Quaternary International xxx (2016) 1–31

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Monitoring and interpreting the use-wear formation processes on quartzite flakes through sequential experiments

Antonella Pedergnana [a, b, *], Andreu Ollé [a, b]

[a] IPHES, Institut Català de Paleoecologia Humana i Evolució Social, Zona educacional 4, Campus Sescelades URV (Edifici W3), 43007 Tarragona, Spain
[b] Àrea de Prehistòria, Universitat Rovira i Virgili, Fac. de Lletres, Av. Catalunya 35, 43002 Tarragona, Spain

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Use-wear analysis
Quartzite
Experimentation
Scanning electron microscopy
Optical microscopy

ABSTRACT

Sequential experiments were performed with quartzite flakes with the main purpose of monitoring use-wear formation processes. The two main objectives of this research were the construction of a wide reference collection to serve for future functional interpretations of the archaeological material and to achieve a better comprehension of the mechanical behaviour of quartzite when subjected to the stress applied in determined prehistoric tasks (e.g., sawing, scraping bone, wood, etc.).

The two objectives are strictly related because the appearance of wear on the tool edges resulting from those tasks would be dependant on the mechanical behaviour of the rock in question. Concepts from tribology were used to provide an explanatory framework. As mechanical behaviour of solid materials always depends on their mechanical proprieties which are unique, each raw material should be treated individually in use-wear analysis. For this reason, there is an urgent need to create a reliable and objective system to identify and interpret wear due to use on quartzite. For data recording, we resorted to both optical and electron microscopes (OLM and SEM) to present a wide photographic documentation and to compare the adequacy and complementarity of those microscopic techniques for microwear studies.

Furthermore, both the experimental residues of the worked materials and the rock particles detached from the active edges were analysed to understand their role as interfacial medium affecting use-wear formation. EDX (Energy- Dispersive X-ray spectroscopy) was used to document the presence of rock particles detached from the tools edges and then embedded in the residues of the worked materials.

The results from analysing the experimental flakes allowed us to infer more closely the mechanical behaviour of quartzite. As a final point, the potential of OLM and SEM for analysing quartzite surfaces was evaluated and it emerged that the combination of the two techniques in an integrated approach is a feasible choice, though the application of SEM is always desirable in order to get more trustworthy results.

1. Introduction

Although use-wear analysis has been largely applied to determine stone tools' functionality, not so many efforts have been done to improve the methods for the analysis of non-chert/flint raw materials (from now on referred to as non-flint raw materials). Despite sporadic studies which provided specific methodologies to recognise use-wear on non-flint raw materials (Richards, 1988; Knutsson, 1988a; Sussman, 1988a; Hurcombe, 1992; Kononenko, 2011), as pointed out by Leipus and Mansur (2007:182), most of the contributions regarding lithic use-wear analysis have focused on the study of flint (Tringham et al., 1974; Keeley, 1980; Vaughan, 1985; Grace, 1989; Van Gijn, 1990; González Urquijo and Ibáñez Estévez, 1994; Levi-Sala, 1996). Nevertheless, non-flint raw materials have been occasionally considered for functional analysis, recently being the central object of sessions in international conferences (Clemente-Conte and Igreja, 2009; Sternke et al., 2009).

Quartzite, as other "secondary raw materials" like rock crystal (Alonso and Mansur, 1990; Pignat and Plisson, 2000; Plisson, 2008; Lombard, 2011; Fernández-Marchena, and Ollé, 2016) and rhyolite (McDevit, 1994; Clemente-Conte and Gibaja-Bao, 2009), have

* Corresponding author. IPHES, Institut Català de Paleoecologia Humana i Evolució Social, Zona educacional 4, Campus Sescelades URV (Edifici W3), 43007 Tarragona, Spain.
E-mail address: apedergnana@iphes.cat (A. Pedergnana).

http://dx.doi.org/10.1016/j.quaint.2016.01.053
1040-6182/

Please cite this article in press as: Pedergnana, A., Ollé, A., Monitoring and interpreting the use-wear formation processes on quartzite flakes through sequential experiments, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2016.01.053

always received less attention by use-wear analysts compared to other lithic raw materials from which stone tools were produced in prehistory. In fact, basalt (Richards, 1988; Rodríguez-Rodríguez, 1997–1998; Asryan et al., 2014), obsidian (Mansur-Franchomme, 1988, 1991; Hurcombe, 1992; Kononenko, 2011), and vein quartz (Beyries and Roche, 1982; Sussman, 1985, 1988a, 1988b; Fullagar, 1986; Knutsson, 1988a, 1988b; Pant, 1989; Bracco and Morel, 1998; Derndarsky and Ocklind, 2001; Jaubert et al., 2005; Igreja et al., 2007; Derndarsky, 2009; Eigeland, 2009; Taipale, 2012; Taipale et al., 2014; Venditti, 2014; Knutsson et al., 2015) are much more known regarding use-wear appearance.

Although functional analyses involving quartzite have been previously performed by archaeologists, practically no specific experimentation focusing on this lithology has ever been undertaken on a systematic basis. We assume that within the framework of use-wear analysis, occasionally a reduced number of experiments on quartzite implements had been performed to provide data comparable with the archaeological record. Nevertheless, the resulting implications of such experiments were hardly ever investigated. Indeed, we noticed that as a prevailing attitude to deal with this methodological weakness (limited published experimental referential data concerning use-wear on quartzite), analysts generally applied the classical methodology developed for flint artefacts (either based on low or high power microscopy as well as on the combination of the two) (among others, Plisson, 1986; Alonso and Mansur, 1990; Pereira, 1993, 1996; Igreja et al., 2007; Leipus and Mansur, 2007; Hroníková et al., 2008; Igreja, 2008; Aubry and Igreja, 2009; Cristiani et al., 2009a; Gibaja et al., 2009). However, in few cases the intrinsic peculiarities of this rock were investigated, trying to evaluate the role of intra-raw material variability in use-wear formation and appearance (Beyries, 1982; Gibaja et al., 2002; Ollé, 2003; Vergès, 2003; Leipus and Mansur, 2007; Clemente-Conte and Gibaja-Bao, 2009; Ollé et al., 2016).

The extreme surface irregularities of quartzite, mainly due to its microcrystalline structure and the differential orientation of crystal surfaces, have always been regarded as a major obstacle by use-wear analysts (Grace, 1990; Mansur, 1999; Clemente-Conte and Gibaja-Bao, 2009). This difficulty was sometimes overcome by the use of DIC (Differential Interference Contrast) (Igreja, 2008, 2009; Cristiani et al., 2009b) and by the observation of the negative silicone moulds (Lemorini et al., 2014; Venditti, 2014) or of the positive resin casts of the artefacts' edges (Banks and Kay, 2003).

Some authors have also pointed out the advantages of Scanning Electron Microscopy (SEM) to avoid the light reflectivity of the rocks' surfaces and the problems of depth of field of irregular samples (Hayden, 1979; Grace, 1990; Borel et al., 2014). In fact, when this microscopic technique was applied on quartzose raw materials, results were characterised by an improved quality of the photographic documentation, resulting in a better comprehension of the use-wear appearance (Sussman, 1988a; Knutsson, 1998a; Carbonell et al., 1999; Márquez et al., 2001; Ollé, 2003; Vergès, 2003). This technique was also employed to monitor use-wear formation processes thanks to its high resolution capacities (Mansur-Franchomme, 1986; Yamada, 1993; Ollé and Vergès, 2008, 2014; Pedergnana and Ollé, 2014).

Some pioneers in use-wear analysis already highlighted the importance of well characterising the specific raw-material types related to one's assemblage (Keeley, 1974; Odell, 1975), probably because they had observed differences in the appearance of use-wear on the distinct lithologies. In fact, knowing that the mechanical behaviour of quartzite differs from that of chert and other lithic raw materials (because of structural differences) (Greiser and Sheets, 1979; Lerner et al., 2007; Lerner, 2014a, 2014b; Pedergnana et al., 2016), we recognised the need to provide a comprehensive use-wear experimental collection for this rock type.

Therefore, a large-scale experimental programme focused on the formation, identification and possible interpretation of use-wear traits on quartzite was initiated. The entire experimental programme was designed to monitor the processes of use-wear formation and the development of wear over time. Sequential experiments involving the use of replicas of the fresh edges were performed (Yamada, 1993; Ollé, 2003; Vergès, 2003; Ollé and Vergès, 2014).

Experiments were thought to serve as a reference for the study of the Middle Pleistocene sites of Gran Dolina (Sierra de Atapuerca, Burgos, Spain) (Ollé et al., 2013) and Payre (Southern France) (Moncel, 2008) and therefore comprising quartzite varieties coming from the surroundings of those archaeological sites.

The involvement of different quartzite varieties, exhibiting slightly different structural characteristics, allowed us to highlight analogies and divergences related to their mechanical behaviour when a force is applied and, as a consequence, to document differences in the wear appearance. The evaluation of the variability of the use-wear appearance is thought to increase the capacity of analysts to interpret use-wear on quartzite. The expected results are thought to improve the knowledge of the mechanical behaviour of this rock, and to make the experimental collection available for other use-wear analysts. With this main purpose in mind, particular attention was devoted to providing satisfactory photographic documentation, an aspect considered very important to allow other researchers to interpret the proposed data (Newcomer et al., 1986; Grace, 1996).

As a latter point, concerning the microscopic techniques employed within this study, we resorted to both optical light microscopy (OLM) and scanning electron microscopy (SEM). By a systematic comparison of these techniques their potential and reliability to record use-wear on quartzite was evaluated. As already demonstrated (Monnier et al., 2012, 2013; Borel et al., 2014), an integrated methodology commonly results in the best option, as the advantages of one technique overcome the disadvantages of the other. However, in the case of quartzite, SEM proved far better in fulfilling the need of the analysts providing images with a much higher resolution and higher magnifications. The limitations of optical microscopy in focusing high depth of fields when analysing very coarse materials such as quartzite are overcome by SEM.

1.1. A tribological approach

Perhaps the most evident obstacles in microwear analysis are the subjectivity of the analysts' observations and the scarcity of standards in terminology and methodology (Keeley, 1974). Those obstacles are frequently accompanied by a lack of interest in reaching a comprehensive understanding of wear formation processes. If the behaviour of the different lithologies is misunderstood, how can microwear analysts attempt to discern and interpret modifications of lithic micro-topographies? This concern was shared by some authors who incorporated concepts from fracture mechanics (Cotterell and Kamminga, 1979; Kamminga, 1979) and tribology (Knutsson, 1988a; Fullagar, 1991; Levi-Sala, 1996; Sala et al., 1998; Burroni et al., 2002; Ollé, 2003; Vergès, 2003; Anderson et al., 2006; Ollé and Vergès, 2008, 2014; Adams, 2014) in their researches.

Tribology (from the Greek *tribos*, rubbing) is defined as the study of contacting surfaces in relative motion and it deals with different aspects of materials' behaviour, such as lubrication, friction and wear (OECD, 1969). Although lubrication (when the two solids are separated by a lubricant) and friction (rubbing of one surface against another in dry conditions) intervene in stone tools' use, the main concern of the functional analyst is indeed “wear” (Semenov,