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Environmental response of a fragile, semiarid landscape (Bardenas Reales Natural Park, NE Spain) to Early Holocene climate variability: A paleo- and environmental-magnetic approach

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ABSTRACT

The Bardenas Reales Natural Park (western Ebro Basin, NE Spain) constitutes a fragile landscape where the prevailing semiarid climate and erodability of the bedrock have resulted in high sensitivity to erosion/sedimentation oscillations during the Holocene. In this paper, we present new chronologic, sedimentologic, paleomagnetic and environmental magnetic results from the oldest unit (Qah1) of a system of nested cut-and-fill alluvial sequences, which is 18 m thick and crops out extensively in the central part of the natural park at the Bardena Blanca Depression. Radiocarbon dating indicates that Early Holocene unit Qah1 is younger than 9.38–8.89 cal kyr BP and gives ages of 8.92–8.42 and 7.59–7.37 cal kyr BP in the middle and uppermost parts of the unit, respectively. Sedimentologic data indicate that distal alluvial sediments of unit Qah1 accumulated in sandy mud flats and ephemeral playa lakes under arid conditions. The coincidence of enhanced magnetite content with moderate to intense root bioturbation in the lowermost and likely also uppermost sediments of unit Qah1 suggests that magnetite formed authigenically in response to relatively wetter conditions at the beginning and end of this dry period. These results indicate that onset and cessation of alluvial aggradation mark the passing of a geomorphologic threshold, most likely plant cover in the watershed, during a progressive drying–wetting event. The radiocarbon-based age model of unit Qah1 indicates that alluvial aggradation under arid conditions began at 9.13 cal kyr BP and ended at 7.16 cal kyr BP. This period is strikingly centered at around the 8.2 kyr cold event but spans a longer time period, supporting the notion of a global climatic deterioration as the underlying cause for this event. Paleomagnetic directions do not clearly display the characteristic patterns recognized in paleosecular variation curves derived from other European lacustrine sediments and cannot be used to refine the radiocarbon-based age model for unit Qah1. Our results demonstrate a quick and strong response of alluvial systems to Early Holocene climate variability in fragile Mediterranean landscapes such as those at the semiarid Bardenas Reales Natural Park.

1. Introduction

Climate models predict that global change will preferentially affect semiarid landscapes such as those within the Mediterranean area (Intergovernamental Panel on Climate Change, 2007). Projected conditions for southern European semiarid regions indicate higher mean temperatures, decreased precipitation, and an increase in high temperature and drought events resulting from enhanced interannual variability (Born et al., 2008; Giorgi and Lionello, 2008). The Ebro Basin (Fig. 1) is a semiarid region located in NE Spain and is therefore expected to be especially vulnerable to future climate change. The Bardenas Reales de Navarra in the western sector of the Ebro Basin constitutes a Natural Park and World Biosphere Reserve aimed at preserving fragile semiarid landscapes and ecosystems typical of the Mediterranean region. The Lower Miocene bedrock of the central sector of Bardenas Reales consists of easily erodable clayey units that

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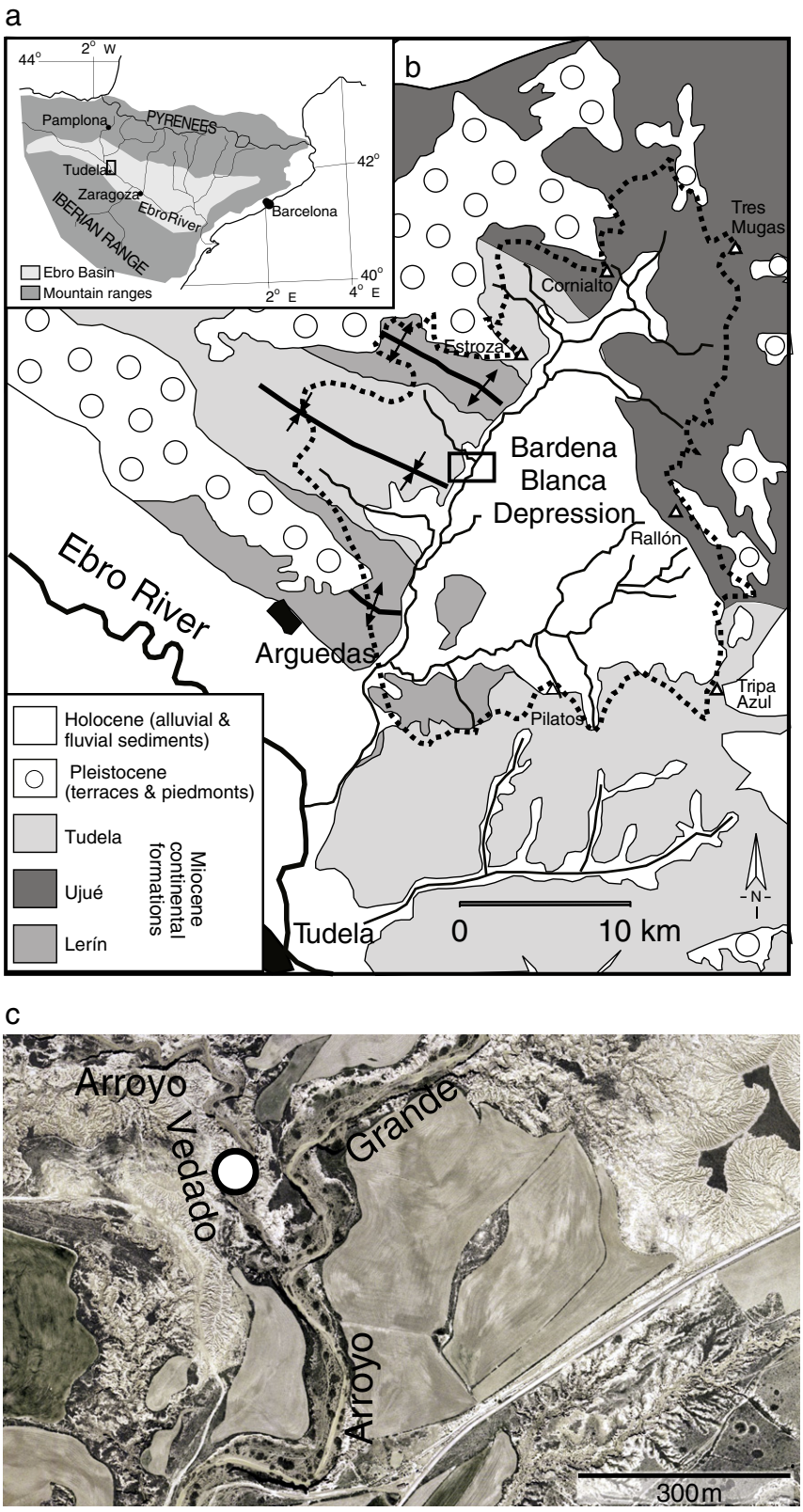

Fig. 1. a) Location of the study area within the context of the NE Iberian Peninsula. b) Geological sketch map of the Bardenas Reales Natural Park area, with location of the Bardena Blanca Depression watershed (dashed line). c) Aerial picture of the studied section at the Arroyo Vedado section whose location is indicated by a white circle (UTM Coordinates ED50/Zone 30N, x: 623001; y: 4675808). The location of the Arroyo Vedado section within the Bardena Blanca Depression is marked by the small rectangle in (b).

have conditioned, along with the prevailing semiarid climate, a particular landscape characterized by a wide depression bordered by high-gradient water divides. These characteristics impose high sensitivity in terms of erosion and sedimentation oscillations, which have resulted in development of several nested cut-and-fill alluvial sequences in response to Holocene climate variability (Sancho et al.,