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Evolution patterns of synsedimentary Pleistocene dolines: clues for present doline evolution?

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Karstification is a very active process in the central part of the Ebro Basin (NE of Spain). Tertiary rocks in this area are mainly evaporites and carbonates generated in shallow lacustrine environments. These are partially covered by Quaternary alluvial (pediments) and fluvial (terraces) sediments. At present, climate in this region is semiarid. The main landforms generated by karstification are alluvial doline fields, and they are more frequent in the three youngest terrace levels. Nowadays, doline evolution causes numerous environmental problems in farming activities but, especially, in civil engineering (extensive damage affects buildings, roads, water-supply systems, etc) with high maintenance costs.

Considering the data obtained from levelling of fields, pavements and buildings damaged during the last decades, subsidence rates for ten dolines were calculated. In addition, in three of these, a periodic survey through the period 1993-1997 was taken into account. The mean rate both in urban and agricultural areas is around 5 cm/year and the maximum rate at the sinking centres range between 1.6 and 11 cm/year.

On the other hand, paleodolines in the Quaternary sediments of the Ebro valley, some of them synsedimentary, are a frequent phenomenon. A study of the characteristics of the fluvial sediments in numerous sections was carried out in this area. Some sites showing a complete record of the deformational history are analysed in detail studying their sedimentological characteristics.

Based on the lithological, geometrical and textural features of these deposits, several architectural elements have been differentiated. Most of them characterize a gravel-

dominated braided fluvial system, but others are not typical of such environment and are interpreted as related to syn-sedimentary deformation caused by karst. Several evolutionary stages for paleodolines were proposed: 1) genesis of collapses and accumulation of gravel due to gravitational processes, 2) flooding of depressions and generation of back-swamp areas, 3) development of several stages of subsidence linked to evaporite dissolution, 4) end of karstification influence and deposition of non-deformed fluvial sediments.

The sedimentary filling of paleodolines was sampled and four samples taken in two sections with good quality exposure gave OSL ages of 77,753 $\pm$ 7,749 and 72,959 $\pm$ 5,153 yr BP, in the first case, and 57,880 $\pm$ 4,411 and 49,876 $\pm$ 5,434 years BP, in the second one, i.e. the sediments analysed were deposited during the Late Pleistocene. These data indicate that the development of these paleodolines involved periods of time in the order of 10^3 years. Considering the thickness of the deposit, the sinking rate is of several mm/y.

Knowledge about rates of subsidence and evolution patterns of natural paleodolines can be applied and confronted with those in present-day dolines controlled by both natural processes and human influence (debris filling, levelling, farming,...). At present, active dolines sink at rates one order of magnitude faster than paleodolines. Natural water availability is not high in this area (climate is semiarid). However, irrigation practices of farmers in the area give an extra income of water in the aquifer of the Ebro valley. We estimate that human influence acts as an accelerator of the natural evolution of dolines.