Human-induced erosion and sedimentation during the Holocene in the central Ebro depression, Spain

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ABSTRACT

Small secondary valleys in the Central Ebro Depression in northeast Spain have tended to be infilled with sediment, and record a complex sequence of accumulations and incisions of Holocene age. Level N3, the main accumulation level based on extent and depth, is characterized by a long period of sedimentation (from the Late Epipaleolithic to the end of the Late Roman period), the dominance of gypsiferous silt resulting from hillslope erosion, and a thickness up to 15 m. This deposit does not connect directly to the fluvial terraces of the Ebro River, and it accumulated over a long period of climate fluctuations. Thus, its evolution appears to have been largely independent of climate variability, but is closely related to human activities (deforestation, forest fires, farming development), particularly those associated with the main human settlements.

Key words: Geoarchaeology, Holocene, Ebro Basin, secondary valleys.

INTRODUCTION

A number of studies have investigated sediment accumulation in the secondary fluvial network forming the tributary of the Ebro and Huerva rivers, in the central sector of the Ebro Depression in northeast Spain (Fig. 1). This network is deeply incised in Miocene gypsums in a radius of 30 km around the city of Saragossa. These studies have revealed the presence of several accumulation levels, which usually connect topographically with the lowest terraces of the Ebro and Huerva rivers.

Recent studies focused on the left margin of the Ebro River (Constante *et al*., 2006; Peña, 1996) have identified a similar organization (Fig. 2), with N4 being the oldest accumulation level, and N3 showing major development in both extent and depth in all the tributaries analyzed (Constante, 2009). In most cases these tributaries end in the alluvial plain throughout alluvial fans.

The main purpose of this report is to explain the functioning of N3 in relation to other accumulation levels in the valleys and fans, with a focus on establishing objective criteria to differentiate climate-related and human-induced deposits. The latter must contain evidence of soil erosion events caused by deforestation in the basin, accompanied by favorable climate conditions for the occurrence of erosion processes.

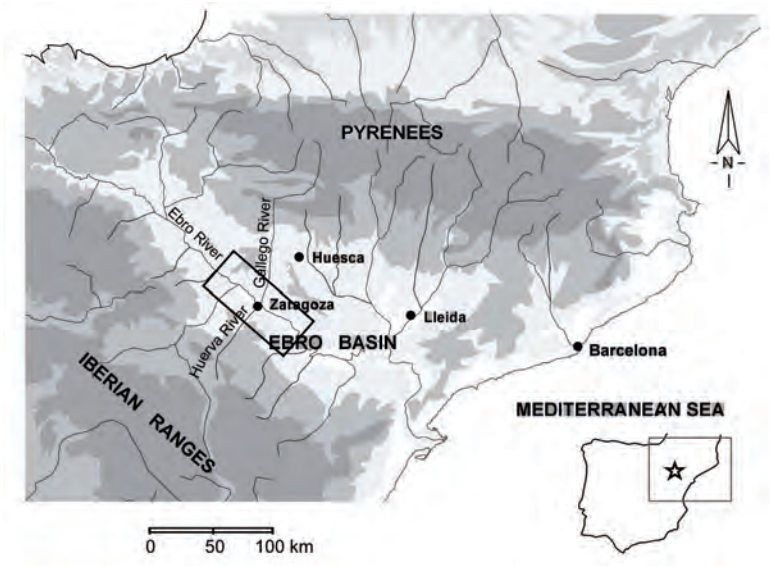

Figure 1. Location map.

METHODS

A geomorphological map (1:20,000) encompassing the area containing the levels and incisions was used to study the various valleys. Cross profiles facilitated observations of the relative organization of the levels (Fig. 2), and the longitudinal profiles showed the gradient and connections with the fans and terrace levels of the main rivers. Sedimentological sections of every level were taken for carbon-14 and archaeological dating.

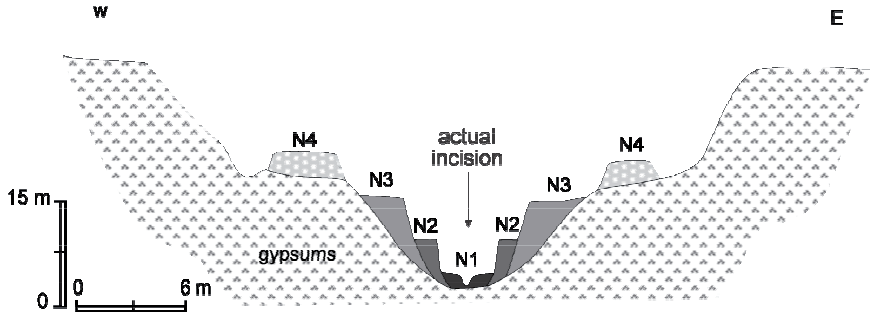

Figure 2. Cross profile of the levels of the Las Casas ravine (left margin of the Ebro River).

RESULTS AND DISCUSSION

The accumulation of level N3 occurred over a long period. The bottom of the level was dated between 7,185 ± 65 and 6,000 years BP (Epipaleolithic to Neolithic periods), and the upper part of the level had sediments dated between 3,135 ± 50 years BP (Bronze Age) and the 4th and 5th centuries (Late Roman period). Level N3 was separated from level N4 by a deep incision on which sedimentation had occurred. A subsequent incision after the Late Roman Period, in some cases reaching the Miocene gypsum bedrock, was the erosive stage supporting level N2 (dated in the Middle Ages/post-Middle Ages), and level N1 was deposited during the 17th and 18th centuries (Peña *et al*., 1996, 2001).

Sedimentological study indicated a clear separation of level N3 from the other accumulation stages. Levels N6, N5 and N4 always corresponded to 2–3 m of homometric gravels, mainly composed of limestone and gypsum clasts. This indicates that fluvial functioning affected the whole of the basin, including the calcareous platforms in the headwater. Levels N2 and N1 are composed of coarse, heterometric gravels (sediment to 1–2 m thickness) of limestone and gypsum. However, level N3 comprises a layer of gravel overlaid by a substantial thickness of gypsiferous silt, with some intercalations of thin layers of fine gravel, in total reaching a thickness of 10–15 m.

As indicated above, only level N3 lacked a direct connection to the terraces of the Huerva and Ebro valleys, whereas the levels above and below appear to correspond to accumulation stages associated with the functioning of the main rivers. This suggests that the development of level N3 was relatively independent of the climatic variability that caused the erosion/accumulation activity in the other levels. In addition, based on the dates determined for level N3, the most important sedimentation period in the ravines of the left margin of the Ebro River occurred during the Bronze Age, whereas Iberian and Roman deposits were minor or absent. This contrasts with the tributaries of the Huerva River, where sediments of Iberian and Roman age prevail. Thus, there is asynchrony in the development of level N3 in the two sectors, confirming that climate was not the main factor in its accumulation.

CONCLUSIONS

The results of this study show major differences in the levels of infilling in ravines of the central sector of the Ebro Depression, particularly for N3, which is the thickest and most extensive level. Pre-N3 sediment accumulations (probably of Upper Pleistocene and lower Holocene age) are composed of homometric gravels, while post-N3 accumulations are torrential deposits, characteristic of highly intense rainstorms and associated sediment transfer. The N3 level, which represents a sedimentary period of at least 7,500 years, has a prevailing silty composition and is much thicker than the other Quaternary sediments in the study area.

In addition, the N3 deposit is dominated by gypsiferous silts suggesting incorporation of sediment from hillslopes and lateral fans, with longitudinal transport from the headwater being of limited importance. A further factor suggesting an anthropogenic contribution to the origin of level N3 is the lack of synchrony in the context of the Central Ebro Depression. Thus, it seems that the most intense sediment accumulation (and hence soil erosion) occurred during the Iberian and Roman period in the Huerva Valley, whereas on the left margin of the Ebro River the maximum accumulation occurred during the Bronze Age. Consequently, level N3 may represent the main deforestation stage in the Central Ebro

Depression. This led to generalized soil erosion due to intense grazing, and resulted in bare or steppic hillslopes still evident centuries later.

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