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Cereal cultivation and domestication as shown by microtexture analysis of sickle gloss through confocal microscopy

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When and where cereal cultivation and domestication took place in the Near East are still matters of debate. This quantitative analysis, using confocal microscopy to study "sickle gloss" texture on flint tools used for cereal harvesting, shows that wild cereals were most probably cultivated during the 13th millennium BP in the Middle Euphrates. At that moment, a local and continuous process of cereal domestication began to unfold in this region of the Northern Levant, lasting for over 3 millennia and culminating at the end of the 10th millennium BP. Thus, our research provides a new method for investigating the origins of agriculture, while the data gathered allow us to support the hypothesis of early cereal cultivation during the Younger Dryas and the protracted model of plant domestication, pointing to the Middle Euphrates as one region where this process occurred.

1. Introduction

The beginning of agriculture, the food production system in which the role of plant domesticates is dominant, was one of the main turning points in human history. Cereals were first cultivated and domesticated in the Near East (Harlan, 1995; Zohary and Hopf, 2000). First, genetic studies on cereals pointed to SE Turkey as the place where domestication would have taken place (Heun et al., 1997; Özkan et al., 2002). There, genetic selection leading to domestication had occurred by cultivation and harvesting with sickles, in a short period of time (Hillman and Davies, 1990) and prior to the first appearance of domestic cereals in archaeological sites in adjacent areas, at around 10,500 BC (Lev-Yadun et al., 2000). However, during the last decade, new studies have pointed to a more complex and protracted scenario for the origins of agriculture (Purugganan and Fuller, 2009; Zeder, 2011). A new generation of genetic analyses shows the existence of a complex, non-linear relationship between wild and domesticated cereals (Luo et al., 2007; Civáň et al., 2013). Archaeobotanical analyses are showing that after the first cereals with a nonbrittle rachis appeared, which is considered the main trait of the domestication syndrome, this trait rose to dominance very slowly (over about 1500 years), with the process occurring more or less rapidly in different places in the Near East (Tanno and Willcox, 2006; Fuller et al., 2012). The exchange of seeds between human groups, the cross-breeding of cultivated crops with seed stocks taken from wild stands, or the existence of dead-end lines of genetic evolution, would have slowed the process (Willcox, 2013; Allaby et al., 2010; Fuller et al., 2011). The long period between the appearance of cereals with nonbrittle rachises and their rise to dominance was preceded by a phase of cultivation of wild cereals of unknown length. This phase could have begun at the beginning of the Holocene (around 11,500 BP) (Willcox, 2013; Weiss et al., 2006) or even before, during the Younger Dryas (Hillman, 2000) with some tentative first trials of cultivation during the Glacial Maximum, as has recently been proposed for the site of Ohalo II (Israel) (Snir et al., 2015). For some researchers, the Younger Dryas (12,700–11,500 BP) would have played a major role in the origins of cultivation, as this sudden cold and dry period may have reduced natural stands of wild cereals and forced the last hunter-gatherers to cultivate (Hillman, 2000; Bar-Yosef and Belfer-Cohen, 2002; Murphy, 2007 Bar-Yosef, 2011). However, data supporting these early experiments in cultivation are still meager (Willcox, 2012) and recent studies on the regional

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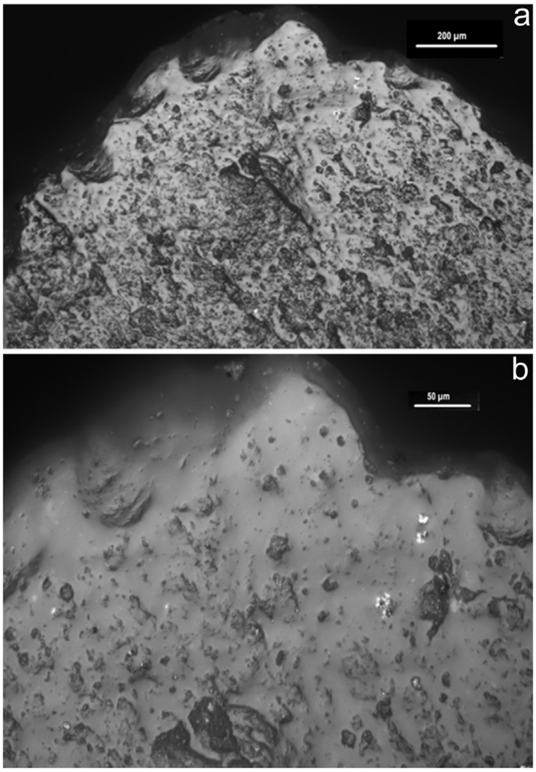

Fig. 1. Use-wear polish from harvesting wild cereals (*Triticum boeticum*) in natural stands, in Syria. Experiment 13. A: 100×; B:same at 200×.

impact of the Younger Dryas in the Near East are showing a more complex climatic scenario than previously thought (Orland et al., 2012; Torfstein et al., 2013).

The recognition of the existence of a long domestication process prior to the appearance of agriculture (Zeder, 2015) reopens the questions of when cultivation began and how many centres of cultivation/domestication existed in the Near East (Fuller, 2007). In this paper we carry out quantitative analysis using confocal microscopy of sickle gloss texture on flint tools used for cereal harvesting, in order to shed new light on this debate.

2. Materials and methods

The identification of the use of prehistoric tools is carried out through use-wear (or microwear) analysis. Using this method, use-wear traces on experimentally-used tools, which are observed using a reflected-light microscope, are compared with traces on archaeological tools observed in the same way. The inference of the use of the archaeological tool is made using visual analogy between the experimental and the archaeological traces (or microwear polishes, Keeley, 1980). During the last decades, use-wear analysis has contributed to a better understanding of the economic, social and symbolic meaning of prehistoric tools. Improving our capacity for micropolish characterization through a quantitative methodology would result in a more reliable and precise inference of the worked materials. Despite efforts invested in quantifying use-wear micropolish, the degree of success has been limited, because of the technical limitations of the methods used, such as interferometry (Dumont, 1982), image analysis (Bietti et al., 1994, 1998; González Urquijo and Ibáñez, 2003; Grace, 1989; Knutsson, 1988; Pijoan et al., 2002; Vila and Gallart, 1993), measure of surface brightness levels (Vardi et al., 2010), 3D rugosimetry (Beyries et al., 1988;

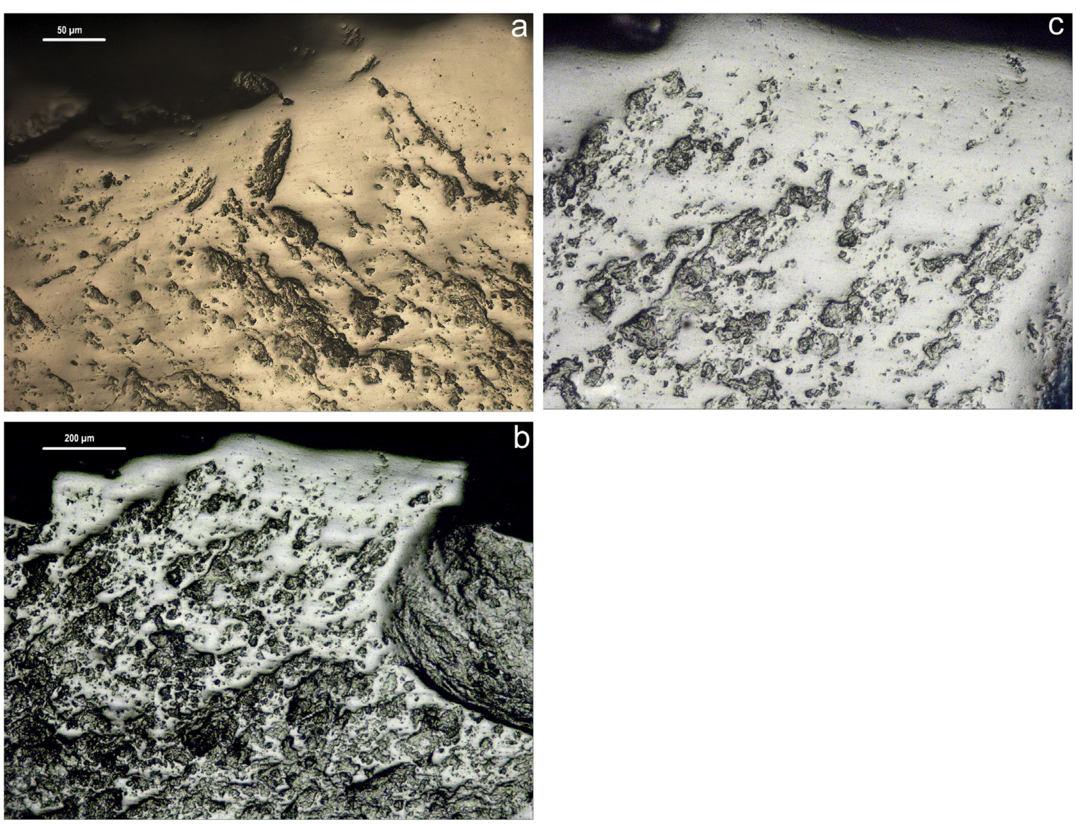

Fig. 2. Use-wear polish from harvesting wild cereals stands (*Triticum dicoccoides* and *Hordeum spontaneum*) in natural stands, in Syria. Experiment 8. A: 200×, B: 100×; C; same at 200×.