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Pedologic analysis of the Danilo Bitinj Site, Central Dalmatia, Croatia

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ABSTRACT

As part of the Early Farming in Dalmatia Project, an interdisciplinary effort toward understanding the origins of European agriculture, we are performing a site-specific geoarchaeological study of the Middle Neolithic Danilo Bitinj site and the Early and Middle Neolithic Pokrovnik site. Here we present the soil description and analysis for Danilo Bitinj. The site, farmed for at least 7000 years, is located at the center of Danilo Polje, a valley in Dalmatia's well-developed karst terrain. Soils both on- and off-site are fine-grained and carbonate-rich. Other measured pedologic properties indicate a stable valley-bottom environment throughout the life of the analyzed solum. The longevity of agriculture corresponds with the high measured calcite content, while electric conductivity and pH measurements indicate a sodic, plant-toxic chemical environment. Soil organic matter stable carbon isotope data indicate a local environment heavily dominated by C_3 plants. Soil carbonate stable carbon and oxygen ratios were also measured, but appear to be out-of-equilibrium with those for organic carbon, and therefore invalid for paleoclimatic interpretation. According to regional paleoclimatic studies, the earliest agricultural occupation at Danilo coincided with a significant drought. This evidence for regional drought is at odds with the on-site isotope data indicating relatively cool, moist conditions. These findings present an interesting scenario in terms of human behavioral ecology: that despite the soil's sodicity, Danilo may have represented a moist and productive resource refuge.

1. Introduction

The Early Farming in Dalmatia Project (EFDP) aims to elucidate the origins of European agriculture through site-specific geoarchaeological, paleobotanical, zooarchaeological, and artifactual analysis; and regional paleoclimatology. Despite nearly 100 years of investigation, the process, character, and diversity of Southeastern European 'neolithization' remain largely unknown — perhaps due to the bias in the record toward sites that would have been unsuitable for farming (Tringham, 2000). The sites under investigation are Danilo Bitinj (Middle Neolithic) and Pokrovnik (Early and Middle Neolithic) (Fig. 1). These EFDP excavations provide a unique opportunity for re-examination and comparison of Neolithic expression at two open lowland sites in central Dalmatia, the bridge between Near East domestication and European farming. The geoarchaeological and paleoclimatological components of this project aim to construct the first multi-scale (local and regional) climate records for Central Dalmatia, and to elucidate site taphonomy. We focus here on description and analysis of the Danilo Bitinj soils.

The Danilo Bitinj site is located at the center of Danilo Polje, an elongate, flat-bottomed karstic valley (Fig. 2). This valley is part of the Dalmatian polje-karst field, whose structure originated in the northwest–southeast structural trend of the Dinaric section of the Alpine orogeny (White, 1988). This region is subject to the Mediterranean, or xeric, moisture regime, in which the majority of annual precipitation falls in winter months. Danilo Bitinj, the type-site for the Dalmatian Middle Neolithic, has been occupied and farmed for at least 7000 years (cal BP) (Moore et al., 2007). Prehistoric cultural deposits contain lithic, ceramic, faunal, and botanical artifacts. Field observation reveals fine soils (clay and silty-clay), and lime- and dolostone bedrock. The reason for the site's long agricultural use-life may be its soils — their texture, parent material, and landscape-setting promote fertility, making the valley-bottom ideal for agriculture, even in times of drought or resource-stress.

2. Methods and materials

Samples are from a single 150-cm profile in Danilo Bitinj archaeological trench 'A' (Fig. 2), taken every 20 cm from the surface to the parent material (sample A1 — 10–20 cm depth to sample A7 — 130–140 cm) (Table 1). Soils throughout the site are locally-termed 'brown soils' (smeđe zemlište or terra fusca), typically having variable depth, poor drainage, and hard structure (Antić et al., 1982). Site soils are dark brown (2.5Y 3/2 and 3/1), developed from a silty yellow (5Y 5/6) parent material. A and B horizons have blocky structures; the B horizon is distinguished by larger, harder peds. We analyzed all seven samples for pH, electrical conductivity, organic carbon content, and

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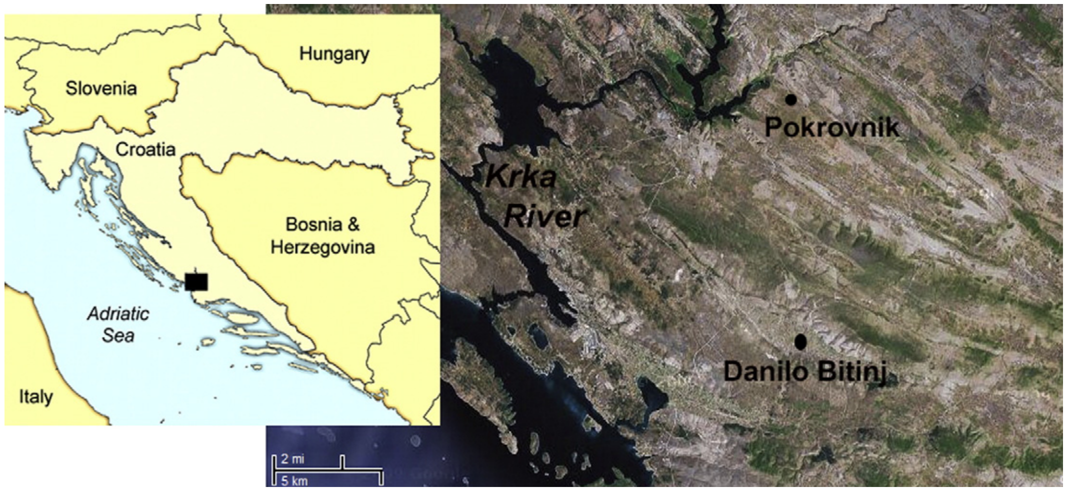

Fig. 1. Modified LANDSAT image of central Dalmatia.

pedogenic carbonate and soil organic matter (SOM) $\delta^{13}C$. We evaluated soil mineralogy through X-ray diffraction (XRD) of two soil samples (70–80 cm, B horizon; and 130–140 cm, C horizon). We prepared samples for electrical conductivity and pH measurement by mixing a 1:5 soil:water paste with an electronic mixer for 1 h (Rayment and Higginson, 1992). We used the Walkley–Black digestion–oxidation method to measure organic carbon content. XRD lets us identify soil minerals based on the characteristic way a mineral's crystal lattice diffracts X-rays. We analyzed the resultant spectra using MDI Jade software.

SOM (carbon) and pedogenic carbonate (carbon and oxygen) stable isotope measurements are valuable sources of paleoclimatic information, in terms of vegetation regime and relative local moisture variations (Cerling and Quade, 1993; Boutton, 1996; Nordt, 2001). Vegetation populations contain varying proportions of plant metabolic pathways — in this region both C_3 and C_4 plants, with the former favored by cooler, wetter conditions; the latter by warmer, more arid conditions. These pathways fractionate carbon differently, leaving a direct record of average plant population – and therefore environmental conditions – in SOM stable carbon. $\delta^{13}C$ averages −26‰ for C_3 populations and −14‰ for C_4 (Nordt, 2001). Stable isotope chemistry is particularly valuable for geoarchaeology, as it provides paleoclimatic data from the actual locus of human use or occupation (Davis and Schweger, 2004; Huckleberry and Fadem, 2007). This site-specific

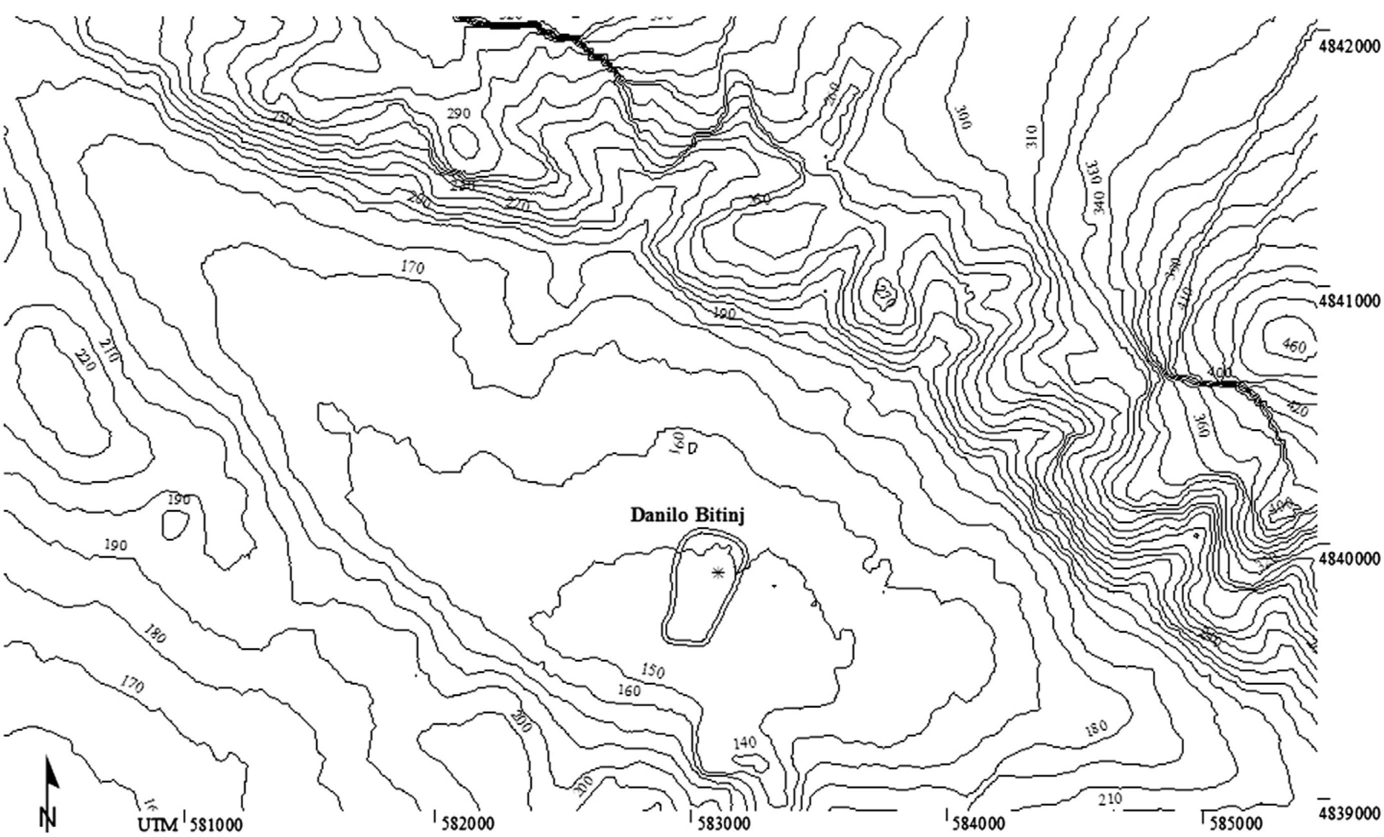

Fig. 2. Topographic contour map of Danilo Polje showing site boundary outline and on-site soil sample collection point.