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Applying SEM to the study of use-wear on unmodified shell tools: an experimental approach

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A B S T R A C T

Although in prehistoric archaeology the evidence provided by molluscs has often been studied, few works have focused on the functional analysis of shells as tools. A number of prehistoric sites around the world are producing evidence from retouched shells that indicates that they were used for certain operations. In recent years, several experimental studies have been conducted for the purpose of gaining insight into the processes involved in shell tool production and use. This paper focuses on the procedures and the preliminary results of a program of use-wear experiments based on SEM analysis, and corroborates that non-retouched shells can also yield interesting results and can be used as a reference against which archaeological materials can be compared.

1. Introduction

Although Carl Von Linné (Linnaeus) was the first to recognise that shell middens were potential indicators of early human culture, it was in the 1970s that a few academics started to analyse the marks on shells in order to understand past human activities. Some authors tried, for example, to understand why specific shell species were used as raw material for manufacturing tools, or how shell microstructure affected breakage patterns and variations in shell working techniques (Szabó, 2008; Szabó and Kopple, 2015). Some tried to understand the techniques used to make fish hooks (Attenbrow et al., 1998; Przywolnik, 2003). Other studies were mainly based on manufacturing shell tools in order to understand retouching or reduction techniques (among others, Cleghorn, 1977; Douka and Spinapolice, 2012; Eyles, 2004; Romagnoli et al., 2004; Jones O'Day, 2002; Toth and Woods, 1989; Tyree, 1998). Some studies focused on the residues present on the shell edges, in order to understand what they were used for and the material they were used on (Barton and White, 1993; Bonomo and Aguirre, 2009; Schmidt et al., 2001; Zilhão et al., 2010). Finally, others tried to analyse the cut marks produced by the shell tools (Toth and Woods, 1989; Choi and Driwantoro, 2006).

Unlike stone tools, few studies involving shell tool use-wear analysis have been carried out, although some researchers have produced relevant work in the field (Cooper, 1988; Cuenca-Solana, 2009, 2013; Cuenca-Solana et al., 2010, 2011, 2013; Douka, 2011; Douka and Spinapolice, 2012; Eaton, 1974; Gauvrit-Roux, 2012; Jones O'Day and Keegan, 2001; Keegan, 1984; Light, 2005; Lucero and Jackson, 2005; Masson, 1988; Peter, 2001; Schmidt et al., 2001; Szabó and Koppel, 2015; Reiger, 1981; Tumung et al., 2012). Most of these authors tried to understand the use-wear features on archaeological samples, although there is an increasing interest in conducting meticulous experiments to test the possible ways use-wear can occur on shells.

Our study focused on how efficiently shell tools can be used without retouching, and on the effect that micro-topographical variations in shell edge types can have on use-wear patterns. For this analysis, we used the SEM, which has proven to be really convenient for lithic use-wear analysis (among others, Borel et al., 2014; Ollé and Vergès 2008, 2014; Knutsson, 1988; Sussman, 1988). We thus tested the feasibility of SEM use-wear analysis on different types of shells in order to assess whether use-wear is a distinguishing indicator of use-action and contact material, as well as to determine which types of features are most useful for identifying the part of a tool that was used, the tool action and the contact material. The results obtained after systematic use of the

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low-vacuum scanning electron microscope were broadly compared with those obtained by other methodologies (Cuenca-Solana, 2009, 2010, 2013; Cuenca-Solana et al., 2010, 2011; Schmidt et al., 2001; Szabó and Kopple, 2015).

2. Materials and methods

Our program of experiments aimed to analyse the type and degree of different wear features that would be caused by using different shell species with different natural edges (serrated, sharp- or fine-edged), on different generic use-materials (wood or soft animal matter), with different use-actions (transverse, longitudinal, uni- or bi-directional) and lastly for different use-times (Table 1). Fresh wood (*Celtis australis* L.) and red deer (*Cervus elaphus* L.) were used in this program of experiments. The variations in the experiments aim to identify major distinguishing categories of change to the shell surface (abrasions, fractures, striations and polishes), depending on the shell, use-material and use-action.

Systematic experiments were conducted to meet the above-mentioned goals. We decided to control certain variables in the experiments, while attempting to perform several basic activities. Although a complete experimental program would obviously require many more combinations of variables, in order to compare, here we maintained a reduced variety of contact materials, including: one kind of, soft and homogeneous wood and a single animal species (for which we worked on fresh meat, skin and bones).

The shells were selected on the criteria of edge shape, thickness, hardness, and microstructure, in order to understand where the use-wear might occur and which shell species would be better suited for use as a non-retouched tool. In the meantime, we took into consideration the shell species present in some European prehistoric sites.

In the experiments, four species of shell were used: *Pecten maximus* (Linnaeus, 1758), *Mytilus galloprovincialis* (Lamark, 1819), *Ruditapes decussatus* (Linnaeus 1758), and *Glycymeris violascens* (Linnaeus, 1767). The first three were collected live from the local fish market, which gave us a wide variety of options and allowed us to select those with edges that had been altered the least by natural effects or human handling. *G. violascens* shells were collected from the beach in Tarragona and selected with various different levels of wear, as they had undergone some natural modifications caused by friction with the sand (Zuschin et al., 2003). All the shell species selected have naturally sharp edges, so no retouching or edge modification was performed.

Several assemblages from European sites dating from the Middle Palaeolithic to the Neolithic era provide evidence of the use of these shells. The *Glycymeris* sp. is present in Middle Palaeolithic sites in Southern Italy and Greece (Douka and Spinapolice, 2012). The use of *M. galloprovincialis* for shell tools has been reported for example at the Mesolithic and Neolithic Spanish sites of Santimamiñe (Cuenca-Solana et al., 2010), La Draga and Serra del Mas Bonet (Clemente-Conte and Cuenca-Solana, 2011).

Because they were bought fresh, the *P. maximus*, *M. galloprovincialis* and *R. decussatus* were first cleaned by hand to remove the flesh, whereas the *G. violascens* shells were not cleaned in this way. Later, all the shells were cleaned twice for the experiment: firstly, to ensure that they were properly clean for making moulds of the fresh edges, and secondly prior to the microscopic examination of surface changes. The cleaning procedure consisted of:

a) 10 min in an ultrasonic bath of H_2O_2 (10% vol.) to soften any adhered organic tissues (of the molluscs themselves and of the materials worked);
b) 10 min in an ultrasonic bath of the neutral phosphate-free detergent Derquim®, with ionic and non-ionic surfactants to eliminate all the residues from the shell surface;
c) Rinsing under cold running water to remove any detergent from the shell surface;
d) 2 min in an ultrasonic bath of acetone to eliminate any fatty residue resulting from the handling.

After these various cleaning steps, the shells were packed in individual plastic bags in order to prevent any future contamination or damage. This cleaning procedure has been shown to yield good results for stone tools (Byrne et al., 2006; Ollé and Vergès, 2014), and was tested on modern shells before the experiments in order to assess its adequacy.

Before making the mould and cast of each shell tool edge, we took photographs of the fresh edges. Since, in some cases, photographs and other taphonomic studies cannot tell us how the use-wear on the edge occurred, we made a mould and cast in order to have a reference copy of the fresh edge which would make it possible to compare a given point after the experiment with the same point on the edge of the mould. This can help us to assess the actual changes to the edge which resulted from its use (thus avoiding misunderstandings of certain features such as natural striations, edge fractures, etc.)

Moulds were prepared using silicon-based dental impression material, Provil® novo Light (Heraeus Kulzer, Inc.). The two components, a base and a catalyst in a ratio of 1:1, were placed on the impression material sheet and mixed at room temperature for 20–30 s so that the colour is uniform, in order to ensure good polymerization. The mixture was then applied to the shells with a

Table 1
List of experiments and principal variables of the program. Delineation h-d (horizontal delineation), p-d (profile delineation).

Ref. no.	Type of shells	Worked material	Species	Delineation		Working angle	Motion	Action	Hand	Time
				h-d	p-d					
MY01	*Mytilus galloprovincialis*	Skin-meat	*Cervus elaphus*	Convex	Straight	90°	Longitudinal bidirectional	Cutting/skinning	Right hand	15
MY02	*Mytilus galloprovincialis*	Meat-bone	*Cervus elaphus*	Convex	Straight	90°	Longitudinal bidirectional	Cutting/defleshing	Right hand	10
MY03	*Mytilus galloprovincialis*	Stem of fresh wood	*Celtis australis*	Convex	Straight	90°	Longitudinal bidirectional	Cutting wood	Right hand	10
MY04	*Mytilus galloprovincialis*	Stem of fresh wood	*Celtis australis*	Convex	Straight	70°	Transverse bidirectional	Scraping wood	Right hand	10
PE01	*Pecten maximus*	Skin-meat	*Cervus elaphus*	Serrated	Serrated	30°–90°	Longitudinal unidirectional	Cutting/skinning	Right hand	15
PE02	*Pecten maximus*	Meat-bone	*Cervus elaphus*	Serrated	Serrated	90°	Longitudinal bidirectional	Cutting/defleshing	Right hand	15
PE03	*Pecten maximus*	Stem of fresh wood	*Celtis australis*	Serrated	Serrated	90°	Longitudinal bidirectional	Cutting wood	Right hand	10
PE04	*Pecten maximus*	Stem of fresh wood	*Celtis australis*	Serrated	Serrated	90°	Transverse bidirectional	Scraping wood	Right hand	10
RU01	*Ruditapes decussatus*	Stem of fresh wood	*Celtis australis*	Convex	Convex	90°	Longitudinal bidirectional	Cutting wood	Right hand	10
RU02	*Ruditapes decussatus*	Stem of fresh wood	*Celtis australis*	Convex	Convex	90°	Transverse unidirectional	Scraping wood	Right hand	5
GL01	*Glycymeris violascens*	Meat-bone	*Cervus elaphus*	Convex	Convex	90°	Longitudinal bidirectional	Cutting/Defleshing	Right hand	10
GL02	*Glycymeris violascens*	Meat-bone	*Cervus elaphus*	Convex	Convex	90°	Longitudinal bidirectional	Cutting/Defleshing	Right hand	10