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Microstratigraphic analysis on a modern central Saharan pastoral campsite. ovicaprine pellets and stabling floors as ethnographic and archaeological referential data

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ABSTRACT

Here we present an accurate microstratigraphic characterization of sheep/goat dung deposits from an ethnographic pastoral campsite located in SW Fazzan, at the border between Libya and Algeria. Research for referential data on current livestock contexts is essential for correctly interpreting archaeological records documented in ancient livestock spaces. Studies on herbivore faecal remains have played a key role in identifying socio-economic activities (e.g. domestic use of fuel, manuring, stabling or foddering strategies). Soil micromorphology, stable isotopes analysis ($\delta^{13}C$ and $\delta^{15}N$, bulk and compound specific), and lipid analysis (*n*-alkane fraction) have been applied on soil samples and dung pellets in order to obtain reference biosignatures for *Caprinae* stabling deposits in arid and hyperarid environments, where the biological material as dung preserves very well. Information about pastoral habitat adaptations in this area, taphonomic processes of dung deposits, significant micro-features related to penning (trampling, bedding and presence of dung spherulites, druses, phytoliths, and/or microfragments of coprolites), diet, and seasonality of herd animals is herein shown.

1. Introduction

The archaeology of pastoralism has traditionally clashed with the problematic visibility of campsites. The paucity of substantial structures, frequent displacements, and light equipment of ancient pastoralists have challenged archaeologists worldwide for decades. Since the 1970s, archaeologists have been looking at the ethnographic present to find clues to recognize and interpret pastoral archaeological sites. Ethnoarchaeological and geoarchaeological research have both played a key role in the understanding of archaeological deposits generated by mobile societies (e.g., David, 1971; Robbins, 1973; Robertshaw, 1978; Hole, 1979; Smith, 1980; Cribb, 1991; Avni, 1992; Banning and Köhler-Rollefson, 1992; Bradley, 1992; Palmer et al., 2007; Saidel, 2009; Biagetti, 2014a). In addition, during the last decade new research has focused on analyses of micro-remains in arid contexts – phytoliths, pollen, organic matter, and soil constituents (Cremaschi and Zerboni, 2009, 2011; Elliott et al., 2015; Friesem et al., 2011; García-Granero et al., 2016; Gur-Arieh et al., 2013; Portillo et al., 2012, 2014; Shahack-Gross et al., 2008, 2011; Shillito, 2011; Cremaschi et al., 2014 to cite just a few) –, indicating that the study of current pastoral societies at a micro-scale can provide a better understanding of the use of space and the management of natural resources and therefore, contribute to correctly interpreting the archaeological record. Although livestock dung at archaeological sites has been studied since the 1980s (e.g. Chang and Koster, 1986; Shahack-Gross et al., 2004; Portillo et al., 2009) and research concerning animal dung is increasing (Elliott et al., 2015; Berna, 2017), building on studies conducted in modern ecosystems and under known conditions, biological and geological taphonomic processes can be tracked, and complexities of isotopic variations in plant-soil systems can be also

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better understood. In this paper, we present an interdisciplinary approach for a controlled study of modern livestock dung in arid lands, in order to allow us to produce a detailed characterization of mobile pastoralist use of space as well as animal and natural resources management. The aim of this study is to serve as a reference for the interpretation of archaeological dung deposits and provide direct insights on ancient land-use and natural resources exploitation via a combined set of micro-analyses (Table 1).

1.1. Overview of micromorphological analyses of dung

Soil micromorphology permits the identification of microscopic constituents and structures in their original microstratigraphic context (Courty et al., 1989). The analysis of archaeological sediment with this method has proven rather effective to identify ovicaprine dung (Brochier et al., 1992; Goren, 1999; Shahack-Gross et al., 2008) and organic matter from stabling deposits in caves and rockshelters (Wattez et al., 1990; Brochier, 1991, 1992; Boschian and Miracle, 2007; Angelucci et al., 2009; Polo Díaz, 2009; Polo Díaz et al., 2013, 2016; Shahack-Gross, 2011; Nicosia and Polo Díaz, 2012; Cremaschi et al., 2014; Égüez et al., 2016; Alonso Eguiluz et al., 2017) helping to explain the socio-economic features of pastoral groups and their interplay with environmental factors at a local and regional level, giving clues about seasonality, trampling, tillage or fuel management among others.

Isotope Ratio Mass Spectrometry (IRMS) is a specialized tool used to give information about the geographic, chemical, and biological origins of substances (Muccio and Jackson, 2008). IRMS is increasingly being used in archaeology especially for establishing dietary and migration patterns by measuring carbon, nitrogen, oxygen, and strontium isotopic abundances (e.g. Makarewicz, 2014; Henton et al., 2017), but also for palaeoenvironmental investigations analysing carbon, oxygen, and hydrogen isotopic abundances (e.g. Ziegler, 1989; Bowen et al., 2005; Finucane, 2007). Stable isotope analysis ($\delta^{13}C$ and $\delta^{15}N$) in archaeological bulk dung remains have been little explored (Linseele et al., 2013), but preliminary results demonstrated how this type of analysis is useful to identify land management, livestock enclosures, and manured grasslands, and to distinguish between different dietary intake pathways (C3 and C4 plants) (Simpson et al., 1999; Shahack-Gross et al., 2008).

Higher resolution is achieved when performing a separation prior to isotope ratio analysis with Gas Chromatography (GC-IRMS) to study isotopic abundances of specific compounds as alkanes, ketones, or fatty acids. Long-chain *n*-alkanes are mostly derived from epicuticular waxes of vascular higher plant leaves (Eglinton and Hamilton, 1967; Rieley et al., 1991) and these molecules are resistant to biodegradation during burial and they exist almost everywhere in soils, sediments, atmospheric dust, and fossil fuels. This new line of research is currently being developed in archaeology (e.g., Dunne et al., 2016) and has been broadly applied in ecology and environmental sciences research since the 60s (e.g., Sachse et al., 2004, 2006, 2015; Hoffmann et al., 2013; Jambrina et al., 2016).

Chemical analysis of organic residues in archaeological soils (through GC-MS), particularly lipid biomarker techniques, have been applied for the detection and characterization of faecal organic matter since the late 90s (e.g., Evershed and Bethell, 1996; Bull et al., 2002; Sistiaga et al., 2014). The dung biosignatures left by the occupations of nomadic pastoral communities in drylands are good and unequivocal indicators for animal husbandry in a site, and often represent the sole material evidence of 'light' and seasonal occupations. In the present study, we have employed all the above-mentioned methods, to demonstrate the usefulness of a combined micromorphological and bio-chemical approach to investigate dung deposits in arid environments.

1.2. Research area

The ethnoarchaeological study was conducted in the southwestern corner of Libya, in the Fazzan region (Fig. 1), in an area nowadays included within the Algerian border, but at the time of our field research was under the control of Libyan authorities, which released the research license. A mid-term (2003–2011) ethnoarchaeological project (Biagetti and Chalcraft, 2012; Biagetti, 2014a, 2015; Biagetti et al., 2016) focused on the study of the adaptation of current pastoralists in the Tadrart Acacus massif, is the main source of data used in the present paper. The Tadrart Acacus is a sandstone massif, north-south oriented, of c. 100 × 50 km in size. Its main physiographic features are the west-east oriented valleys or wadis (dried river beds that can occasionally reactivate in case of rain), and a series of structural and climatic terraces, covered by a desert pavement (Zerboni et al., 2015). Due to ancestral solutional processes, the flanks of the wadis are dotted by many caves and rock shelter, being attended by humans since the Upper Pleistocene (Cremaschi and Zerboni, 2011). The climate of the area is currently hyperarid, with very low and uneven rainfall, ranging from 0 to 20 mm per year. A proper rainy season cannot be envisaged, and years without rainfall are not uncommon. In spite of the lack of precipitation, the Tadrart Acacus massif features a patchy, permanent plant cover (Mercuri, 2008), in the form of trees (*Acacia* sp, *Tamarix* and more rarely, *Ficus*), shrubs (*Panicum turgidum*, *Zilla spinosa*), and grass (mostly *Aristida pungens*).

1.3. Pastoral habitat adaptations

The Tadrart Acacus is home to a small community of pastoral Tuareg, the Kel Tadrart. Less than 60 persons have been recorded living along the wadis of the Tadrart Acacus massif, roaming the dried river valleys with herds of sheep and goats, along with few camels and donkeys. No other inhabitants dwell this area. Mainly living upon their herds, the Kel Tadrart are (and have been) involved in a range of other activities, as wage workers, soldiers, and tour guides, although pastoralism has always played a major

Table 1
Relevance of the different methods applied in the paper showing the potential information achieved when applied to archaeological samples.

Method	Potential information achieved from archaeological samples
Soil Micromorphology	Clearance and low impact activities (e.g., herding, cultivation, manuring, burning); identification of structures and occupation surfaces (e.g., trampling, trackways, ditches, hearths).
Soil Bulk Stable Isotope Analysis (C, N)	Composition of regional vegetation and past vegetation changes (C3, CAM, C4 plants). Diet, trophic level (herbivore, omnivore, carnivore).
n-alkanes Compound Specific Stable Isotope Analysis	Identification of fossil fuel contamination and burning, dietary practices, composition of regional vegetation and past vegetation changes (C3, CAM, C4 plants). Isotopic fractionation behavior.
Lipid analysis (*n*-alkanes)	Biogeochemical transformations, organic matter input (aquatic, subaquatic, terrestrial plants), taphonomical processes (degradation/preservation).

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