Earth-Science Reviews 172 (2017) 27–42

Contents lists available at ScienceDirect

Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

From the semiarid landscapes of southwestern USA to the wet tropical zone of southeastern Brazil: Reflections on the development of cuestas, pediments, and talus

Marcos Roberto Pinheiro*, José Pereira de Queiroz Neto

Laboratory of Pedology, – Department of Geography, - Faculty of Philosophy, Languages and Literature, and Human Sciences, - University of São Paulo, Brazil. Avenida Prof. Lineu Prestes, 338. Cidade Universitária. São Paulo. CEP: 05508-080, - Caixa Postal: 72042, Brazil.

ARTICLE INFO

Keywords:
Cuesta landform
Pediment
Talus
Correlative deposit
Quaternary

ABSTRACT

Classical geomorphological models consider that escarpment retreat of cuesta landforms is fastest in arid and semiarid regions, which would be expected to lead to increased talus production. However, this is in disagreement with the piedmont zone of the Colorado Plateau cliffs (arid/semiarid region of southwestern USA), where talus is as inconspicuous as the deposits of the cuesta escarpment footslopes of the Parana Basin (wet tropical region of southeastern Brazil). Thus, this paper discusses the evolutionary processes of cuesta escarpments, pediments, and piedmont deposits in both wet tropical regions and arid zones, considering the key areas of the Serra Geral Ridge in the Parana Basin and the eastern central Colorado Plateau as examples. This manuscript constitutes a comprehensive and critical review of the principal literature on the landform development of such regions. Research has revealed that despite the production of sediment (fine–coarse) from the escarpments in the arid southwestern USA, geochemical weathering and freeze–thaw cycles quickly destroy talus deposits. Furthermore, chemical weathering dissolves minerals and forms caverns within the rock walls of mesas and in amphitheaters and canyons, influencing escarpment retreat directly, despite mechanical processes being the most important factors controlling landform development. On the other hand, in regions characterized by the wet tropical climate of Brazil, geochemical processes are more intense and they destroy the talus very quickly, enhancing deep weathering. However, mechanical morphogenesis is also frequent in such regions, forming, in deforested areas, features very similar to those found in the badlands of dry zones. Chemical and physical/mechanical processes have very different intensities in dry/arid and wet/tropical areas, but these processes are very relevant to landform development in both environments. The rates of escarpment retreat are higher in the dry areas of the Colorado Plateau than estimated for the Brazilian tropical zones, which is in accordance with classical models. These variations are probably related not only to climate but also to lithological differences; the tops of the mesas on the Colorado Plateau are supported by thin strongly cemented conglomeratic fluvial sandstones, whereas the caprocks of the Brazilian cuesta landforms comprise thick basalt flows capped by ferruginous cuirasses. In some cases, lithological characteristics are more important than climate regarding escarpment retreat.

1. Introduction

Cuestas are asymmetric landforms characterized by a scarp along the plateau front and a gentle backslope (Fig. 1), and they are formed in areas with gently dipping rocks (Goudie, 2014), as found on the edge of homoclinal sedimentary basins (Penteado, 1983). The origin of cuestas is classically attributed to differences in the resistance of rocks (i.e., Davis, 1899; De Martonne, 1940; Büdel, 1957; Derruau, 1970), whereby the backslope of the landform is maintained by a layer of resistant rock (cap rock) and the lower zones comprise weaker rocks. However, some researchers have considered that cuestas might also be influenced by tectonics (Tricart, 1949; Demangeot, 1961; Pinheiro, 2014).

Cuestas are one of the most important structural landforms in the world because they occupy large areas in very different geotectonic, lithostratigraphic, and climatic contexts. For example, they can be found in the Ebro Basin in Spain (Gutiérrez et al., 1998), the Adriatic area of central Italy (Buccolini et al., 2007), the Bandiagara region of Mali (Aghassy, 1970), the central MacDonnell Ranges in Australia (Twidale, 2007), the Paris Basin in France (Fort and André, 2014),

* Corresponding author.
E-mail addresses: m3279574@usp.br (M.R. Pinheiro), jpqneto@outlook.com (J.P.d. Queiroz Neto).

http://dx.doi.org/10.1016/j.earscirev.2017.07.005
Received 3 September 2016; Received in revised form 4 July 2017; Accepted 12 July 2017
Available online 14 July 2017
0012-8252/

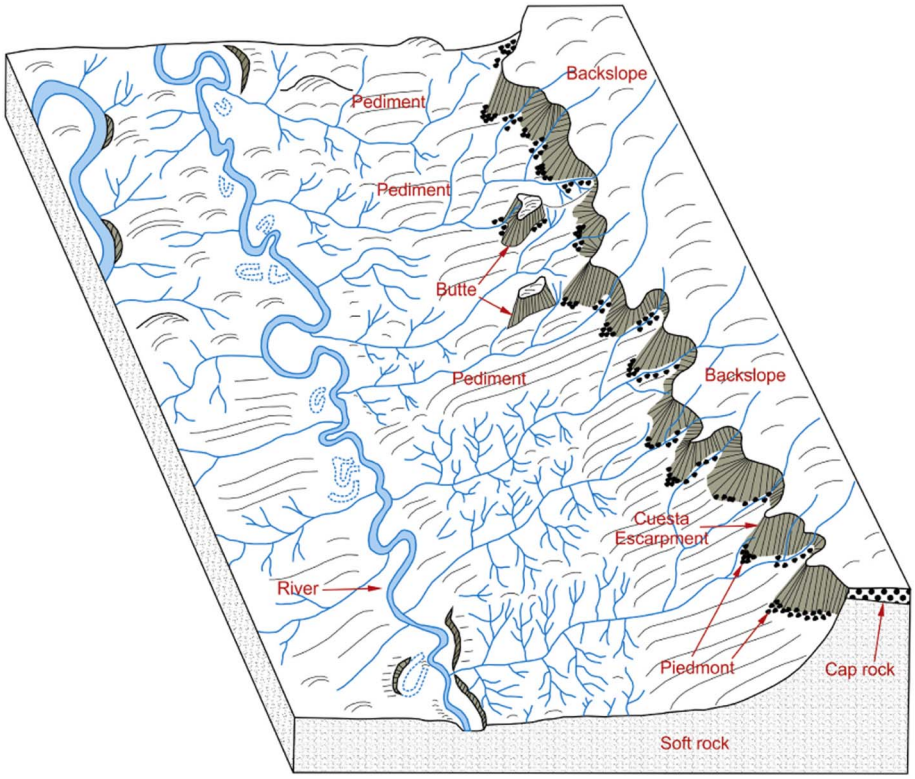

Fig. 1. Example of a typical cuesta landform.

Patagonia in Argentina (Ross, 2016), the Colorado Plateau in the USA (Schumm and Chorley, 1966; Schmidt, 1985, 1988, 1989, 1996), and the Parana Basin in Brazil (Almeida, 1949, 1964; Ab'Saber, 1965; Penteado, 1976; Melo, 1995; Pinheiro, 2014; Pinheiro and Queiroz Neto, 2014, 2015, 2016). Despite the classical asymmetric profile of these and other cuestas, these landforms have important differences related to the specific natural characteristics of each region.

Generally, the front of a cuesta escarpment is characterized by pediments (Fig. 1), which are zones of lower elevation composed of smooth and elongated hills whose tops are gently convex. This term was used originally by Gilbert (1877), who defined pediments as erosional surfaces sculpted in weak rocks. The author admitted the possibility that pediments could have a sedimentary cover, the source of which would have been the higher and steeper zones composed of rocks with greater resistance. According to Gilbert (1877), pediments are not exclusively geomorphological features of a specific landscape. However, they are generally associated with semiarid and arid climates (Bigarella et al., 1965; Oberlander, 1997; Bigarella, 2003; Gutiérrez, 2013), despite records of their occurrence in tropical regions (Rodhenburg, 1982; Embrechts and De Dapper, 1987; Storani and Perez Filho, 2012, 2015).

The evolution of cuesta escarpments is related to the combined action of many factors including climate, lithology, stratigraphy, and structural setting. The role of each of these factors varies depending on context, but climate retains a very important role in all scenarios. It influences vegetation and it controls landform development not only by fluvial dissection but also by weathering (physical and chemical), as well as via landslides and erosional processes.

In this context, following the principles of King (1953) regarding landform evolution, which have formed the basis of many studies performed in Brazil and Africa (i.e., Bigarella et al., 1965; Ab'Saber, 1965; Penteado, 1968, 1976; Coutard et al., 1978; Mabbutt, 1977; Bigarella, 2003), a dry climate would be expected to cause planing and parallel retreat of hillslopes (Fig. 2). In cuesta regions, this process would cause escarpment retreat and increases of the pediment area and talus production. If the climate became wet, talus production from the escarpment would decrease and vertical incisions by rivers would be accelerated. This in turn would cause carving of the pediments, talus, and fluvial deposits and the formation of fluvial terraces. Climate oscillations would also create other particular traces in the landscape, such as the talus flatirons, which record the previous positions of the escarpment footslopes. This process has been recorded on the Colorado Plateau in the USA (Schmidt, 1985, 1989, 1996) and in the Ebro Depression in Spain (Gutiérrez et al., 1998), both under the present-day semiarid climate.

According to these classic principles of geomorphology, we would expect an increase of talus in areas under arid or semiarid climates, and a less common presence of such piedmont deposits in areas with tropical climate. However, these considerations contrast with observations of the cuesta landforms of both the Parana Basin in wet, tropical southeastern and western central Brazil and the Colorado Plateau in the semiarid area of the western USA. Despite existing ideas, talus deposits are rare. In this context, the aim of this paper is to discuss the evolutionary processes of cuesta escarpments, pediments, and piedmont deposits in both wet tropical areas and dry zones. For this purpose the characteristics of two key areas will be present: the São Pedro and Itaqueri ridges (regionally named the Serra Geral Ridge) in the Parana Basin, and the eastern central Colorado Plateau (in the region of the Monument Valley Navajo Tribal Park and nearby regions). This paper comprises a comprehensive critical review of the most important literature regarding the landform development of these areas.

2. Geological, geomorphological, and paleoenvironmental context

2.1. The Colorado Plateau and the Monument Valley region

The Colorado Plateau (Fig. 3) is the main tectonic and physiographic unit of the southwestern USA and it covers an area of 3.5×10^5 km^2. It was considered relatively stable during most of the Paleozoic and Mesozoic, suggesting that the general Cenozoic plateau structure would be an inherited feature (Morgan and Swanberg, 1985) and that the area was preserved as a relatively rigid block resistant to