Minor Forms in a Badlands Landscape Framework

J.L. Díaz-Hernández[(1)], J. Yepes[(2)], A. Romero-Díaz[(3)]

(1) IFAPA, Junta de Andalucía, Granada (Spain). E-mail: josel.diaz@juntadeandalucia.es

(2) Dpto. Ingeniería Civil, Universidad de Las Palmas (Spain). E-mail: jyepes@dic.ulpgc.es

(3) Dpto. Geografía, Universidad de Murcia (Spain). E-mail: arodi@um.es

ABSTRACT

We describe and classify some medium-scale erosional morphologies in badlands areas. They have been categorized in three different types: A) Surficial forms on horizontal surfaces (soil surface crusts, cracks, popcorn) and walls ("slips", pseudo-stalactites). B) Punctual fingerprints: rain impact and micro-collapses (dimples). C) Ruiniform morphologies (caves, shelters, residual pinnacles). The A-type shapes are caused by damping-desiccation phenomena on clayey soils; morphologies on walls are due to laminar runoff on weak lithologies (clay, loam), also dubbed pseudo-speleothemes. Their scale is centimetric-decimetric. B-type forms may be an external passive process (impact) or an internal dynamic process (dimples) occurring in granular sediments inside shelters, in conditions of apparent calm, measuring up to a few centimetres. The caves and shelters of type C generally involve an excavation following stratification or jointing planes, while the residual pinnacles are vertical forms linked to advanced piping and fluting. Both forms are decametric in scale.

Key words: Badlands, slips, dimples, micro-collapses, pinnacles.

INTRODUCTION

The Guadix-Baza basin is located in the Betic cordillera (SE Spain). Most of the lithologies in this badlands region are weak materials: marl and silts in the Guadix sector, gypsum-bearing marl in the Baza part (IGME, 1973-1999). The sediments lie horizontally, but locally blocks are tilted due to the high activity of the Cadiz-Alicante fault (Estévez et al., 1978). These badlands present specific medium-scale morphologies that we could call minor because, even though they are characteristic of these areas, their impact on badlands development is secondary and they depend on the main processes. Although there are references to some of these forms, some are confused and others unknown, which we hope to clarify by the systematic classification presented here.

GEOMORPHOLOGICAL PATTERN

The climate of the basin is semiarid hot in summer, with frequent frosts in winter. Mean annual precipitation is about 250-300mm in the central part and about 400mm in the higher fans located along the mountain fronts. Rainfall occurs mainly during the autumn-winter months; in summer rain is scarce and falls in a few, short storms. The mean annual temperature is 15°C. The rocky relief surrounding the Guadix-Baza depression coincides partially with the Atlantic-Mediterranean divide. The depression is characterized by having elevations ranging from 1500m a.s.l. on the edges to 650m a.s.l. at the Guadiana Menor River. The area occupied by badlands and floodplains of the main rivers represents approximately half of the basin.

Semi-arid badlands are usually quite old, with alternate phases of stability and instability (Calvo et al., 1991; Nogueras et al., 2000). Wise et al. (1989) proved that archaeological structures had survived 4000yr on the surface of badlands landscapes in SE Spain. Díaz-Hernández and Juliá (2006) found that the incision phase (or main modelling) of the badlands in this depression took place within the 115,000-48,000yr range (within Interstadial 13-24 of the Greenland GRIP ice core). Erosion processes controlling badlands development are mainly rainsplash, piping and mass movements, assuming the pre-installation of two main piedmont (glacis) surfaces (Romero-Díaz, 1989; Díaz-Hernández and Juliá, 2006).

MINOR FORMS

These can be classified into three different types: A) Surficial forms, B) Punctual fingerprints and C) Ruiniform morphologies.

A) Surficial forms. These morphologies are mud recoveries that were water-dependent at some point in their formation. In general they involve: i) a colloidal phase formed by rainwater and fine sediments (clays, silts) with plastic behaviour; ii) consolidation on a surface through evaporation; iii) a physical process (movement) linked to the mud phase. They are found on horizontal and vertical surfaces.

Horizontal surfaces: Soil surface crusts are relatively thin (<5cm), dense, rather continuous layers of non-aggregated soil particles on exposed soil surfaces. Structural crusts develop when a sealed-over soil surface dries out after rainfall. Water droplets striking soil aggregates and water flowing across soil break aggregates into individual soil particles. Fine soil particles wash, settle into and block surface pores causing the soil surface to seal over and preventing water from soaking into the soil. As the muddy soil surface dries out, it crusts over. Cracks (Fig. 1a) represent advanced stages of mud desiccation on the soil surface with a characteristic polygonal shape. Popcorn textures (Fig. 1b) are the result of repeated shrink/swell cycles, producing marble-sized pellets, in a similar way to mud cracking as it dries. These forms show progressive soil destructuring.

Vertical surfaces: “slips” (Fig. 1c). These forms are often linked to pipes and consist of a mud coating ranging from millimetres to several centimetres thick. They represent epidermic colloidal outflows of plastic consistency that slid slowly from the top of the scarps to the base, causing masking of the substratum. When dry they can detach and fall to the ground. In some shelters they partially cover the ground in the form of drips from the wall. Pseudo-stalactites (Fig. 1d) are an advanced stage of the previous form that can reach several decimetres in length. In general, they presuppose “slips”, of which they are enlargements in overhang situations, free of obstacles in the direction of growth. These morphologies require colloidal suspension to overcome the Atterberg liquid limit (semi-fluid consistency).

B) Punctual fingerprints. These morphologies are gravity-dependent at some point of formation. We have observed two main types:

Raindrop fingerprints (Fig. 1e), caused by raindrop impacts on fresh mud. These shapes are an indicator of the irregular rain regime. After copious rain small ponds are produced where mud forms; after evaporation, another very short rain episode occurs, often with large raindrops falling on the fresh mud. These forms may reach up to around 1cm, with frequent scarped edges.

“Dimples” (Fig. 1f). These dainty forms are inverted hollow cones appearing inside shelters. They need stable situations, with no exposure to water flow, rain impact or animal traffic. They have been observed on uncemented granular substrata, reaching several centimetres thickness. Their genesis is linked to the detachment of particles inside the shelter, mainly

from the walls, but also from the roof. These particles fall to the ground and cover it chaotically, forming a stacked playing-card structure with many hollows, implying a high degree of instability. The weight of several centimetres of built up particles breaks the internal equilibrium between particles, causing these shapes through collapse. The dimensions can be enlarged by successive collapses or by coalescence of neighbouring "dimples".

C) Ruiniform morphologies are destructive forms involving an advance of the erosional stage by breakage of the previous structure. We can establish three main types requiring excavation in the original sediment: caves, shelters, and pinnacles.

Caves and shelters (Fig. 1g). These forms are often restricted to discontinuity joints (stratification, fractures). Such weakness planes facilitate the progressive loss of material when one of the two faces of the discontinuity is poorly consolidated. The principal agents forming these morphologies are weathering by temperature change, and wind and water action. In these caves the most frequent shapes are "dimples" on the ground, while the outer walls present "slips". The main difference between caves and shelters is depth with caves in the Guadix-Baza basin usually around 10m deep.

Pinnacles (Fig. 1h) appear in areas with piping or fluting as a result of the coalescence of neighbouring pipes. Consolidated layers of original sediment can remain on the top of these pinnacles. The slimmest pinnacles observed can reach about 15m in height.

CONCLUSIONS

We present a systematic classification of morphologies in a badlands landscape, some of them unnoticed until now. Forms on vertical surfaces and ruiniform shapes are karst-like, while the "dimples" formed on unattached materials by micro-collapses are more specific and require quite different processes such as gravitational breakdown of particles stacked on playing-cards structures.

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Figure 1. Minor forms in the badlands of Guadix-Baza basin. A) Surficial forms: Horizontal surfaces (soils): Cracks (a), Popcorns (b); Vertical surfaces (walls): Slips (c), Pseudo-stalactites (d). B) Punctual fingerprints: Raindrops fingerprints (e); Microcollapses ("dimples") (f). C) Ruiniform morphologies: Caves and Shelters (g), Pinnacles (h).