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Erosion and stabilisation sequences in relation to base level changes in the El Cautivo badlands, SE Spain

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ABSTRACT

The complex multiple-age badlands at El Cautivo are cut in upper Miocene marls of the uplifted and dissected Tabernas Basin, Almería, in semi-arid SE Spain. Previous work identified six episodes of erosion and subsequent stabilisation, with ages ranging from the late Pleistocene to the present day. This paper uses newly-acquired digital elevation models, orthorectified aerial photographs, and field survey data to illustrate the development sequence of a series of gullies which drain into the Rambla de Tabernas. Changing drainage directions and phases of incision and stabilisation are related to the filling and subsequent dissection of the Tabernas lower lake sediments, differential material strengths, changing process mixes on hillslopes and, in more recent times, land-use changes.

We propose that the erosional phases differed considerably in both time-span and depth of incision. A long period of stability during the existence of the lake led to extensive pediment development in the area. Subsequent incision into the lake sediments by the Rambla de Tabernas produced a limited amount of localised pediment incision in the tributary catchment. Subsequent aggradation occurred in the lower reaches of gullies when incision by the Rambla de Tabernas reached the underlying bedrock. Following incision through the lip of the lake the Rambla de Tabernas cut rapidly into the bedrock leading to an altered drainage direction in the tributary catchments and the major phase of badland development visible today. Stabilisation of the pediments and some of the north-facing slopes occurred subsequently. Increased sediment loads, caused by climatic shift, a change in land use, or both, gave rise to a later phase of valley fill in the gullies. The modern channels have reduced this fill to isolated terrace benches and there are also localised remnants of a lower, more recent fill.

Whilst supporting the general interpretation of the site's development by Alexander et al. [Alexander, R.W., Harvey, A.M., Calvo, A., James, P.A., Cerda, A., 1994. Natural stabilisation mechanisms on badlands slopes: Tabernas, Almería, Spain. In: Millington, A.C., Pye, K. (eds.), Environmental Change in Drylands: Biogeographical and Geomorphological Perspectives. Wiley, Chichester, pp 85–111.], this re-analysis highlights the importance of changing drainage direction to the pattern of landform development and attempts to assess the magnitude and overall rate of incision.

1. Introduction

Process-form relationships are at the heart of much geomorphological enquiry. Geomorphology has made significant and successful efforts in relating landscape forms to the operating processes, as well as in the identification of the processes that, at different times, are responsible for these forms. Another key aim of geomorphology is to discover the speed at which landscapes change. The usual slow rate of operation of many processes in relation to the human lifespan, and the complexity of process interactions in space and time as a consequence of environmental changes or the occurrence of intrinsic thresholds, have created the need for landform comparison at different points in their evolution in order to assess the rate of change. In most places the only way to study this is by the ergodic approach or the analysis of present-day landforms that in different places have different ages; for example, Savigear (1952) and Calvo-Cases (1987), both studying paleosea-cliff retreat, give good examples of this assumption and an idea about the magnitude of the changes over time. In other cases, mathematical models and laboratory and computer simulations have been used in order to develop and test theories concerning landform development. Badlands have been seen as an environment where processes operate with sufficient speed to study their development by

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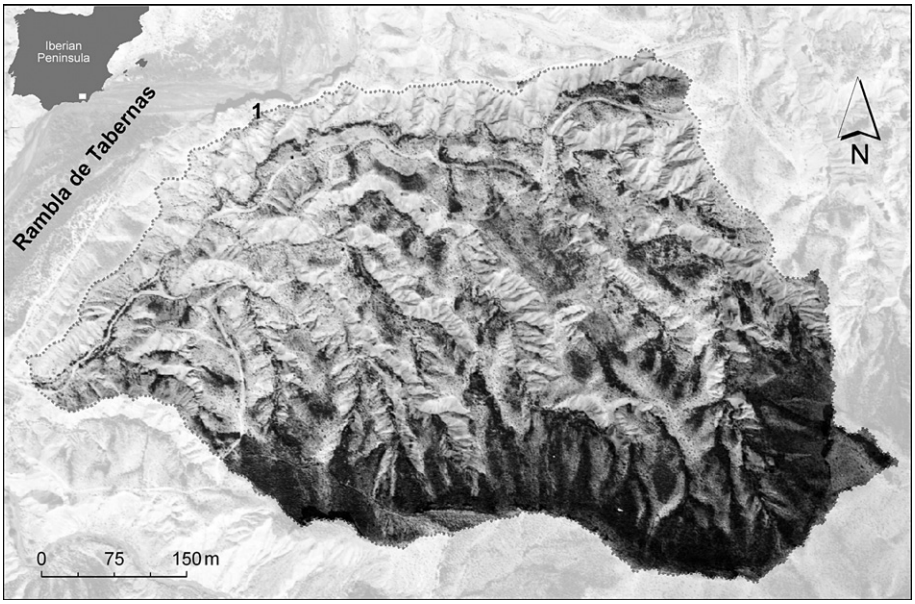

Fig. 1. Location map and orthophoto for El Cautivo Badlands catchment (Point 1, see Fig. 8).

direct measurement, and thus they have often been used as natural laboratories (Campbell, 1997). Despite the apparent rapidity of their development dominated by overland flow processes (Bryan and Yair, 1982), many badlands sites show considerable complexity of process interactions (Harvey and Calvo-Cases, 1991; Harvey, 2002) changing over time in response to both intrinsic and extrinsic factors (Faulkner, 2008-this issue).

Badlands may be unconnected to a drainage system at their base and thus develop independently of the base level, or they may be connected to a drainage system (Howard, 1997, 1999; Harvey, 2002) and thus respond to fluctuations in base levels. In the latter case development may be driven from below with erosion being (re-) activated in response to a lowering of base level and aggradation occurring when base level rises. Whilst badlands do have a role to play as microcosms or analogues for larger, more slowly evolving landscapes, a thorough understanding of badland development and form requires the study of their spatial context. This study can benefit considerably from the use of digital data to simulate and model landscape development over longer time periods.

The high sensitivity of badlands, their response with relative rapidity to changes in both intrinsic and, particularly, extrinsic controlling factors, and the consequential changes in process suites, leave evidence of the old forms in the landscape from which reconstruction can be attempted. The El Cautivo badlands near Tabernas in Almería, SE Spain (Figs. 1 and 2) represent an example of such a situation. They contain a series of remnant surfaces that represent earlier phases of stability during the episodic erosion of the area. Fluctuating base levels in particular, have caused a switch between phases of incision and stabilisation with the incision phases frequently being too short to erode the whole area. Work at the site in the early 1990s (Alexander et al., 1994), identified six stages of episodic

Fig. 2. General view of El Cautivo Badlands area.