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Gullies and badland landscapes in Neogene basins, region of Murcia, Spain

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Abstract: The area occupied by gullies and ravines in Murcia Region is 161,028 hectares, representing 14.63%. The origin of these erosive forms are related to several factors such as: lithological and stratigraphic features, mineralogy and geochemistry of the sediments, tectonics, climatic characteristics, low vegetation cover and poorly developed soils.

Keywords: Neogene basins, badland, gullies, semiarid region, Spain

Introduction and area of study

Rills and gullies landscapes are very striking, with geomorphologic processes which act very quickly and, on occasions, produce high erosion rates causing negative effects on infrastructures and crops.

Due to climatic conditions, scarce vegetation cover and easily erodible lithologies, areas with rills and bandland landscapes are abundant in the Region of Murcia. But not all bandland landscapes are the same; the diversity of landforms and geomorphologic evolution is often linked to lithological and climatic characteristics and to the uses of soil specific to each area.

The Region of Murcia, located in southeast Spain (Fig. 1), is part of the great morpho-structural unity of the Betic ranges, which stretch across the south and southeast of the Iberian Peninsula. These ridges were formed together with important relief features, namely intermontane depressions subsequently filled with Neogene sediments.

The Neogene basins of the region of Murcia have been shaped by general and local tectonics and by the climate-induced processes of erosion and sedimentation. There are numerous post-orogenic basins or depressions in the Region of Murcia that reflect differences in evolution. However, deposits of marl and gypsum are common to all, especially marls. Following a widespread marine regression, erosion processes formed exceptional badland areas as observed in the basins of Fortuna-Abanilla, Mula, or Gebas (Fig. 2).

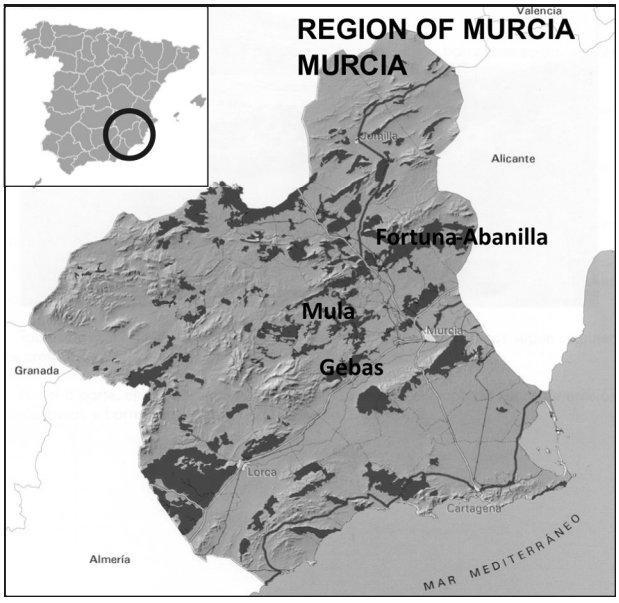

Fig. 1. Rills and gullies areas in the Region of Murcia (Source: MMA 2002)

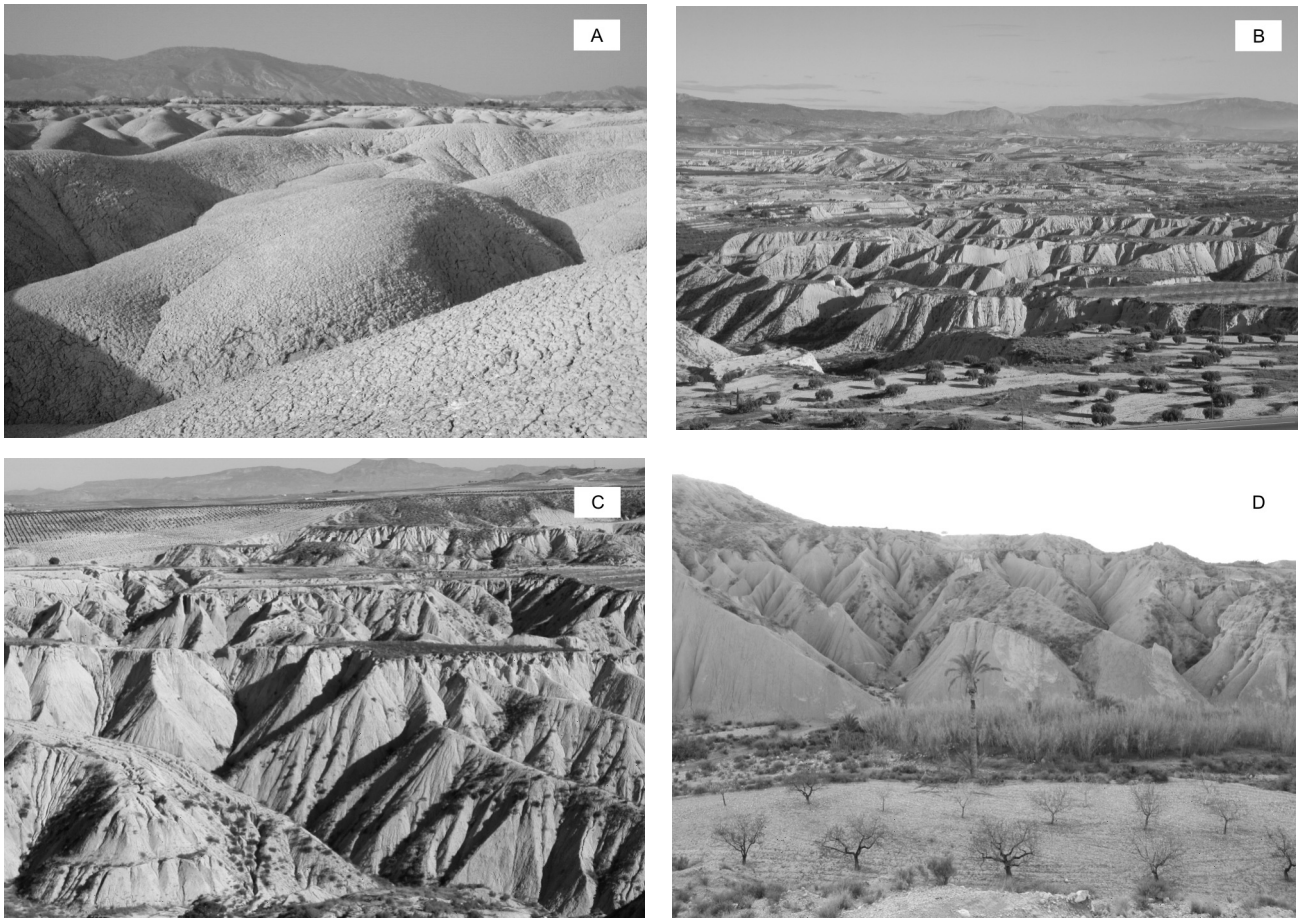

Fig. 2. Diferent badland lanscapes in the Región of Murcia: A – "Los Barrancos" in the basin of Abanilla; B – the basin of Mula; C – "Barrancos de Gebas"; D – the basin of Fortuna

Methodology

Rills and gullies areas in the Region of Murcia (Fig. 1) have been identified by photointerpretation of aerial photographs at an approximate scale of 1:40,000, corresponding to the 1997 photography flight. Later on, the different areas have been located in orthoimages and their contour data have been digitized (MMA 2002). Erosion rates have been estimated by the use of the RUSLE equation.

This paper describes some of the main neogene-quaternary basins of the Region of Murcia (Fortuna-Abanilla, Mula and Gebas) and aims to analyse the causes of the origin of these badland landscapes.

Results and discusion

Characteristics of the sedimentary basins

The geomorphologic history of the neogene-quaternary basins within the mountains of the Region of Murcia has been determined by the local and general tectonics and by the erosion and sedimentation processes of climatic origin. The dynamics of these processes were not continuous since they presented an alternation of marine and continental environments according to the palaeographic changes connected to differentiated tectonic movements. The most extensive basins are those of *Mula* and *Fortuna* together with the *Guadalentín* (Guillén Mondejar & del Ramo 2009) one.

Originally all flattened areas were flooded by the sea. The progressive withdrawal of water during the Pliocene period (IGME 1974) gave way to the prominence of erosive agents, causing some of these areas to become endorreic, and leading to the formation of lakes where the rivers flowed into. For this reason, the neogene basins present a strong sedimentary filling which usually appears structured in superimposed units of marine, lacustrine and fluvial origin. The neogene-quaternary basins of the Region of Murcia are excellent scenarios to observe and study hydrological and erosive phenomena, due to their tectonic and topographic shaping, to the erodibility of their lithologies and to the bioclimatic characteristics.

Neogene sedimentary filling, as in the case of the basins of Mula and Abanilla-Fortuna, or the Rambla of Algeciras, mainly consists of a marl-sand series with calcareous and conglomeratic interlayers of ma-

rine nature, possibly attributed to Tortonian and Messinian (IGME 1974). Quaternary sedimentation is related to the formation of rivers and "ramblas" and also to the development of glacis and alluvial fan systems, which appeared from the relief pattern generated during the Neogene basin emersion and immersion in the Plio-Quaternary (Romero Díaz & López Bermúdez 2009). Alluvial fans and glacis developed at the foot of these relieves, but at present are very dissected by erosion.

Main causes of the formation of rills and badland landscapes

In the Region of Murcia, the origin of these forms is predominantly linked to such factors as: (A) lithology and stratigraphy, (B) mineralogy and geochemistry of the sediments, (C) tectonics (D) climatic characteristics, (E) sparse vegetation, and (F) poorly developed soils. The different forms, found in particular areas, correspond to local variations in compaction, cementation, disintegration, salt content, diaclases, faults etc.

Ad. A. Lithology and stratigraphy. The alternation between different rock types and degree of compaction and cementation affects the permeability and mechanical properties of the rocks, such as their cohesion, resistance to breakage, and resistance to disgregation by water (Atterberg indexes). This leads to highly varied erosion forms. In competent materials, to the northeast of *Gebas*, the forms are more abrupt: great *pipes* that evolve into ravines with vertical walls and circular heads of dozens of metres, structures in the shape of bridges, natural tunnels, chimneys, etc. However, in the crumbly white marine marl of the centre of the depresions of Abanilla, Mula or Gebas there is a predominance of ravines with sloping walls, forming the typical *badland* landscapes.

Ad. B. Mineralogy and geochemistry. Sediments contain minerals that are highly influential on rock disgregation due to their capacity to change their volume according to humidity: *smectite, palygorskite* and *anhydrite.* They also show high concentrations of salts, such as sulphates and chlorides, as a result of their marine origin. This geochemical composition favours rock disgregation by haloclastic processes and the structural loss of the clayey sediments and soil. The type of cation exchange found affects this phenomenon, which is especially high in presence of lithium and sodium cations. It is frequent to find significant concentrations of salts in the beds of ravines and on sheared edges. Some of these mineralogical characteristics could explain the diversity of landforms in the badlands (Fig. 2): from hilly landscapes (in the basin of *Fortuna-Abanilla*) to more vertical walls (in the basins of *Mula* and *Algeciras*).

Ad. C. Tectonics. The most competent rocks (marlaceous lime, sandstone and gypsum) are in some sectors intensely fractured into perfect rectangular blocks which can easily become detached. The scarce vegetation often grows along these cracks, favouring the initiation of rock erosion at these weak points. Many of the ravines are shaped by faults. Piping processes are also determined by the tectonics of the area. Specifically, long *pipes* can be found following the direction of the local faults.

Ad. D. Climatic conditions with highly intense rains which cause important loss of soil, and high temperatures which give rise to soil dissecation and formation of surface cracks.

Ad. E. Scarce vegetation cover with scrubs in an advanced stage of degradation.

Ad. F. Poor and shallow soils and influence of inadequate human activity and agricultural practices.

Surface area affected by rills and gullies in the Region of Murcia and erosion rates

The estimated area in the Region of Murcia with erosion forms in gullies and ravines is 161,028 hectares, representing 14.63% of the regional area. The gullies and ravines are found in 35.71% of the areas with very degraded scrub, in 22.55% of the wooded areas and 5.37% of the cultivated areas in the region. In these areas, two types of landscapes are distinguished: badlands areas and or localized gullies areas.

As far as erosion levels are concerned it is important to highlight how erosion in gullies and badlands gives a higher percentage in the greater erosion levels (higher than 50 t ha^{-1} yr^{-1}), and a lower percentage in lower soil loss levels (Table 1).

In accordance with RUSLE estimations (MMA 2002), the existence of badlands and gullies deter-

Table 1. Erosion surfaces in gullies and badlands, according to sheet erosion levels and in irrigation channels (MMA 2002)

Soil losses (t ha^{-1} yr^{-1})	Erodible surface area (ha)	Erosion surface area in gullies and badlands	
		ha	%*
0–5	513,233	70,438	13.72
5–10	217,849	31,053	15.25
10–25	199,536	30,315	16.19
25–50	82,834	13,329	16.09
50–100	49,029	8,532	17.40
100–200	27,433	5,327	19.42
>200	10,923	2,034	18.62
Total	1,100,837	161,028	14.63

*Percentages refer to each erosion level

Table 2. Surfaces in erosion areas of gullies and badlands according to the protection scheme (MMA, 2002)

Protection scheme	Erodible surface area (ha)	Erosion surface area in gullies and badlands	
		ha	%*
Regional Natural Park	48,913	10,891	22.27
Natural Reserve	225	57	25.14
Protected Landscape	5,986	1,990	33.24
Protected Natural Areas	20,924	3,604	17.23
Without protection	1,024,788	144,485	14.10

*Percentages refer to each type of protection scheme

mines erosion intensity. Therefore, with big gullies the estimated soil losses are always higher than 50 t ha^{-1} yr^{-1}.

There is generally a strong contrast between badland areas and those cultivated with scarse or null erosion. Nevertheless, there is proven evidence that some of the rill areas register a moderate or low erosion rates during long periods and very high erosion rates for short periods, coinciding with highly intense rainfall. This is, furthermore, a question of the magnitude and frequency of the erosion events.

High erosion problems affect: (a) marginal agricultural drylands with slope gradients over 12% and no soil conservation practices, and (b) areas with sparse scrub vegetation, poor and shallow soils and soft lithologies with slope gradients over 25%.

Particularly, the basins of Mula and Abanilla-Fortuna have been the object of a great deal of experimental research of processes and assessment of erosion rates (Albaladejo 1995, Romero Díaz et al. 1995, 1999, 2004, Boix Fayos et al. 2006 etc.). One of the erosion processes linked to badlands is piping, which is very important in these basins (López Bermúdez & Romero Díaz 1989, Romero Díaz et al. 2007). In some cases, calculation of soil loss rates in piping areas in the basin of Mula has resulted in values higher than 200 ton ha^{-1} yr^{-1} (Romero Díaz et al. 2009).

Another fact to be highlighted in the Region of Murcia is that most of badland areas are under some kind of protection scheme. In regional natural parks, 22.3% corresponds to gullies and badlands. In nature reserves, this percentage is 25.1; in protected landscapes this percentage is 33.2 and in protected natural areas this is 17.2% (Table 2).

The uniqueness of some of these landscapes, such as "Los barrancos de Gebas", has meant that these areas have been declared as "Protected Landscape of the Region of Murcia" (Law 4/92, Planning and Land Protection Region of Murcia). This area has also been included in the *Catalogue of geological interesting sites of the Region of Murcia* (Arana et al. 1999). According to this catalogue, Gebas is interesting from a national and international point of view, and therefore, it can be used with scientific, educational and tourist purposes.

Conclusions

In the Region of Murcia, 14.63% of the area is occupied by badlands and badland landscapes, which normally coincide with Quaternary Neogene basins. These basins are characterized by having an advanced state of excavation and the evacuation of their sedimentary deposits. The current drainage, hierarchized and chanelled by rivers and watercourses (Mula River, Chícamo River, Algeciras Watercourse…), affluents to the Segura River, has emptied and is still emptying the depressions of the marl and clay materials which used to fill them. The unimportance of materials, the arid climate features supported by the Region of Murcia, together with the poor vegetal cover and, frequently, the inadequate agricultural practices, have formed these landscapes where erosion rates are very high.

It is important to highlight the landscape importance that badlands have on the landscape in the Region of Murcia, as some of them have been declared Protected Landscapes, such as the badlands "Los barrancos de Gebas".

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