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Paleoenvironmental evolution of southern South America during the Cenozoic

E. Ortiz-Jaureguizar*, G.A. Cladera

Laboratorio de Biogeografía Histórica y Macroecología (BIOMA), Museo Paleontológico "Egidio Feruglio", Fontana 140, U9100GYO Trelew, Argentina

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Abstract

Southern South America (SSA) has today a high diversity of climates, environments, biomes, and biotas, as a result of the complex interaction through time of plants and animals with the geological forces (e.g. plate tectonics, sea-level changes, glaciations) that modulated the geography of the continent. Arid biomes are well represented in SSA today, but were arid biomes similarly important in the geologic past? How long in time can be found major arid biomes in SSA? With the aim of replaying these questions, in this paper we summarized the paleoenvironmental changes of SSA through Cenozoic, emphasizing the relationships between biomes and the geological forces that, through different climatic-environmental factors, have driven its evolution. We define SSA the south of the 15°S area. We prefer this geographical delimitation because with it we can see and follow the history of the biogeographic (historic and ecologic) relationships of Patagonian biota with the rest of the South American biota. Additionally, with this delimitation we possess the most complete Cenozoic South American land-mammal fossil record. We use biomes because biomes are taxon-free analytical units, and their pattern of change can be traced through time independently of the taxa present at different geological periods. Data on plate tectonics, volcanism, sea-level changes, marine paleotemperatures, and glaciations were taken from literature. To analyse the pattern of change of southern South American climates and environments through the Cenozoic, we used the fossil record of land-mammals as information source. When available, the record of vascular plants were used to contrast the inferences derived from land-mammals. Finally, we used standard geologic divisions (i.e. Epochs) as chronological units. The main conclusion of this paper is that from Early Paleocene to Late Pleistocene, southern South American climatic conditions changed from warm, wet, and non-seasonal, to colder, dryer, and seasonal. Concomitantly, biomes changed from tropical forest to steppes, across a sequence constituted by subtropical forests, woodland savanna, park-savanna, and grassland savanna. During the Quaternary, and as a consequence of glacial cycles, cold and dry conditions were interrupted by warmer and wet periods. Accordingly, several pulses of expansion

*Corresponding author. Tel.: +54 2965 43 2100; fax: +54 2965 42 0012.
E-mail addresses: eortiz@mef.org.ar (E. Ortiz-Jaureguizar), gcladera@mef.org.ar (G.A. Cladera).

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and retraction of steppes (and, concomitantly, advances and retreats of the northern tropical forests) are recorded. This cyclic pattern of changes produced the provincialism that has characterized the South American biota from Early Pleistocene to the present.

Keywords: Paleoecology; Paleoclimatology; Paleogeography; Fossil land-mammals; Paleoflora; Biome evolution; Andean orogeny; Sea-level changes; Glaciations

1. Introduction

Southern South America (SSA) has today a high diversity of climates, environments, biomes and biotas. For example, 15 of the 24 biogeographic provinces (Cabrera and Willink, 1980), and 10 of the 11 biomes, recognized for the entire continent, are found in SSA (Dinerstein et al., 1995; Olson and Dinerstein, 2002). This complex mosaic is the result of the interaction through time of plants and animals with the geological forces (e.g. plate tectonics, sea-level changes, glaciations) that modulated the geography of the continent.

A high diversity of tropical, highland, coastal and continental arid biomes (e.g. montane grasslands, Mediterranean scrubs, desert and xeric shrublands; see Roig-Juñent et al. Fig. 2, 2006) can be found in SSA today. But, were arid biomes similarly important in the geologic past? How long in time can be found major arid biomes in SSA? With the aim of answering these questions, in this paper we summarized the paleoenvironmental changes of SSA through Cenozoic, emphasizing the relationships between biomes and the geological forces that, through different climatic-environmental factors, have driven its evolution.

2. Conceptual and methodological framework

The term "southern South America" has not a unique definition. For example, Crisci et al. (1991) define SSA as the area south of 30°S, plus the Andean highlands north of 30°S. This definition is based on the geographical distribution of 27 arthropods and vascular plants, and according to the authors, is consistent with the biogeographic schemes of Kuschel (1969), Takhtajan (1986) and Humphries and Parenti (1986). On the other hand, Dinerstein et al. (1995) define SSA as the bioregion that comprises 10 ecoregions: Southern Andean steppe, Patagonian steppe, Patagonian grasslands, Argentine Monte, Argentine Espinal, Pampas, Uruguayan savannas, Chilean winter-rain forests, Valdivian temperate forests, and Subpolar *Nothofagus* forests (see also Map 1 in Dinerstein et al., 1995). According to these authors, a bioregion is a geographically related assemblage of ecoregions that share a similar biogeographic history and, thus, have strong affinities at higher taxonomic levels (e.g. genera, families).

The concepts of Crisci et al. (1991) and Dinerstein et al. (1995) have in common the biogeographic history, despite differences in the extension of what each consider SSA. Still, both papers are based on living taxa, while fossils and geologic time are not considered. When groups with good fossil records (e.g. mammals) are included in the analysis, biogeographic differences about areas become less clearly delimitated. For example, living platyrrhines are recorded today in the northern part of SSA, while fossils are recorded in Patagonia from Oligocene to Middle Miocene; or polydolopids, an extinct group of small marsupials, have been recorded during Late Paleocene close to Sao José de Itaboraí