ROCK-MAGNETIC PROPERTIES AND ABSOLUTE PALEOINTENSITY DETERMINATION ON LITHIC CLASTS BURNED UNDER CONTROLLED TEMPERATURE AND FIELD CONDITIONS: ARCHAEOLOGICAL AND GEOMAGNETIC IMPLICATIONS

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ABSTRACT

A combined thermal and magnetic evaluation on experimentally knapped clasts of different lithologies (chert, quartzite, limestone, sandstone and obsidian) heated under controlled field and temperature conditions were carried out. The main aim of this study is to estimate the feasibility of use of these raw materials, which are commonly found in prehistoric archaeological sites, for archaeomagnetic purposes. Rock magnetic analysis included measurements of low-field magnetic susceptibility, isothermal remanent magnetisation (IRM) acquisition curves, hysteresis loops and thermomagnetic curves of lithic clasts both before and after experimental heating. All lithologies, except the obsidian, recorded an increase of up two orders of magnitude in their magnetic concentration-dependent parameters revealing the formation of new ferrimagnetic minerals. Obsidian and sandstone are the most reliable magnetic carriers, followed by limestone, chert and quartzite. Magnetic susceptibility values show significant differences among lithologies. Isothermal remanent magnetisation proved also to be highly discriminatory as well as the room temperature hysteresis parameters. The main macroscopic alterations resulted in colour changes, rubefactions, potlids in cherts and the massive formation of internal fissures in obsidian specimens. The multispecimen absolute geomagnetic intensity technique was applied on selected samples yielding satisfactory results for heated obsidian and sandstone samples. The archaeological applicability of the results is discussed as well as their geomagnetic significance.

Keywords: experimental fires, rock-magnetism, thermoremanence, magnetite, palaeointensity, multi-specimen method, prehistory.

INTRODUCTION

Ferromagnetic minerals (*s.l.*) are particularly sensitive to modify their magnetic properties by heating which makes rock-magnetic methods a very efficient tool to identify fire in archaeological sites (*e.g.* Herries 2009). This is particularly true in palaeolithic contexts where its identification is not straightforward and thermal alteration evidences (*e.g.*: ashes, charcoals, etc.) are usually few, ambiguous and generally poorly preserved. Thus, the rock-magnetic information may be very useful to evaluate the technological characteristics of prehistoric societies and the cultural interpretation of prehistoric sites. As far as the study of archaeological lithic assemblages is concerned, mineral magnetic analyses have been mostly used to identify source or provenance areas in different parts of the world (*e.g.*: McDougall *et al*. 1983, Vásquez *et al*. 2001, Thacker, Ellwood 2002, Stewart *et al*. 2003, Zanella *et al*. 2012). However, studies concerning how heating alter the magnetic properties of prehistoric lithic assemblages are relatively scarce and basically restricted to obsidians and cherts (Borradaile *et al*. 1993, 1998; Thacker, Ellwood, 2002).

This work is an experimental study about the variations of magnetic and macroscopic properties induced by heating on an experimental set of lithic clasts from different lithologies commonly found in prehistoric archaeological sites. A collection of experimentally knapped lithic artefacts from five diverse lithologies (chert, limestone, quartzite, sandstone and obsidian) was heated under controlled field and temperature conditions monitored by standard thermocouples. The main objectives of this study are: ***i)*** characterise the main magnetic and macroscopic properties of these materials induced by heating, ***ii)*** establish magnetic criteria in order to identify heating processes in analogous prehistoric lithic materials and, ***iii)*** evaluate the magnetic stability and determine the suitability of these lithologies to obtain absolute palaeointensity determinations as well as discuss its methodological implications. Therefore, the interest of this contribution is posed both from a geophysical and archaeological perspective.

EXPERIMENTAL PROCEDURES AND MAIN RESULTS

Experimental heating was carried out on a clayish substrate at the locality of Humienta (Burgos, Spain; fig. 1a) on May 2008. A clayish substrate was selected because of the availability to perform the field experiment and because this type of substrates are quite common in archaeological contexts. To avoid possible contaminations the upper 15 - 20 cm of the superficial soil were removed. Temperature variations during the burning were recorded at 5 minutes intervals with a K-type thermocouple system distributed linearly at 0 - 1 cm of depth and another one at 3 cm of depth in the centre of the experimental hearth. Temperatures recorded in the embers were the lithic artefacts were located exceeded 700º C during at least 60 minutes, so it seems reasonable to assume that a thermo-remanent magnetisation (TRM) was acquired. A comprehensive rock-magnetic study was carried out in order to verify it.

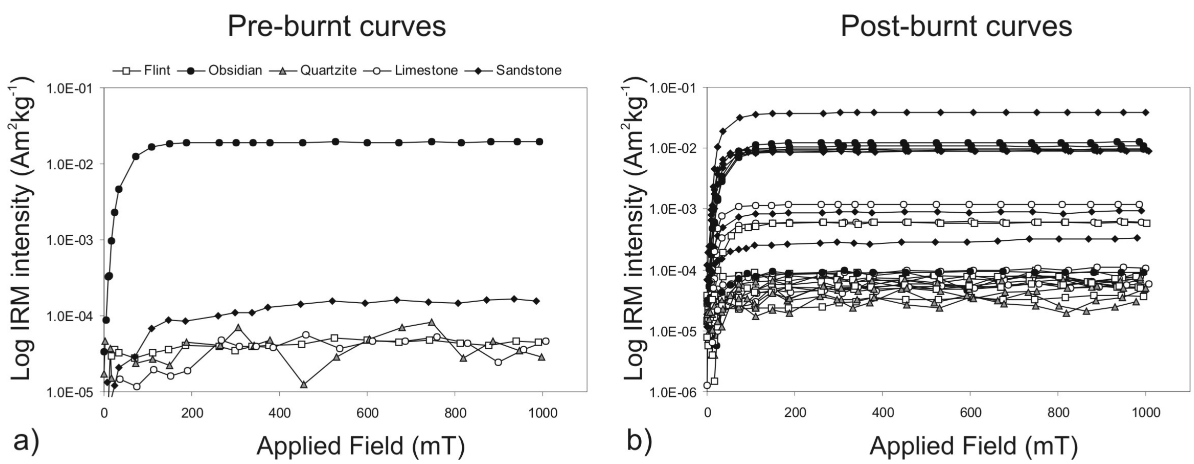

Figure 1 (a-b). Progressive Isothermal remanent magnetisation (IRM) acquisition curves of the different lithologies before and after burning experiments.

Progressive IRM acquisition curves of the different lithologies before and after burning are illustrated in Figure 1a and b, respectively. As expected, the studied pre-burning samples show a rather variable ferromagnetic content and thus distinct behaviour (fig. 1a). All IRM curves except the obsidian exhibit in general unstable and noisy behaviours. Most lithologies saturate around 200 mT indicating that a low-coercivity ferromagnetic mineral (magnetite and/or maghaemite) is the main magnetic carrier. Limestone and sandstone specimens do not reach saturation suggesting that some remanence is also carried by a higher coercive phase, most probably haematite (fig. 1a). Progressive IRM acquisition curves of post-burned lithologies reach saturation around 150 – 200 mT indicating that magnetisation is dominated by a low-coercivity mineral (fig. 1b). The variation in the intensity of magnetisation among lithologies is remarkable, between one and two orders of magnitude. Regardless of the quadrant analysed, obsidian and sandstone are the most stable magnetic lithologies followed in decreasing order by limestone (~ 10 times weaker) and finally by chert and quartzite, which is the weakest one.

Obsidians and sandstone samples showed high-intensity, stable univectorial NRM demagnetization diagrams as well as fully reversible thermomagnetic behaviour (not shown here). The good concordance between temperatures recorded in the field (~ 700° C) and the high degree of reversibility in their thermomagnetic curves confirms the acquisition of a stable TRM. For these reasons they were selected as the most suitable lithologies to perform absolute palaeointensity experiments. Both palaeodirectional and absolute palaeointensity data are essential to define the geomagnetic vector, being the latter generally more difficult to extract from lavas and other baked material due to irreversible magnetic mineralogical changes upon conventional heating experiments (Thellier, Thellier, 1959). Recent advances have demonstrated the usefulness of an alternative methodology; the multi-specimen parallel differential pTRM method (Dekkers, Böhnel, 2006), in which minimal heating is required, thus increasing probabilities of obtaining accurate data. The multispecimen palaeointensity technique was successfully applied to obsidian and sandstone specimens yielding a field estimation of 46.2 ± 2.4 µT (original field 45, 302 µT).

The main macroscopic alterations observed comprise colour changes, rubefaction, potlids and microretouches being particularly evident in cherts which barely modify their magnetic properties after burning. Alternatively, obsidians hardly change their magnetic properties by heating but the massive formation of internal fissures can be used as macroscopic criterion to detect heat treatment in archaeological sites. This study has shown how mineral magnetic methods combined with macroscopic observations can readily provide information about the burn history of lithic assemblages as well as obtain geomagnetic field information.

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