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The genesis of irrigated terraces in al-Andalus. A geoarchaeological perspective on intensive agriculture in semi-arid environments (Ricote, Murcia, Spain)

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ABSTRACT

Irrigated terraces in the Iberian Peninsula are associated with al-Andalus; the name with which the region was known following the migration of Arabic–Berber tribes across the Strait of Gibraltar, starting from 711 AD. Several of these agricultural areas have remained in use in the west Mediterranean to the present day. Historical texts usually refer to later extensions of the original Andalusi irrigated terrace fields, yet little is known about their foundation period. In this study we examined the micromorphology and undertook physico-chemical analyses and radiocarbon dating of a buried soil found in Ricote (Murcia, Spain) to provide relevant information to understand the initial stages of terrace building within al-Andalus. Results of our study show that: (1) Andalusi peasants selected a saline Hipercalcic Calcisol developed on colluvial materials on which to build the first irrigated terraces, (2) The soil was probably cleared of bushes by fire prior to terrace construction, (3) The shifting of sediments implied in the building of terraces seems to have entailed the inversion of the original soil stratigraphy, (4) Radiocarbon dating of submillimetric fragments of charred wood embedded in the top horizon of the buried Hipercalcic Calcisol (2σ 647–778 AD) suggests the original irrigated terraces of Ricote were built shortly after the arrival of Arabic and Berber tribes in the Iberian Peninsula.

1. Introduction

Terracing is a common agricultural strategy that is attested worldwide. The construction of agricultural terraces involves the shifting of sediments along a slope to obtain a staircase sequence of flattened parcels with deep agricultural soils capable of adequate moisture retention (Treacy and Denevan, 1994). Terrace fields can therefore be defined as constructed fields. Although this definition encompasses all agricultural land, terrace fields demand more labour than most (Torró, 2007) and have a greater impact in terms of anthropogenic transformations of the slope gradient and connected physiographical and ecological processes. Terraces are never built in isolation: each terrace represents a portion of a larger, complex system (Barceló et al., 1998; Torró, 2007). Terrace systems are consistently built from the bottom of the slope upwards, as lower terraces support those constructed above. For the same reason, terraces built at the base of the slope are generally bigger that those lying above. This was noticed in the 16th and 17th centuries by Inca Garcilaso de la Vega (1609), whose general observations of Inca terrace-building apply to most terraced areas.

Slight variations within this general procedure may apply, as multiple factors affect terrace construction, e.g. the characteristics of the chosen environment or the aims of the builders. For example, hydromorphic soils must be drained before terracing to prevent landslides and protect the stability of the system in case of heavy precipitation. Likewise, rocks are usually removed from stony soils before terrace construction begins. Wild plants are also removed, and different types of vegetation imply the use of different weeding procedures (Cooter, 1978). Topographical conditions determine the shape of terraces. In general, the construction of terrace walls is more difficult on steep slopes, while the flattening of the terrace surface is more problematic when gentle slopes are involved (Treacy and Denevan, 1994). Terrace walls tend to be built with local stones. However, earth banks, to which plant cover may be added to increase stability, are also common (Veeck et al., 1995). Soil and sediment added to new-built terraces may proceed from the same slope or from deposits found elsewhere. Terraces built with imported soils and sediments have been identified previously in Peru (Keeley, 1985), Yemen (Wilkinson, 2006) and Israel (Ackerman et al., 2005). The type of crop that will be cultivated on a given terrace may also condition its shape (e.g. exposure, surface topography) and composition (e.g. due to the necessity of adding allochthonous soils and sediments) (Hudson, 1992).

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Building procedures become more complex when the construction of irrigated terraces is involved, as they require previous design to ensure correct articulation between (1) location of the water source, (2) topography of the catchment, (3) network of channels and (4) cultivation area (Barceló, 1989). Gravity is the main constrain in the design of hydraulic systems, as it allows water to flow. Slopes must be calculated and the layout of channels and terraces carefully planned. Due to gravity, hydraulic systems tend to have rigid and easily recognisable boundaries. In order to maintain the efficiency of the original system, later transformations must be undertaken with close reference to the initial design. In this sense, the original design of any given hydraulic system strongly determines the nature and scope of potential future alterations. This implies that the original irrigated terraces and later additions or modifications remain discernible through time, unless the original system is completely obliterated to allow the construction of a brand new one (Barceló, 1989).

The construction of irrigated terraces in the Iberian Peninsula (henceforth referred to as al-Andalus) was a preferential agrarian option following the arrival of Arabic–Berber tribes in 711 AD. Hydraulic systems were accompanied with the introduction of exotic plants such as artichoke, cucumber, lemon, orange and sugar cane, to name but a few (Watson, 1983). The spread of hydraulic systems and related plant species across the Mediterranean was defined by Glick (1991) as a large scale propagation of oriental landscapes, and by Watson (1983) as an agricultural revolution. Historically, the expansion and propagation of Andalusi hydraulic systems in the Iberian Peninsula was boosted by the feudal conquest of al-Andalus between the 11th century and 1495 AD. Feudal lords modified, altered and extended Andalusi irrigated fields. Many of them remain active in the present day, and some, such as those in Murcia and Valencia, are still recognised among the biggest and most productive agricultural areas in Europe (Acosta et al., 2011). These hydraulic systems, known in Spain as *huertas*, have functioned persistently over the past millennia through contrasting climatic phases, including the Medieval Climatic Anomaly (MCA) and the Little Ice Age (LIA) (Morellón et al., 2011; Moreno et al., 2011). This makes them extremely interesting in terms of understanding pre-industrial agriculture technology in semi-arid environments. Apart from the inherent historical and archaeological value, the study of al-Andalus irrigated terraces is most relevant for the development of present-day sustainable agricultural strategies. In these terms, a number of key factors remain largely unknown, including (1) the characteristics of the pre-existing environments over which the irrigated terraces were built, (2) the timing of their construction and (3) their construction process. In this paper, such questions are approached through the geoarchaeological study of the Andalusi irrigated terraces of Ricote (Murcia, Spain). The aim is to stress the importance that the introduction of irrigated agricultural systems have had in the making of some of the most emblematic Mediterranean landscapes.

1.1. *Ricote: physiography, history and archaeology*

Ricote is one of the eight villages found in the Ricote Valley, in the southeast of the Iberian Peninsula (Fig. 1a). The regional climate is semi-arid with strong seasonality. Average summer and winter temperatures are 31–34 °C and 1–5 °C respectively. Annual rainfall oscillates between 200 and 350 mm, and evapotranspiration between 750 and 900 mm (López Bermúdez, 1973). The low precipitation regime, the sharp seasonal differences in rainfall and the high evapotranspiration rate create conditions of aridity comparable to those found in wide regions of North Africa. In some of the villages annual average temperature (which varies from 12.7 to 17.7 °C) can be over 4 °C above the Spanish average (13 °C) (Pantaleón Cano et al., 2003).

The village of Ricote currently houses 1450 inhabitants. It is located in a *hoya*, a pot-shaped plain surrounded by mountains. Irrigated terraces extend over approximately 120 ha; they climb from the lowest elevation in the *hoya* (235 m asl) up the surrounding slopes (375 m asl). Lemon trees are the main produce presently cultivated within those terraces. Mountains surrounding the Ricote irrigated fields are essentially limestone and Keuper marls, with minor outcrops of polygenic sandstone and gypsum. Quaternary colluvial and silty-clay sediments detached from the hillsides have resulted in Haplic (Calcaric) Fluvisols and Haplic Calcisols in the flattest and lowest reaches of the *hoya*. To the west, Triassic calcareous marlstones support Lithic Leptosols and Haplic Gypsisols. To the south, the same geological substratum led to the formation of Haplic (Calcaric) Regosols and Haplic Calcisols (FAO, 2006; Puy, 2012).

The earliest textual mention of Ricote dates back to 896 AD. In his *Muqtabis* (literally 'the one who takes the candle from another', a sort of annals), Ibn Hayyān narrates the military campaign launched by the Emir against a group of insurgents that sought refuge in the fortification of *al-Sujūr,* the current castle of Ricote (Lévi-Provençal, 1953). The presence of Andalusi kitchenware distributed throughout the complex suggests that the structure was permanently inhabited (Eiroa Rodríguez, personal communication). Two centuries later, al-Bakrī mentioned the *alquería* of *Riqūt* (Carmona, 2005). *Alquería* was a term referring to a residential complex occupied by a reduced number of inhabitants and the associated agricultural areas. The main settlement was probably located in Cabezo del Algezar, to the north of the present day village. The hilltop has yielded pottery dated to the 11th century (Manzano Martínez, 2002). The presence of at least one Andalusi settlement in the 9th century suggests this as the latest plausible period for the creation of the original hydraulic system (Puy, 2012) (Fig. 1b).

The relative chronology of the successive extensions composing the hydraulic system of Ricote was determined previous to the present work following the principles of hydraulic archaeology (Kirchner and Navarro, 1993). The method is based on systematic field survey, morphological analysis of the relationship between channel network and irrigated terraces and the study of written records. In the case of Ricote, written records are preserved in the Órdenes Militares (Archivo Histórico Nacional de Madrid, AHN) and in the Protocolos (Archivo Histórico Provincial de Murcia, AHPM), and cover the 15th–19th centuries. The data obtained showed that most additions made to the current extension of the hydraulic system (120 ha) were in two main steps. The first major enlargement (c. 50 ha) was undertaken between the feudal conquest (1243 AD) and the end of the 15th century. The second was completed before 1613 AD, leading to a total extension of c. 118 ha. A final minor addition (c. 2 ha) took place in the 18th century, when the hydraulic system reached its present extension (Fig. 1c). Written records are not available for the foundational period of the hydraulic system at Ricote. Results presented here help filling this documentary gap, contributing to the understanding of the construction of the original irrigated area that covered a surface of 1.9 ha (Puy, 2012).

2. Materials and methods: the geoarchaeological approach

A trench was opened by mechanical means in one of the terraces within the original Andalusi irrigated area (Fig. 1c, d). The trench, dug perpendicular to the retaining wall, was restricted to 6 m^2 to avoid disturbance of the planted lemon trees.

The maximum depth reached was 280 cm below the surface. Bedrock was not reached. The exposed stratigraphy included two