, at the height of the pintles, which was protected with lead. The sheathing, that originally reached 12 in. (ca. 30.5 cm) below the waterline, was extended up to 16 in. (ca. 40.5 cm) above the latter since 1783, by a warrant of the Navy Board (McKay and Coleman, 1992:8).

[2] During the 18th century, the industrial production of some metal artifacts gradually became a centralized and standardized task. Regulations concerning the processes, materials and products were also established in many places. And an increased level of specialization of the craftsmen was encouraged (see Coriat, 2008). This was framed in a process of technological change that affected labor organization and materials used in many areas of industry in Britain and other places (see Musson, 1972; Harris, 1992; among others). In the case of a maritime power such as Britain, which had a long established program of ship construction and had faced continuous conflicts with other European countries, manufacture centers owned or directly supervised by the government were not uncommon (see Rodger, 2004). This centralization made it possible to achieve a better control of production and obtain more uniform qualities than that expected from craft production in domestic workshops.

Since the last quarter of the 18th century, the need to protect the hulls of an increasing number of Navy ships demanded vast quantities of copper sheets and their fastenings, including the bolts and nails used to secure the plating to the structure. These needed be of the same composition to avoid the effects of galvanic corrosion. The data reported by Winfield (2005:76) on the 50-gun vessel *Hannibal* are supportive: 2010 copper sheets (total weight: 6 t and 12 cwt, equivalent to about 6700 kg) and 40.5 cwt of sheathing tacks (about 2050 kg). If an amount of approximately 90 tacks per pound is considered (see Section 4.1), it follows that a fourth rate British warship of the late 18th century required about 400,000 sheathing tacks. To illustrate the amount of sheets and tacks that a first rate ship required, around 17 t of sheathing were removed during the reparation tasks of the HMS *Victory* (1765–present) in the 1960s (Bingeman et al., 2000:226). For comparison, at the beginning of the 19th century a 130-gun Spanish vessel required 2.128 sheets (total weight, ca. 340 cwt) and ca. 50 cwt of nails (i.e. tacks) (Artiñano y de Galdácano, 1920:380). These are significant numbers if it is taken into account that the British fleet, considering first to fourth rate vessels and frigates, consisted in more than 250 units in service during the 1800 decade (see Gardiner, 2011).

Several contributions have been made within the fields of history and maritime archeology to improve the knowledge of this technology. Regarding the period that is dealt with in this work, it is worth mentioning the characterization studies of the sheathing elements (sheets and tacks) and the structural fastenings from various shipwrecks (e.g. Bethencourt, 2008/9; Ciarlo et al., 2013; De Rosa et al., 2008; Jones, 2004; Samuels, 1983, 1992; Viduka and Ness, 2004). Taking into account that a ship's sheathing used to be periodically repaired (Winfield, 2005:76), the remains from shipwrecks can include materials from different provenances (see Section 5). The materials used for the initial equipment could also come from different factories, if the common practice of supplied the Navy by contractors is taken into account (Stanbury, 1994:37). For instance, the chemical composition analyses of sheathing samples found in the HMS *Sirius* (1790) allowed the identification of two distinct batches, providing evidence about the initial fitting out of the vessel in 1781, and the later refurbishment in 1786 (see MacLeod, 1994:274,275). The Deltebre I site constitutes an exceptional case to this respect, as it provides an opportunity to analyze aspects of this technology in a specific time and place.

3. Materials and methods

From the hundreds of sheathing tacks recovered at the site, twenty-five were selected to be analyzed. Given that all tacks came from the same location in the site, the array considered for this study was sampled randomly. Nonetheless, as general criteria, complete and well preserved tacks were selected. The main morphological features of the tacks were registered by macroscopic observation with the naked eye and optical stereomicroscope (20×).

After that, the pieces were axially sectioned for the energy dispersive X-ray spectrometry analysis (EDS). The surface was ground with emery papers reaching a particle size of 1000. In the case of the attached sheathing tacks (see Section 4.1), only the shank was ground, from the tip to a sector close to the head. Aiming to obtain a surface free of dirt, the pieces were ultrasonic cleaned, immersed in acetone. Measurements were performed on a layer that, as was observed in the metallographic analysis, presented a non-corroded structure.

Artifacts made of a copper-zinc alloy (brass) are susceptible to deterioration in seawater by a selective dissolution of zinc, process known as dezincification. This implies a drawback, especially when surface chemical analyses of samples from this environment are performed, as it is likely that results do not represent the original composition. MacLeod and Pitrun demonstrated that both different site conditions (e.g. chloride ion activity, temperature, water velocity and oxygen), and variances in chemical composition and microstructure of artifacts from shipwrecks, play a key role in the long-term materials' behavior, and