Using Ichnofossils to Characterize Chert Tools: A Preliminary Study from Southern Iberia

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Characterizing raw material of stone tools used by Late Neolithic and Copper Age communities is important for interpreting access to available sources and establishing regional routes of distribution. Ichnological analysis may be used to help characterize lithic material and determine the source of artifacts. Here we report for the first time the existence of trace fossils in artifacts from the Late Neolithic and Copper Age of southern Spain. Ichnological analysis indicates a trace fossil assemblage consisting of relatively scarce small-sized *Chondrites* and abundant *Phycosiphon*. A regional survey of natural outcrops and chert quarries indicates the presence of discrete trace fossils only in the samples from geological formations that are part of the Campo de Gibraltar Complex. Ichnological composition in these samples is similar to that discerned in the artifacts and suggests that this was the probable source of the chert used in tool manufacture.

INTRODUCTION

Chert or flint artifacts are relatively abundant among archaeological objects from prehistoric sites. The identification of geological sources for chert tools is of special interest to archaeologists for understanding the supply of raw materials and the transport or exchange of objects. Characterization of raw material in artifacts is usually based exclusively on visual methods of analysis to avoid any alteration of these objects. In the case of chert, characterization can be approached on the basis of different visual macrogeological features (i.e., color, aspect, transparency, fracture, presence of inclusions, etc.). This visual approach has thus far proven insufficient, however, and in recent years additional criteria have been applied to characterize siliceous rocks including sedimentary petrography (Séronie-Vivien & Séronie-Vivien, 1987; Delange, 2003; Odell, 2004) and geochemical analysis (McDonnell, Kars, & Jansen, 1997; Malyk-Selivanova et al., 1998; Bressy, 2003; Eerkens et al., 2007; Milne, Hamilton, & Fayek, 2009). Unfortunately, most of these methodologies entail a major disadvantage: the partial destruction of the archaeological piece.

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Ichnology is the study of traces, as structures produced in rocks and sediments by the life processes of organisms (Bromley, 1996:xv). A trace fossil is defined as "a morphologically recurrent structure resulting from the life activity of an individual organism (or homotypic organism) modifying the substrate" (Bertling et al., 2006:266). From an archaeological perspective, traces include signs of human biology such as footprints (Roberts & Berger, 1997; Facorellis, Kyparissi, & Maniatis, 2001; Zhang & Li, 2002; Mietto, Avanzini, & Rolandi, 2003; Webb, Cupper, & Robins, 2006; Bennett et al., 2009) and feces (i.e., Callen, 1969; Bryant, 1974; Bryant & Williams-Dean, 1975; Reinhard & Bryant, 1992), as well as signs of predation (bite and gnaw structures). However, signs of human technology and pathological structures are not considered traces. Hominid artifacts are excluded because it is impractical to claim a trace fossil nature for archaeological objects, and pathological structures such as tumorous swellings of bones, caries in teeth, osteoporosis, healed injuries of bones, and so on, are more properly considered as objects of palaeopathology (Bertling et al., 2006).

Ichnology is rarely applied in archaeological research, and the potential archaeological value of trace fossils is not well known. As pointed out by Gautier (1993), the application of ichnofossils in archaeozoology is usually limited to marks left by animals and people on animal bones, with special attention to hominids. However, ichnological analysis can be of greater significance to archaeological research, especially when one is limited to direct, nondestructive observation of stone artifacts. Here we present, for the first time, the application of trace fossil analysis in archaeological research to characterize chert used in stone tool manufacture from the Late Neolithic and Copper Age (ca. 3500–2300 BC) of the southern Iberian Peninsula including a preliminary analysis of the source area.

USE OF CHERT IN TOOL PRODUCTION IN SOUTHERN IBERIA

Archaeological evidence from Neolithic sites in the southern Iberian peninsula indicates a semisedentary way of life in dispersed villages. This settlement pattern changed ca. 4000–3500 BC to a higher frequency and concentration of farming villages (Nocete, 2001; Molina & Cámara, 2005), characterized by enclosures and circular huts with pit structures. This was followed in the Copper Age by the appearance of large towns featuring complex defensive systems or walled settlements, as recognized in the well-known site of Los Millares (Figure 1). This site contains the greatest and best-preserved stonewall from the Copper Age in the European continent (Molina & Cámara, 2005). Moreover, increased social complexity at Los Millares is inferred from craft specialization and the appearance of copper metallurgy. These important developments date ca. 3500 to 2300–2200 BC (Castro, Lull, & Micó, 1996; Molina et al., 2004; Cámara, Molina, & Afonso, 2005).

Another important cultural trait associated with the Late Neolithic and Copper Age from southern Iberia is blade technology (Figure 2) and bifacial flaked stone artifacts (the so-called halberds) of siliceous rocks demanding highly skilled manufacture (Morgado & Pelegrin, 2006; Pelegrin, 2006; Morgado et al., 2008). Specifically, the

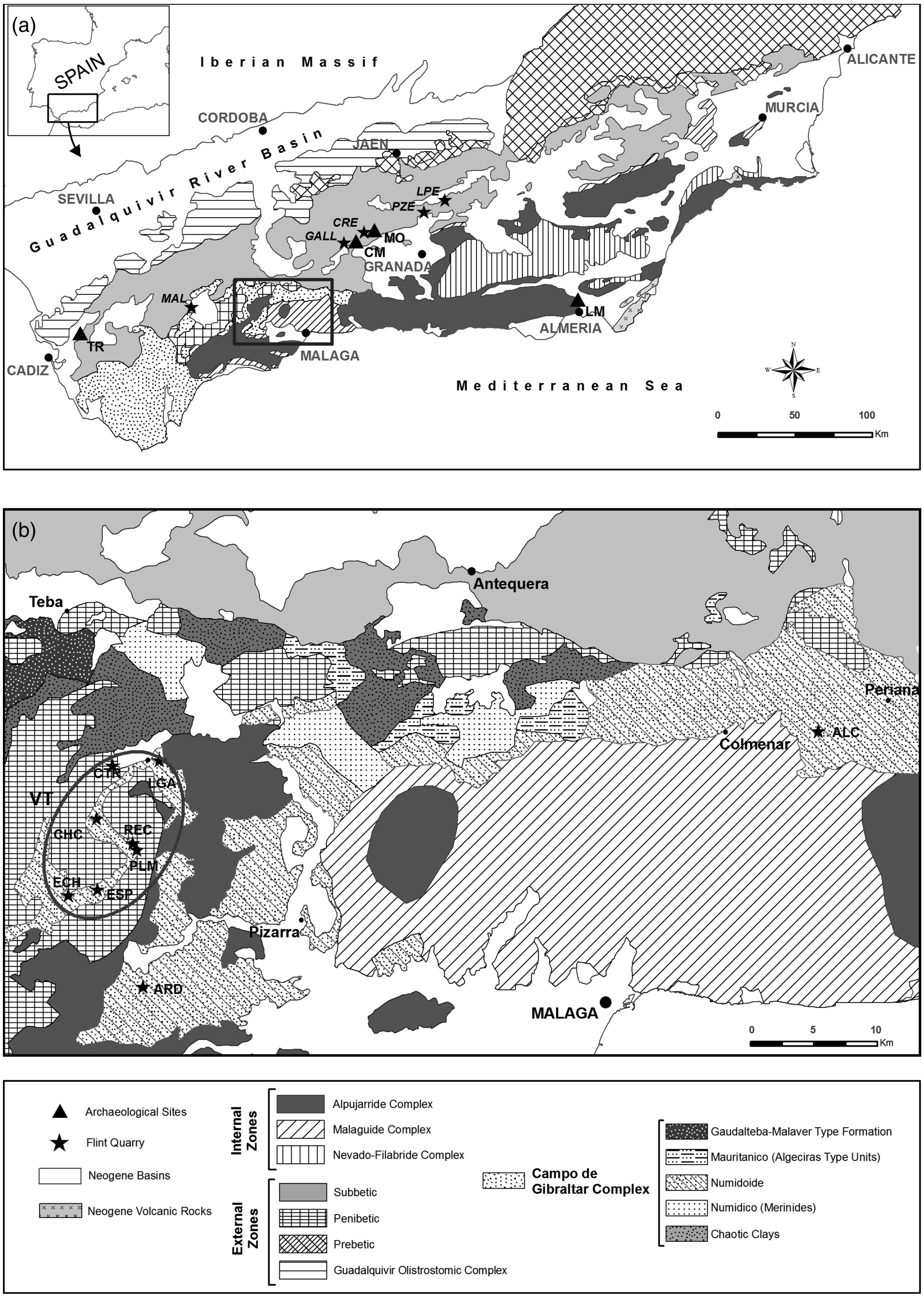

Figure 1. Geological map of southern Spain showing selected geological outcrops (stars) in the Median Subbetic, Campo de Gibraltar Complex, and archaeological sites (triangles) discussed in the text. Selected outcrops in the Median Subbetic include Gallumbares (GALL), Malaver (MAL), Puerto del Zegrí (PZE), Cerro del Reloj (CRE), and Loma de Los Pedernales (LPE). Selected outcrops in the Campo de Gibraltar Complex include the Ardite (ARD), Cerro Alcolea (ALC), and Valle del Turón (VT) areas in the Betic Cordillera. Archaeological quarries located in the Valle del Turón include Canchal Herrizas del Carnero (CHC), Castillo del Turón (CTR), El Chorrito (ECH), Espíldora (ESP), La Galeota (LGA), Puerto de Los Martínez (PLM), and Los Reconcos (REC). Archaeological sites are Los Castillejos de Montefrío (Granada, MO), Cortijo de la Merced (Loja, Granada, CM), Torre Melgarejo (Jerez, Cádiz, TR), and Los Millares (Santa Fe de Mondujar, Almería, LM).

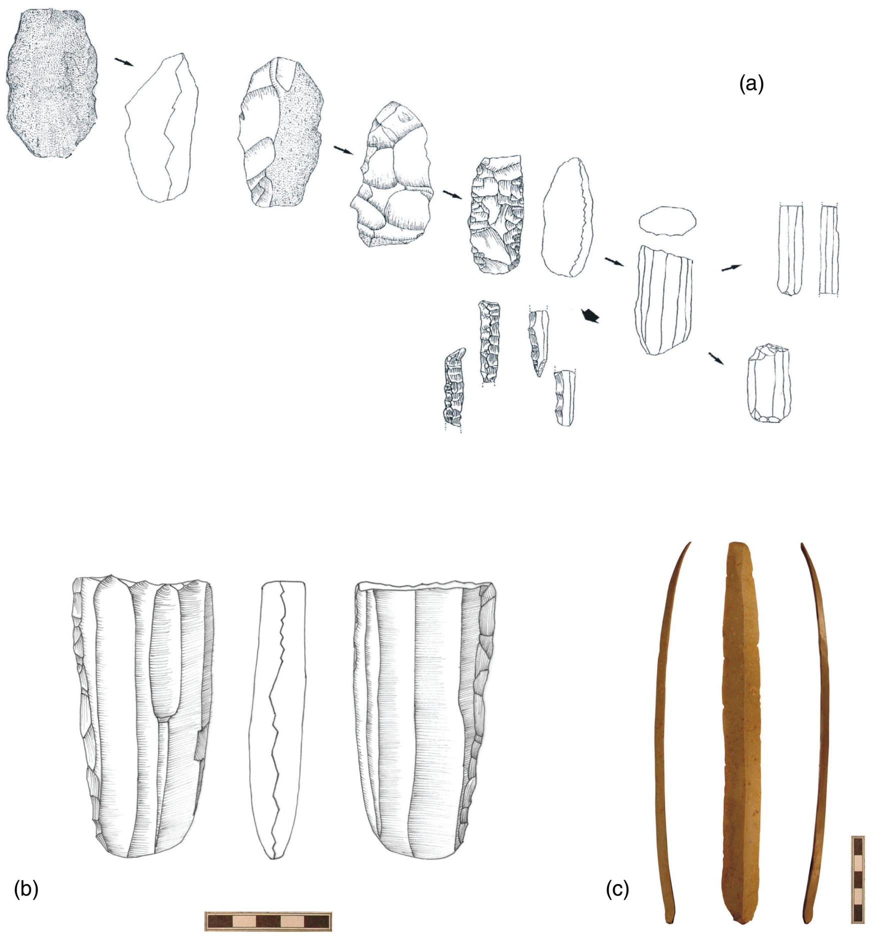

Figure 2. (a) Lithic reduction sequence of blade technology from the Late Neolithic and Copper Age in the southern Iberian Peninsula. (b) Chert core of blades. (c) Large chert blade.

general features of blade production in southern Spain have only recently been elucidated (Martínez Fernández, 1997; Martínez Fernández & Morgado, 2005; Pelegrin & Morgado, 2007; Morgado et al., 2008). Technically, prismatic preforms were obtained from chert cores before blade extraction. Preforms had several lateral crests for the purpose of guiding later blade extraction through pressure knapping (Figure 2). Pressure could be applied either manually or through a lever pressure system in the case of large blades. Such technology required high-quality, cryptocrystalline geological material.

GEOLOGICAL SOURCES

A few natural chert outcrops exploited for blade and bifacial flake technology have been documented in southern Spain. These sites display lithological variability and can be classified into two distinctive petrological groups: siliceous volcanic acid rocks and sedimentary detritic rocks formed through diagenetic silicification (Ramos Millán, 1997; Nocete et al., 2005; Martínez Fernández et al., 2006). Siliceous rocks of sedimentary origin can be found in several areas within the Betic Cordillera of southern Spain, which corresponds to the westernmost Alpine Mediterranean chain, occupying a belt ca. 600 km long and 200 km wide (García-Hernández et al., 1980). Two main geological realms are usually differentiated—the Internal and the External Zones, separated by the Campo de Gibraltar Complex (Vera, 2004, and references therein; Figure 1). In the External Zone, a 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 records 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 (the so-called flysch units) consists mostly of allochthonous Paleogene and lower Miocene flysch sediments, but Cretaceous rocks also occur locally (Martín-Algarra, 1987). The flysch units comprise clayey and sandy sediments, locally conglomeratic, that were deposited in deep-water environments or flysch troughs.

MATERIALS AND METHODS

Flaked stone material analyzed during our investigation came from archaeological sites in Los Castillejos de Montefrío (Granada), Cortijo de la Merced (Loja, Granada), Torre Melgarejo (Jerez, Cádiz), and Los Millares (Santa Fe de Mondujar, Almería) (Figure 1; Table I). We also analyzed debitage from chert quarries in the region. To date, 14 chert mines associated with specialized lithic workmanship have been recognized in the Betic Cordillera (Fernández & Márquez, 1985; Ramos Muñoz, Espejo, & Cantalejo, 1986; Vallespí et al., 1988; Ramos Muñoz, 1997; Aguayo & Moreno, 1998; Martínez Fernández et al., 2006), belonging to the Median Subbetic and the Campo de Gibraltar Complex (Figure 1). Selected outcrops and chert quarries in the Median Subbetic visited during this investigation include Gallumbares, Malaver, Puerto del Zegrí, Cerro del Reloj, and Loma de Los Pedernales. In the Campo de Gibraltar Complex, selected outcrops and chert quarries include Ardite, Valle del Turón (Canchal Herrizas del Carnero, Castillo del Turón, El Chorrito, Espíldora, La Galeota, Puerto de Los Martínez, Los Reconcos), and Cerro Alcolea. We selected raw material and debitage from nine of the chert quarries for analysis (Table I).

Ichnological analysis of artifacts is based on nondestructive, detailed macro- and microobservations (Figures 3 and 4). For these pieces, we determined trace-fossil features and qualitative data (dimensions, abundance, orientations, and densities of traces) with as much accuracy and precision as possible, photography being a fundamental technique of documentation. Highly detailed observations were focused on filling material (composition, grain size, and color), geometry, burrow boundary with the surrounding sediment, and crosscutting relationships. To enhance ichnological features, the surface of the archaeological piece was wetted with water.

Table I. Location and Description of Chert Artifacts and Debitage.

Key[1]	Site	Type	Geographical Location	Description/Measures (mm)	Period/Date	Bibliography
MO	Los Castillejos de Montefrío	Settlement	Montefrio, Granada	Blades core 86, 52, 13	Late Neolithic (16th stratigraphic phase) Beta 135665 (1σ): 3340–3130 BC	Cámara, Molina, & Afonso, 2005
CM	Cortijo La Merced/ Los Gallumbares	Settlement	Loja, Granada	Blades core 91, 54, 32	Copper Age	Morgado et al., 2001
TR	Torre Melgarejo	Collective burial Artificial cave	Jerez, Cadiz	Bifacially flaked halberd 145, 48, 14	Copper Age	González Rodríguez & Ramos Muñoz, 1988
M	Los Millares	Megalithic necropolis *Tholos* type	Santa Fe Mondujar, Almeria	Fragment long blade 117, 27, 5	Copper Age KN 72 (1σ): 3330–2890 BC	Almagro & Arribas, 1963 Chapman, 1990 Molina et al., 2004
RD	Ardite	Chert quarry	Coín, Málaga	Blade technology debitage	Copper Age	Fernández & Márquez, 1985
CHC	Canchal Herrizas del Carnero	Chert quarry	Casarabonela, Málaga	Blade technology debitage	Copper Age	Avila, 1986
CTR	Castillo del Turón	Chert quarry	Ardales, Málaga	Blade technology debitage	Copper Age	Ramos-Muñoz, Espejo, & Cantalejo, 1986
ECH	El Chorrito	Chert quarry	El Burgo, Málaga	Blade technology debitage	Copper Age	Avila, 1986 Morgado & Lozano, 2009
ESP	Espíldora	Chert quarry	Casarabonela, Málaga	Blade technology debitage	Copper Age	Morgado & Lozano, 2009
LGA	La Galeota	Chert quarry	Ardales, Málaga	Blade technology debitage	Copper Age	Espejo & Cantalejo 1989–1990
PLM	Puerto de los Martínez	Chert quarry	Casarabonela, Málaga	Blade technology debitage	Copper Age	Morgado & Lozano 2009
REC	Los Reconcos	Chert quarry	Casarabonela, Málaga	Blade technology debitage	Copper Age	Morgado & Lozano 2009
ALC	Alcolea	Chert quarry	Periana, Málaga	Blade technology debitage	Copper Age	Ramos Muñoz, 1997

[1] See Figure 1.

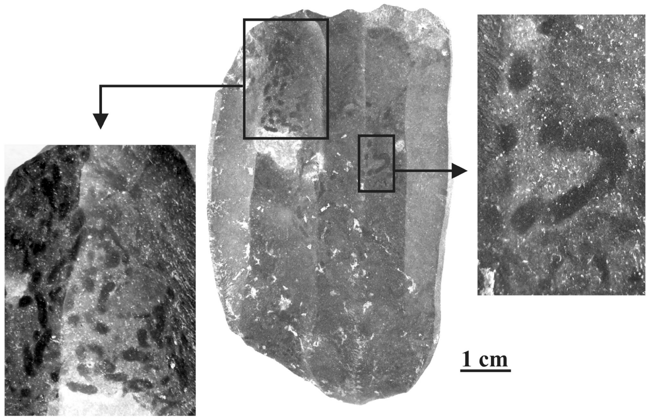

Figure 3. Blade core at Los Castillejos de Montefrío (MO) showing *Phycosiphon* structures, with detail of paired tubes (lower left) and curved small lobe (upper right).

In the chert quarry samples, specimens of trace fossils were characterized, and ichnofabric analysis included all aspects of the texture and internal structures due to bioturbation at all scales. In this case, samples were cut and their fabrics studied in detail on the variably oriented polished surfaces. The surfaces were oiled in order to improve color contrast and to facilitate the analysis of ichnological details (modification of the Bushinsky oil technique; Bromley, 1981).

Microscopic analysis of the biogenic structures (e.g., fill material and burrow boundaries) registered in the raw material, debitage, and flaked artifacts was performed at the Department of Stratigraphy and Paleontology of the University of Granada with a Leica MZ12, 12.5:1 zoom stereomicroscope; close-up photomicrographs were taken with the Ricoh R3 single-lens reflex camera.

RESULTS

Monotonous lithological composition of the chert composing both archaeological pieces and rock samples impeded recognition of any distinctive stratigraphic features. Nonetheless, detailed ichnological analysis revealed patterns suggestive of source. First, several artifacts contain discrete trace fossils. The trace fossil assemblage is little diversified, with two ichnotaxa being differentiated: *Chondrites* (regularly branching tunnel systems consisting of a small number of master shafts open to the surface which ramify at depth to form a dendritic network) and *Phycosiphon* (planar, horizontal, or oblique lobate spreiten structures encircled at least partially by a marginal tunnel). All the registered biogenic structures are filled with fine-grained, dark sediment (Figure 3).

Comparison between raw material from outcrops and chert quarries located in the Median Subbetic with those from the Campo de Gibraltar Complex shows a clear differentiation, with the absence of discrete trace fossils in the former and the presence of distinguishable biogenic structures in the latter (Figure 4). Moreover, the trace fossil composition registered in the samples from the Campo de Gibraltar Complex

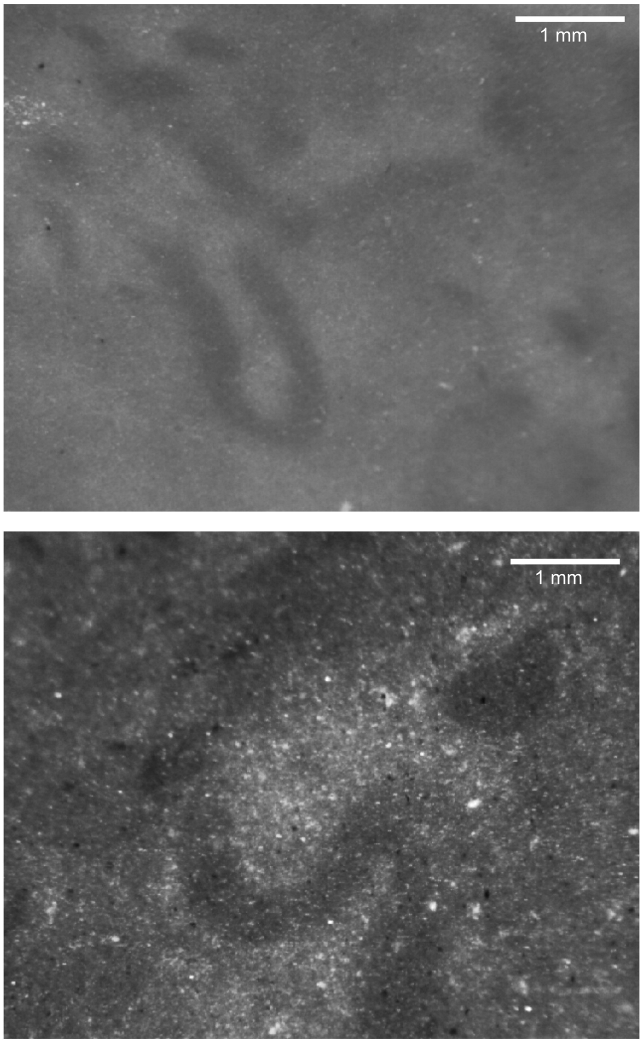

Figure 4. Binocular zoom microscope (Leica zoom 2000) images (20X) of *Phycosiphon* structures from chert quarry at Cerro Alcolea (ALC).

shows no significant differences with respect to that recognized in the archaeological pieces.

Ichnological features of the registered trace fossils allow taxonomic classification at the ichnogenus level and tentatively at the ichnospecies level. *Chondrites* appear as patches of circular to elliptical spots and short bars with occasional branches, which are ca. 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. This trace is relatively scarce and mainly registered in the rock samples from all the selected outcrops in the Campo de Gibraltar Complex.

Numerous structures of *Phycosiphon* are registered 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 (Figures 3 and 4). Cylindrical cores are usually slightly curved. Dark filling of the core is surrounded by lighter-colored material. Usually cross sections reveal that the tubes are paired (2–3 mm in width); only occasionally is the space between tubes filled with reworked mantle material; this implies the presence of a spreite. This trace is comparatively abundant, being registered in all the studied archaeological pieces, as well as in rock samples from all the selected outcrops in the Campo de Gibraltar Complex.

DISCUSSION

Chert used to produce artifacts has been traditionally characterized on the basis of the integration of macro- and micro-observations including palaeontological, mineralogical, or geochemical features, among others. Yet no attempts to differentiate the traces produced by organisms in archaeological chert have been documented. Our study of chert artifacts of the Late Neolithic and Copper Age of southern Iberia (ca. 3500–2300 BC) and rock samples from natural outcrops and quarries located in the Median Subbetic and Campo de Gibraltar Complex represents a new approach to characterizing archaeological chert that includes ichnological analysis. This approach is particularly favorable for archaeological research where one is limited to nondestructive methods of analysis and allows for the addition of new variables (trace fossil data) to characterize the material.

We believe that the obtained ichnological data are highly informative in several ways. Of the several chert quarries associated with specialized lithic workmanship recognized in the Betic Cordillera, only samples belonging to the Campo de Gibraltar Complex contain distinguishable trace fossils; those from the Median Subbetic lack discrete biogenic structures. Comparison between trace fossils differentiated in the artifacts and those registered in the rock samples and quarry debitage from the Campo de Gibraltar Complex reveals a similar trace fossil composition, with only minor differences in their relative abundance (Figures 3 and 4). *Phycosiphon* is comparatively abundant, being present in all the studied samples (artifacts and raw material), while *Chondrites* are comparatively scarce and mainly recorded in the raw material. This may be due to lower presence of *Chondrite* trace makers, together with the small size of the flaked artifacts and debitage, which makes it difficult to record comparatively large traces (*Chondrites*).

As a preliminary interpretation, the similarity between trace fossil compositions registered in flaked artifacts from Los Castillejos de Montefrío, Cortijo de la Merced, Torre Melgarejo, and Los Millares and in rock samples and debitage from quarry sites suggests that the geological source for the chert belongs to the Campo de Gibraltar Complex (Betic Cordillera, southern Spain) rather than the Median Subbetic. The comparatively abundant record of *Phycosiphon*, usually recognized in flysch deposits (Wetzel & Bromley, 1994; Uchman, 1995), matches materials belonging to the Campo de Gibraltar Complex, dominated by turbiditic sediments deposited in deep-water environments. This is congruent with previous interpretations of provenience based on lithic technology. In the quarries of Campo de Gibraltar, chert nodules were transformed into preforms for blade extraction by means of two anterolateral crests that would later guide the first extractions. In most cases the posterior side of cores and preforms was not knapped; this left the natural surface untouched or flat.

CONCLUSIONS

Raw material characterization of flaked tools used by Late Neolithic and Copper Age communities is important for assessing access to source material and understanding regional routes of distribution. Preliminary research presented here underlines the usefulness of ichnological analysis in characterizing chert material composing archaeological pieces, thereby opening new opportunities in determining the original source area of this material.

Ichnological analysis based on nondestructive, detailed micro- and macro-observations of artifacts from sites and burials located in the southern Iberian Peninsula dating to the fourth and third millenniums BC reveals the existence of distinctive trace fossils. Similar analysis performed on rock samples and debitage from selected quarries located in the Betic Cordillera of southern Spain indicates an absence of discrete biogenic structures in samples from the Median Subbetic and their presence in those from the Campo de Gibraltar Complex. Trace fossil composition consists of scarce small-sized *Chondrites*, mainly registered in the rock samples, and abundant *Phycosiphon*, recorded in both the archaeological and rock samples. The similar ichnological composition of the artifacts and rock samples from chert quarries suggests that outcrops of flysch units in the Campo de Gibraltar Complex were the source for the chert composing the artifacts. The frequent record of *Phycosiphon* in flysch deposits agrees with the character of rock units belonging to the Campo de Gibraltar Complex, dominated by turbiditic sediments deposited in deep-water environments.

The ichnological characterization of chert from the ancient quarries of the Campo de Gibraltar Complex likewise allows for differentiation from other quarries located in southern Iberia. Flint knappers appear to have preferred chert from quarries belonging to the Campo de Gibraltar Complex, regardless of distance to settlements, as it provided the most valuable material for the production of tools such as blades and halberds.

This research underlines the potential of ichnological analysis in archaeological research, as a new tool for characterizing certain types of lithic material and thereby providing new opportunities for determining provenience.

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REFERENCES

Almagro, M., & Arribas, A. (1963). El poblado y la necrópolis megalítica de Los Millares (Santa Fé de Mondújar). Biblioteca Praehistorica Hispanica III. Madrid: Ministerio de Cultura.

Aguayo, P., & Moreno, F. (1998). El complejo arqueológico de Malaver-Lagarín y su significación en el suministro de rocas silíceas en el mediodía peninsular. In J. Bernabeu, T. Orozco, & X. Terradas (Eds.), Los recursos abióticos en la prehistoria: Caracterización, aprovisionamiento e intercambio (pp. 111–125). Valencia: Universitat de València.

Avila, J.A. (1986). Los talleres líticos de valle del río Turón. Memoria de licenciatura. Málaga: Universidad de Málaga.

Bennett, M.R., Harris, J.W.K., Richmond, B.G., Braun, D.R., Mbua, E., Kiura, P., Olago, D., Kibunjia, M., Omuombo, C., Behrensmeyer, A.K., Huddart, D., & Gonzalez, S. (2009). Early hominin foot morphology based on 1.5-million-year-old footprints from Ileret, Kenya. Science, 323, 1197–1201.

Bertling, M., Braddy, S.J., Bromley, R.G., Demathieu, G.R., Genise, J., Mikuláš, R., Nielsen, J.K., Nielsen, K.S.S., Rindsberg, A.K., Schlirf, M., & Uchman, A. (2006). Names for trace fossils: A uniform approach. Lethaia, 39, 265–286.

Bressy, C. (2003). Caractérisation et gestion du silex des sites mésolithiques et néolithiques du Nord-Ouest de l'arc alpin: Une approche pétrographique et géochimique. BAR, International Series 1114. Oxford: British Archaeological Reports.

Bromley, R. (1981). Enhancement of visibility of structures in marly chalk: Modification of the Bushinsky oil technique. Bulletin of the Geological Society of Denmark, 29, 111–118.

Bromley, R. (1996). Trace fossils. Biology, taphonomy and applications. London: Chapman & Hall.

Bryant, V.R. (1974). The role of coprolite analysis in archaeology. Bulletin Texas Archaeological Society, 45, 1–28.

Bryant, V.M., & Williams-Dean, G. (1975). The coprolites of man. Scientific American, 232, 100–109.

Callen, E.O. (1969). Les coprolithes de la cabane acheuleenne du Lazaret: analyse et diagnostic. Mémoires de la Société Préhistorique Française, 7, 123–124.

Cámara, J.A., Molina, F., & Afonso, J.A. (2005). La cronología absoluta de "Los Castillejos en las Peñas de los Gitanos" (Montefrío, Granada). In P. Arias, R. Ontañón, & C. García-Moncó (Eds.), III Congreso del Neolítico en la Península Ibérica (pp. 123–145). Santander: Universidad de Cantabria.

Castro, P.V., Lull, V., & Micó, R. (1996). Cronología de la Prehistoria Reciente de la Península Ibérica y Baleares (c. 2800–900 cal. ANE). BAR, International Series 652. Oxford: British Archaeological Reports.

Chapman, R.W. (1990). Emerging Complexity: The later prehistory of south-east Spain, Iberia and the west Mediterranean. Cambridge: Cambridge University Press.

Delange, C. (2003). Siliceous rocks and prehistory. Bibliography on geo-archaeological approaches to chert sourcing and prehistoric exploitation. BAR, International Series 1168. Oxford: British Archaeological Reports.

Eerkens, J.W., Ferguson, J.R., Glascock, M.D., Skinner, C.E., & Waechter, (2007). Reduction strategies and geochemical characterization of lithic assemblages: A comparison of three case studies from western North America. American Antiquity, 72, 585–597.

Espejo, M.M., & Cantalejo, P. (1989–1990). La Galeota, un taller de sílex calcolítico (Ardales, Málaga). Colección Martín Domínguez. Mainake, 11–12, 21–40.

Facorellis, Y., Kyparissi, N., & Maniatis, Y. (2001). The cave of Theopetra, Kalambaka: Radiocarbon evidence for 50,000 years of human presence. Radiocarbon, 43, 1029–1048.

Fernández, J., & Márquez, J.E. (1985). El taller de Ardite, Coín (Málaga). Cuadernos de Prehistoria de la Universidad de Granada, 10, 103–129.

García-Hernández, M., López-Garrido, A.C., Rivas, P., Sanz de Galdeano, C., & Vera, J.A. (1980). Mesozoic paleogeographic evolution of the External Zones of the Betic Cordillera. Geologie en Mijnbouw, 59, 155–168.

Gautier, A. (1993). Trace fossils in archaeozoology. Journal of Archaeological Science, 20, 511–523.

González Rodríguez, R., & Ramos Muñoz, J. (1988). Torre Melgarejo, un sepulcro de inhumación colectiva en los Llanos de Caulina (Jerez, Cádiz). In Anuario Arqueológico de Andalucía/1988, Vol. 3 (pp. 84–98). Sevilla: Junta de Andalucia.

Malyk-Selivanova, N., Ashley, G.M., Gal, R., Glascok, M.D., & Neff, H. (1998). Geological-geochemical approach to "sourcing" of prehistoric chert artifacts, northwestern Alaska. Geoarchaeology, 13, 673–708.

Martín-Algarra, A. (1987). Evolución geológica alpina del contacto entre las Zonas Internas y las Zonas Externas de la Cordillera Bética. Ph.D. dissertation, Universidad de Granada.

Martínez Fernández, G. (1997). Late prehistory blade production in Andalusia (Spain). In A. Ramos-Millán, & M.A. Bustillo (Eds.), Siliceous rocks and culture (pp. 427–436). Granada: Universidad de Granada.

Martínez Fernández, G., & Morgado, A. (2005). Los contextos de elaboración de hojas prismáticas de sílex en Andalucía oriental durante el Neolítico reciente. Aspectos técnicos, modelos de trabajo y estructuración social. In P. Arias, R. Ontañón, & C. García-Moncó (Eds.), III Congreso del Neolítico en la Península Ibérica (pp. 359–368). Santander: Universidad de Cantabria.

Martínez Fernández, G., Morgado, A., Afonso Marrero, J.A., Cámara Serrano, J.A., & Cultrone, G. (2006). Explotación de rocas silíceas y producción lítica especializada en el subbético central granadino (IV–III milenios cal. BC). In G. Martínez Fernández, A. Morgado, & J.A. Afonso (Eds.), Sociedades prehistóricas, territorio y recursos abióticos (pp. 293–313). Granada: Fundación Ibn-al-Jatib.

McDonnell, R.D., Kars, H., & Jansen, B.H. (1997). Petrography and geochemistry of flint from six Neolithic sources in southern Limburg (the Netherlands) and Northern Belgium. In A. Ramos Millán, & M.A. Bustillo (Eds.), Siliceous rocks and culture (pp. 371–384). Granada: Universidad de Granada.

Mietto, P., Avanzini, M., & Rolandi, G. (2003). Human footprints in Pleistocene volcanic ash. Nature, 422, 133.

Milne, S.B., Hamilton, A., & Fayek, M. (2009). Combining visual and geochemical analyses to source chert on Southern Baffin Island, Arctic Canada. Geoarchaeology, 24, 429–449.

Molina, F., & Cámara, J.A. (2005). Los Millares. Guía del yacimiento arqueológico. Sevilla: Junta de Andalucía.

Molina, F., Cámara, J.A., Nájera, T., & Sáez, L. (2004). Los Millares y la periodización de la Prehistoria Reciente del Sureste. II–III Simposios de Prehistoria Cueva de Nerja (pp. 142–158). Málaga: Fundación Cueva de Nerja.

Morgado, A., & Lozano, J.A. (2009). Geological Factors of Flint Mining in the Betic Cordillera (Spain, IV–III mill. BC). The case of long blade production. II International Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times, Abstracts. Madrid: CSIC.

Morgado, A., & Pelegrin, J., (2006). Origin and development of pressure blade production in the South of the Iberian Peninsula (VI–III mil. cal. BC). In XV Congress International Union for Prehistoric and Protohistoric Sciences I (p. 346). Lisbon: UISPP.

Morgado, A., Martínez, G., Martín, M., & Roncal, E. (2001). Prospección arqueológica en relación con la explotación prehistórica de rocas silíceas en el sector occidental de la región de Los Montes (Granada), avance preliminar. In Anuario Arqueológico de Andalucía/1997, Vol. 2 (pp. 77–85). Sevilla: Junta de Andalucía.

Morgado, A., Pelegrin, J., Martínez, G., & Afonso, J.A. (2008). La production de grandes lames dans la Péninsule ibérique (c. IV–III mil. cal. AC). In M.E. Dias-Meirinho, et al. (Eds.), Les industries lithiques taillées des IVe et IIIe millénaires en Europe occidentale (pp. 309–330). BAR, International Series 1884. Oxford: British Archaeological Reports.

Nocete, F. (2001). Tercer milenio antes de nuestra era. Relaciones y contradicciones centro/periferia en el valle del Guadalquivir. Barcelona: Bellaterra.

Nocete, F., Sáez, R., Nieto, J.M., Cruz-Auñón, R., Cabrero, R., Alex, E., & Bayona, M. (2005). Circulation of silicified oolitic limestone blades in South-Iberian (Spain and Portugal) during the third millennium B.C.: An expression of core/periphery framework. Journal of Anthropological Archaeology, 24, 62–81.

Odell, G.H. (2004). Lithic analysis. New York: Kluwer Academic/Plenum.

Pelegrin, J. (2006). Long blade technology in the old world: An experimental approach and some archaeological results. In J. Apel, & E. Knutsson (Eds.), Skilled production and social reproduction (pp.37–68). Upsalla: Societas Archaeologica Upsaliensis.

Pelegrin, J., & Morgado, A. (2007). Primeras experimentaciones sobre la producción laminar del Neolítico Reciente-Edad del Cobre del sur de la Península Ibérica. In M.L. Ramos, J.E. González, & J. Baena (Eds.), Arqueología Experimental en la Península Ibérica: Investigación, didáctica y patrimonio (pp. 131–139). Santander: Asociación Española de Arqueología Experimental.

Ramos Millán, A. (1997). Flint political economy in a tribal society. A material-culture study in the El Malagón settlement (Iberian Southeast). In A. Ramos Millán, & M.A. Bustillo (Eds.), Siliceous rocks and culture (pp. 671–711). Granada: Universidad de Granada.

Ramos Muñoz, J., Espejo, M.M., & Cantalejo, P. (1986). El taller Calcolítico del Castillo del Turón, Ardales (Málaga). Málaga: Ayuntamiento de Ardales.

Ramos Muñoz, J. (1997). Tecnología lítica de los talleres de cantera de la Axarquía de Málaga. Aproximación al estudio de las formaciones económicas de la Prehistoria Reciente. Málaga: Diputación Provincial de Málaga.

Reinhard, K.J., & Bryant, V.M. (1992). Coprolite analysis: A biological perspective on archaeology. In M.B. Shiffer (Ed.), Archaeological method and theory, Vol. 4 pp. 245–288). Tucson: University of Arizona Press.

Roberts, D., & Berger, L.R. (1997). Last interglacial (ca. 117 kyr) human footprints from South Africa. South African Journal of Science, 93, 349–350.

Seronie-Vivien, M.R., & Seronie-Vivien, M. (1987). Le silex du Mésozoique nord-aquitain. Approche géologique de l'étude des silex pour servir à la recherche prehistorique. Bulletin de la Société Linéenne de Bordeaux, supplément tome XV. Bourdeaux: Société Linéenne.

Uchman, A. (1995). Taxonomy and palaeoecology of flysch trace fossils: The Marnose-arenacea Formation and associated facies (Miocene, Northern Apennines, Italy). Beringeria, 15, 1–115.

Vallespí, E., Ramos, J., Martín, E., Espejo, M.M., & Cantalejo, P. (1988). Talleres líticos andaluces del Calcolítico y Bronce. Revista de Arqueología, 90, 14–24.

Vera, J.A. (2004). Cordillera Bética y Baleares. In J.A. Vera (Ed.), Geología de España (pp. 345–464). Madrid: SGE-IGME.

Webb, S., Cupper, M.L., & Robins, R. (2006). Pleistocene human footprints from the Willandra Lakes, southeastern Australia. Journal of Human Evolution, 50, 405–413.

Wetzel, A., & Bromley, R. (1994). *Phycosiphon incertum* revisited: *Anconichnus horizontalis* is its junior subjective synonym. Journal of Paleontology, 68, 1396–1402.

Zhang, D.D., & Li, S.H. (2002). Optical dating of Tibetan human hand- and footprints: An implication for the palaeoenvironment of the last glaciation of the Tibetan Plateau. Geophysical Research Letters, 29, 1072–1074.

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