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Deciphering age and origin of gullied-shaped landscapes in Sierra de las Nieves National Park (South of Spain)

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Landscapes characterised with the existence of gullies and badlands are common in Mediterranean regions, but not so frequent in high mountains environments exceeding 1,500 m.a.s.l. This is the case of the study area: gullies and badlands located in the Sierra de las Nieves National Park. Both morphologies are not very extensive but has a remarkable impact in the landscape, geomorphology, and vegetation dynamic. In fact, their presence highly enriches the geodiversity of the national park. However, these morphologies have not been very much studied unless the geological characterization of the materials which let their development. Questions related to their origins and dynamic still remain unsolved.

This study aims to shed light on the age and origin of these gullied and badland morphologies located in the upper area from the Sierra de las Nieves National Park. Origin of gullies and badlands usually is related to either climate or human activity shifts, more common in cold regions the former whilst in semiarid regions the latter. In this case, Sierra de las Nieves, mainly of built on calcareous rocks, is characterised by Mediterranean mountain climate (exceeding 1,000 mm y-1 and humid and cold winter) and a long tradition of human activity in previous centuries. The experimental area is located in its upper part close to the highest peak (La Torrecilla, 1,919 m.a.s.l) forming plateu-like relief between 1,600 and 1,700 m.a.s.l where calcareous hills are separated by valleys of lower slopes filled with marls and quaternary sediments. Gullies and badlands are located in these materials. Vegetation corresponds to an opened-mixed vegetal formation of *Quercus Faginea* and *Abies pinsapo Boiss.* With typical high mountain shrubs and meadows. The current land use is a natural protected area, though goat and sheep grazing is permitted if the number of cattle is low. Before the declaration as protected area, the grazing pressure was major. In addition, the deforestation had a huge impact in last centuries.

To carry out the study, one transect was defined in one selected gullied-area including 15-sampling points and ecogeomorphology described: vegetation, soil surface conditions, and geomorphic processes. In addition, soils were also sampled in depth at the same points and some properties analysed in laboratory: color, texture, organic carbon, organic matter, pH, electrical conductivity, aggregate stability, and water holding. The transect run along the maximum slope line from one hill to the valley bottom and continue towards the top of the opposite hill. In the valley bottom, there was a fluvial Quaternary deposit covering and fossilising the marls formation.

When outcropped, these marls were affected by concentrate water erosion forming gullies. Also, its surface developed typical morphologies of Badlands: cracks and crusts in dry conditions, short and shallow mudflows in wet conditions, and popcorn in winter. In that deposit, samples were taking in depth until the marls was reached and dated by means C14 technique. Ecogeomorphology inventory, soil properties, and datations have been used to shed light on the age and origin of the formation of gullies and badlands.