ACTIVITY OF GULLIES DURING THE HOLOCENE IN THE EBRO VALLEY

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1. Introduction

The flat-bottomed valleys in the central sector of the Ebro Depression keep sediment records that enable the paleoenvironmental reconstruction from the Upper Holocene, differentiating alluviation phases alternated with incision phases and explaining the presence of active gullies since the Roman era.

2. Study Area

The central sector of the Ebro Depression is characterized by the presence of lake Miocene sedimentary series, composed of lutites, sands and evaporitic formations with limestones at their top levels. During the Pliocene, the discharge of the lake basin to the Mediterranean Sea started (García-Castellanos et al, 2003) through the Ebro fluvial network formation, which has shaped land configurations of the "muela" type (flat-topped tabular mountain of ~700 m) and has opened broad valleys with important Quaternary accumulations. Among them, the flat-bottomed valleys, locally called "*vales*," constitute one of the most representative landscape formations. These are valleys filled with sediments coming from the erosion of the surrounding hillsides that could not be drained through the fluvial network. In some cases, these bottoms are incised by still active gullies (Peña et al., 2004), linked to other processes such as piping or landslides, which are also observed in other sites (in the low Huerva valley, Barrón et al., 1995; in Southeast Spain in dispersive marls, Harvey, 1982; López Bermúdez and Romero, 1989; Faulkner et al., 2003 or Desir and Marín, 2006, in Bardenas, in the Ebro Basin).

Some of the factors that help understand the piping dynamics include the presence of easily dispersible silty soil, scarce plant cover, flat topography accelerating water infiltration and favoured by surface cracks, and a water gradient facilitating the mechanical erosion of water (Gutiérrez et al., 1988).

3. Holocene evolution and gulling activity

The Holocene evolution of the *vales* in the central sector of the Ebro Depression is represented by the existence of three accumulative levels, the oldest of which (N3) takes up a large extension, while the more recent ones (N2 and N1), only appear in sectors of fluvial incision. The dating of these deposits has been carried out by means of geoarchaeological prospection techniques, such as geomorphologic mapping and the analysis of organic remains, through ^{14}C, or archaeological remains.

N3 level, or general level, reaches a great continuity in all the *vales* analyzed, being this one, in many cases, the single level. The basal sediments show ages ranging between 6015±75 yr BP for the *val de la Morera*, 5910±270 yr BP in *Las Lenas* (in the Huerva valley) and 4270±55 yr BP in the *Barranco de Alfocea* (Fig. 1) or *Barranco de Los Lecheros*, a tributary on the left bank of the River Ebro (Constante et al, 2006), coinciding with the dryer and warmer climate of the Atlantic Climate Optimum, although it is true that some marginal sediments in *Las Lenas* present pre-Holocene ages (Andres et al., 2002). The *barranco de Miranda* is a tributary on the left bank of the River Ebro and contains important archaeological remains (Fatás, 1972 a, b) that range from the Iron Age to the Iberian-Roman Period (V BC-I AD), which has enabled us to establish the relative chronology of the various cumulative levels, as well as to relate it with the environmental characteristics and the human occupation of the territory (Peña, 1996). The top of the accumulation, constituted by silts of the late Post-Roman Period (1.500 yr BP), forms a totally flat surface linked to alluvial fans at their exits towards the main valleys. The time coincidence of these fillings with periods of intense human occupation of the environment, since the Bronze Age to the Roman Period, allows us to imagine that deforestation has been decisive in the increase of the erosion rates, since the hillslopes are no longer protected.

Once this filling stage ends, an incision period starts that lasts up to nowadays and remains active in the most important *vales*, or with an increased longitudinal gradient. The sediments are transported from the *vales* to the main streams (e.g., Huerva River and Ebro River), which carries them towards the Mediterranean Sea, widening the Ebro River Delta since the 4th century.

Gully developments over the last 1500 years triggered by a combination of human-induced land cover changes and extreme rainfalls have been documented (Faulkner, 1995, in southern Spain; Peña et al., 2000, in the Ebro Basin; Poesen et al., 2000, in Belgium).

Fig. 1. Gully in the *Barranco de Alfocea*.

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Inside these gullies there were sedimentation episodes that originated N2 levels, from the Medieval or Post-Medieval Ages associated with the Medieval Climate Optimum (Peña, 1996) and N1 levels, 380±60 yr BP, that can be related to extreme events of the Little Ice Age. The subsequent incision has left this terrace inactive, remaining a current bed subjected to short alternating filling and incision cycles. The good longitudinal connection between levels N1 and N2 and the corresponding alluvial terraces of the Huerva River support the climatic nature of these deposits from the Post-Roman Period, with a less important anthropic action in an environment that has not recovered its biostasic state since the main disturbance of the Iron Age-late Roman Period.

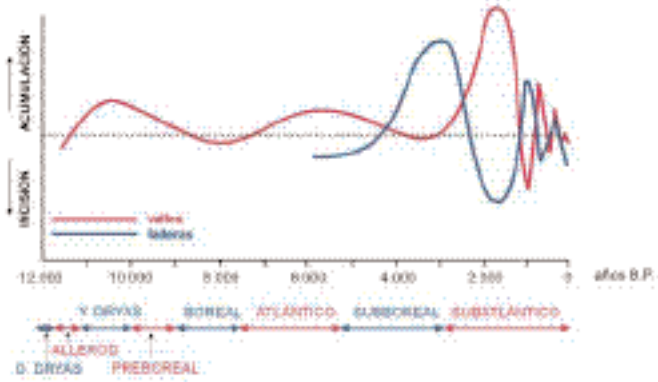

Fig. 2. Accumulation and incision phases in hillslopes and Holocene valley fillings, chronologic connection with the Holocene division and large phases based on archaeological data of the NE of Spain (Peña et al., 2005).

4. Conclusions

The use of detailed geomorphology for the study of the Upper Holocene and the application of geoarchaeology and radiometric datings make it possible to get important results on the recent stages of valley bottom shaping. The timing of the aggradation and degradation phases shows the activity of the processes over the last 8000 years and the decisive influence of the Holocene evolution on present landscapes (Fig. 2).

The reasons for this phase alternation are anthropo-climatic, as Jordá and Vaudour (1980), Bintliff (1981, 1982), Gutiérrez and Peña (1998) and Peña (1996), Peña et al. (2000, 2004) recognize in different sectors of the Mediterranean basin.

The gullies formation and activity from the late Roman Period has progressed by means of a regressive activity of the headwaters, although the excavation process has been temporarily interrupted by new fillings.

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