AN INTERNATIONAL JOURNAL OF PALAEONTOLOGY AND STRATIGRAPHY

*Lethaia Seminar*
*Lethaia*, Vol. 43, pp. 587–590. Copenhagen, 2010

# Ichnological analysis: a non-destructive tool in archaeology

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Since the early 1970s, ichnology has provided valuable information in many fields including zoology, ecology, geochemistry, sedimentology, biostratigraphy, palaeobiology, and evolutionary palaeoecology. This is clear from the profuse ichnological information published in several symposium volumes together with books and monographs from the beginning of this millennium (e.g. Buatois *et al.* 2002; Hasiotis 2002; Kelley *et al.* 2003; McIlroy 2004; Webby *et al.* 2004; Bromley *et al.* 2007; Miller 2007; Wisshak & Tapanila 2008). However, the wide range of applications show some fields where the ichnological research is, at the moment, scarcely used, for example archaeology.

To date, the application of ichnofossils in archaeozoology is usually limited to marks left by animals and humans on animal bones (Gautier 1993), with reference to feeding processes, and the reconstruction of the palaeoecology of early hominids, together with differences between pre-human and modern human behaviour (Noe-Nygaard 1989; Haynes 2002). Invertebrate trace fossils on bones are relatively rare, and sometimes difficult to differentiate from other types of damage. This may explain the scarcity of papers dealing with the analysis of invertebrate trace fossils, or with the application of ichnology in archaeological research apart from that involving human predation (Gautier 1993; West & Hasiotis 2007). Some alternative applications of ichnology in archaeology have been presented in the last few years, such as framing human activity (Mesolithic to Modern) within an ichnological and sedimentological context (Mikuláš 1999), or the interpretation of variations in sea-level and time of exposure based on the degree of bioerosion of a collection of marble statues (Bromley & Asgaard 2003). An updated review of the application of ichnological methods in archaeology was recently presented by Baucon *et al.* (2008).

Detailed analysis of archaeological objects from pre-historic sites offers the opportunity to address the socio-cultural pattern of human communities. Especially informative is the material composing the archaeological artefacts; the identification of the geological sources is useful in interpreting the supply of raw materials and the transport or exchange of objects. This is the case for the chert or flint artefacts comprising the majority of the archaeological objects from pre-historic sites. Traditionally, the characterization of raw materials in archaeological artefacts with flaked chert is conducted exclusively on the visual macro-geological features, avoiding any alteration of these samples. However, this visual approach is insufficient, and more recently, sedimentary petrographic criteria (e.g. texture, composition, structures, etc.), together with geochemical analyses, have been applied to characterize the source areas for chert (Sieveking *et al.* 1972; Luedtke 1979; Takács-Biró & Tolnai-Dobosi 1991; Ferguson & Warren 1992; Féblot-Augustin 1997; McDonnell *et al.* 1997; Affolter 2002). Nevertheless, these methodologies require removal of part of the artefact. In this context, ichnological features can be used in the analysis of archaeological artefacts, since direct observations of samples can be made by non-destructive methods. Here, we apply trace fossil analysis to characterize chert used in archaeological artefacts from the Late Neolithic and Copper

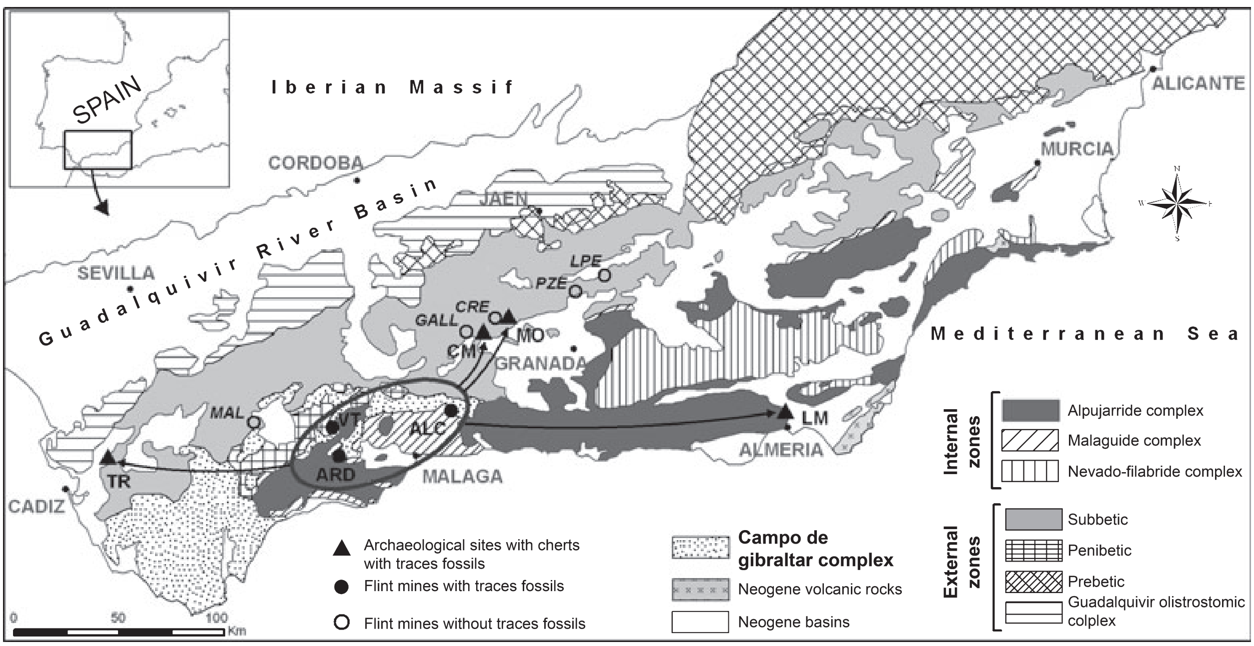


*Fig. 1.* Geological location of the selected flint mines in the Campo de Gibraltar Complex (black circles): Alcolea (ALC), Ardite (ARD) and Valle del Turón (VT), and in the Median Subbetic (circles): Gallumbares (GALL), Malaver (MAL), Puerto del Zegrí (PZE), Cerro del Reloj (CRE) and Loma de Los Pedernales (LPE). Location of the archaeological sites (triangles): Torre Melgarejo (TR), Cortijo de la Merced (CM), Los Castillejos de Montefrío (MO), Los Millares (LM). Arrows for distribution of the archaeological artefacts with trace fossils and from the flint mines.

DOI 10.1111/j.1502-3931.2010.00225.x 

Age of the southern Iberian Peninsula (Fourth–Third Millennium BC), including the interpretation of the source area, and its implications for populations displacements.

The Neolithic on the Iberian Peninsula, commencing in the Fourth Millennium BC, reveals a significant change in the life style and technology used by the last hunters and gatherers, with the external introduction of new productive systems as well as the manufacture of new artefacts. Blade technology and bifacial flaked stone artefacts (the so-called 'halberds') of siliceous rocks from Late Neolithic and Copper Age sites on the Iberian Peninsula, demanded highly skilled manufacture (Pelegrin 2006; Morgado *et al.* 2008), including specifically selected raw materials, a high level of technical ability, the restriction of craftsmanship to designated individuals or communities, and the distribution of these products across extensive regions and distances. One important aspect in blade production is the selection of the appropriate raw material. Although siliceous rock resources in southern Iberian Peninsula are abundant, blade manufacture by pressure-knapping imposed the selection of particular source areas, i.e. those with large chert samples, allowing for easy knapping, and with high quantities of raw materials to satisfy the growing demand, not only for actual manufactured tools, but also for the lengthy learning process for mastering the craft. As a result, only a few pre-historic chert sites associated with specialized lithic technology have been documented in southern Spain.

In the Betic Cordillera (southern Spain), which corresponds to the westernmost Alpine Mediterranean chain, occupying a belt about 600 km long and 200 km wide (García-Hernández *et al.* 1980), two main geological belts are usually differentiated, the Internal and the External, separated by the Campo de Gibraltar Complex (Vera 2004; and references therein, Fig. 1). In the External Zones, the first major subdivision is between the Prebetic Zone, characterized by shallow-water facies, and the Subbetic Zone, mainly consisting of pelagic facies. The Subbetic Zone shows a well-defined submarine topography, with deep subsiding troughs (Median Subbetic) and moderately deep high bottom and/or submarine plateau areas (External and Internal Subbetic). The Campo de Gibraltar Complex (Martín-Algarra *et al.* 2004) is mapped as a series of tectonic units along the contact between the External Zones and Internal zones of the Betic Cordillera. In the Betic Cordillera, siliceous rocks of sedimentary origin occur in several areas, but, actually, only around ten chert mines, located in the Median Subbetic and the Campo de Gibraltar Complex, associated with specialized lithic workmanship have been recognized (Morgado & Lozano 2009). Presently, the precise identification of the source area for the chert composing the archaeological artefacts has not been located.

Ichnological analysis of the chert archaeological artefacts of the Late Neolithic and Copper Age sites from the southern Iberian has been conducted, and compared with chert samples obtained from outcrops belonging to different flint mines located in the Median Subbetic and the Campo de Gibraltar Complex. Artefacts have been characterized based on a non-destructive investigation, mainly macro- and micro- observations, determining trace-fossil composition, ichnological features and qualitative data (dimensions, abundance, orientations and densities of traces). Detailed observations were focused on the filling material (composition, grain size, and colour), geometry, burrow boundary with the surrounding sediment, and cross-cutting relationships. Rock samples and associated archaeological remains were studied directly in the flit mines and in the laboratory, to characterize the ichnotaxa and for ichnofabric analysis. Surfaces were oiled in order to improve colour contrast, and to facilitate the analysis of ichnological details (modification of the Bushinsky oil technique; Bromley 1981).

Ichnological analysis revealed the presence of discrete trace fossils in the archaeological artefacts (Fig. 2A), even considering space limitation due to the size of the artefacts, as well as significant differences between the studied samples from the mines. The trace fossil assemblage from the artefacts is quite monotonous and of low diversity, containing only *Chondrites* and *Phycosiphon*. All the registered biogenic structures are filled with fine-grained, dark sediment. *Chondrites* is very scarce, appearing as patches of circular to elliptical spots and short bars with local branches, which are around 1 mm wide and 5 mm long. Only fragments of burrow systems were observed, corresponding to cross-sections of the branched tunnel system filled with dark material, that difficult a

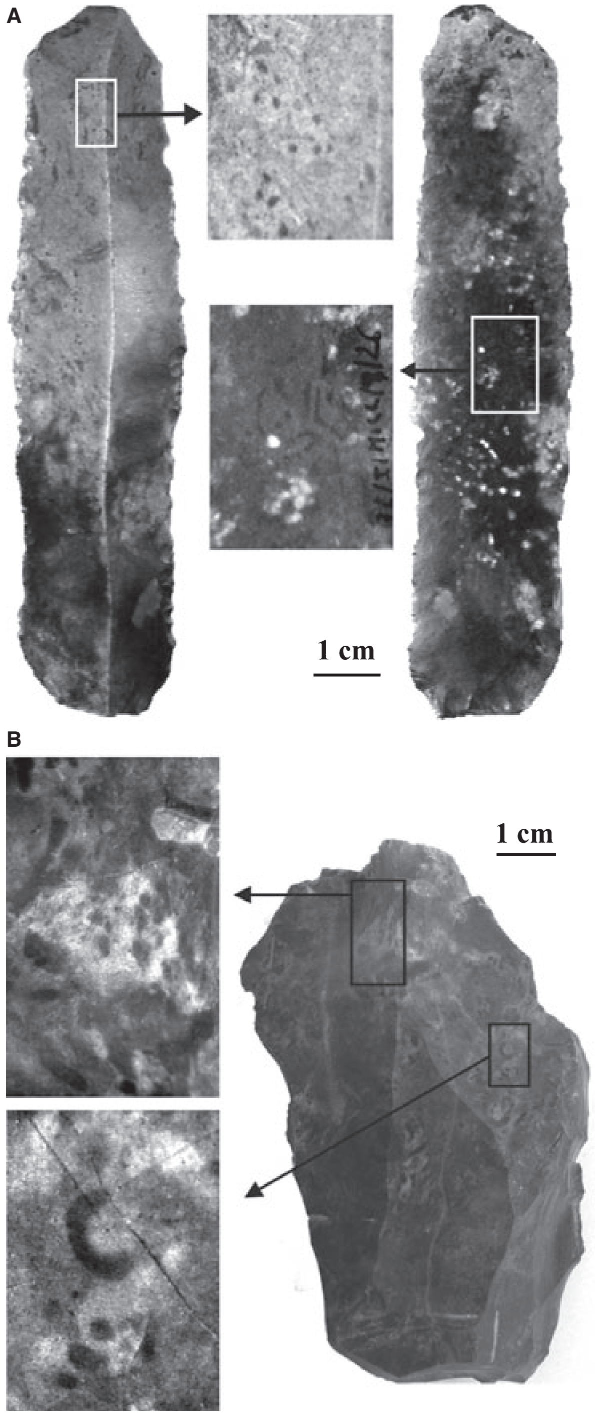


*Fig. 2.* A, blade core from the settlement of Los Millares (LM) showing *Phycosiphon*, with close-up of paired tubes (upper left and middle right) and curved small lobe (middle right). B, geological sample from the flint mines of Valle del Turón (VT) showing *Phycosiphon*, with close-up of curved small lobe (lower right) and of paired tubes (upper left). *Chondrites* probably also appears in the upper left, detailed view. Note distance in Figure 1 between the settlement of LM and the flint mines from the Campo de Gibraltar Complex.

conclusive characterization at the ichnospecies level; from the four ichnospecies distinguished by Fu (1991), the reported *Chondrites* are in the range of the large forms of *Chondrites intricatus* (Brongniart) or the smaller forms of *Chondrites targionii* (Brongniart). *Phycosiphon* is comparatively abundant; numerous structures occur in patches, oriented randomly. Curved small lobes (less than 5 mm wide) and dark fine-grained, cylindrical to circular cores (less than 1 mm in diameter) are differentiated. Cylindrical cores are commonly slightly curved. The dark filling of the core is surrounded by lighter coloured material. Usually cross-sections reveal that the tubes are paired (2–3 mm in width); only locally the space between tubes is filled with reworked mantle material implying the presence of a spreite. *Phycosiphon* could be tentatively assigned to the ichnospecies, *Phycosiphon incertum*. Whereas those flint mines selected from the Campo de Gibraltar Complex reveal a similar ichnological composition (Fig. 2B) to that of the artefacts; the Median Subbetic outcrops do not exhibit discrete trace fossils.

Detailed analysis of flint archaeological artefacts and chert samples from Late Neolithic and Copper Age sites of the southern Iberian Peninsula (Fourth–Third Millennium BC) reveals the presence of discrete trace fossils. *Phycosiphon* is comparatively abundant, being recorded in all the studied samples (archaeological artefacts and rocks), while *Chondrites* is comparatively scarce and mainly recorded in the rock samples. This fact may reflect the original scarcity of *Chondrites* but also the fact that the small size of the studied archaeological artefacts makes it difficult to record comparatively larger structures (*Chondrites*). The ichnological assemblage in the archaeological artefacts is quite similar to those recorded in the rock samples and associated archaeological remains from the Campo de Gibraltar Complex. The detected pattern suggests that the source area for the chert used to craft these archaeological artefacts was located in the Campo de Gibraltar Complex (Betic Cordillera, South Spain), excluding other flint mines from the southern Iberian Peninsula, such as those located in the Median Subbetic Zone (Fig. 1). The comparatively abundant record of *Phycosiphon*, occurring from shallow to deep marine settings but usually recognized in flysch deposits (Wetzel & Bromley 1994), agrees well with the type of rocks belonging to the Campo de Gibraltar Complex, dominated by turbiditic sediments deposited in deep-water environments.

Identification of the raw material for the archaeological flaked objects used by the Late Neolithic and Copper Age communities allows a preliminary interpretation of access to available sources as well the establishment of the regional routes of distribution. The presence of technological flaked objects of blade production, such as cores out and blades, present in archaeological sites far from the Campo de Gibraltar Complex, and near the Median Subbetic flint mines (i.e. Cortijo de la Merced, MC; Los Castillejos de Montefrío, MO), reveals: (1) an important selection of the chert source, independent of distance; and (2) the dispersion of the artefacts over a distance covering the southern Iberian Peninsula.

The results and interpretations suggest a further dimension to archaeological research, revealing the usefulness of ichnology, especially as a non-destructive method for the study of delicate archaeological artefacts.

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