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Consensus between genes and stones in the biogeographic and evolutionary history of Central America

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ABSTRACT

Results from genetic and geologic studies can be combined to elucidate some general patterns of the biogeographic and evolutionary history of Central America (CA) and of its biota. Based on an ample review of geologic, biogeographic and genetic studies, our aim was to examine how common genetic patterns can be linked with geologic processes. Considering information about geologic and tectonic evolution of CA, we subdivided the region into four tectonic blocks: Maya, Chortis, Chorotega and Chocó. Species exchange between North/South America and CA encompasses three events: a first migration during the Late Cretaceous–Early Paleocene, a second through a terrestrial corridor preceding the formation of the Isthmus of Panama (IP), and the third involving a major dispersion through the IP. Such events caused similar genetic differentiation patterns and left a signature on the diversification of extant taxa, which we propose as three evolutionary groups: 1) Mayan, characterized by marked genetic structure and divergence, multiple refugia and formation of cryptic species; 2) Mid-CA, defined by high differentiation at the population level and between highland and lowlands, associated with intense volcanic activity; 3) Panamian, distinguished by migration from north to south and vice versa via de IP, with markedly high species divergence and speciation.

Introduction

Central America is considered an outstanding region for the study of biological processes like speciation, extinction and diversification of flora and fauna, mainly because of its intricate geologic and biogeographic history, diversity of habitats and dynamic climatic and tectonic history (Cavers et al., 2003; Iturralde-Vinent, 2006; Daza et al., 2010; Gutiérrez-García and Vázquez-Domínguez, 2012). The increase of available genetic and phylogeographic information of a diverse array of taxa from this region, particularly from the Pliocene and Pleistocene, has helped decipher and date genetic and evolutionary processes associated with geological events. These studies have shown how the region's geologic and climatic history over the past several million years caused similar patterns of genetic differentiation for complexes of resident and/or migrant fauna (Daza et al., 2010). However, despite the association of the genetic results with the geology of the region, very few include a thorough description of the geological processes. Both genetic and geologic information are key for the understanding of historical patterns and processes that have shaped the diversification of species (lineages) at different spatial and temporal scales.

Based on the review of different studies and on our own data, it became evident that the common genetic and phylogeographic patterns of different taxa from this region correspond to large spatial and temporal scales, and consequently the evolutionary patterns identified are associated with geologic factors and processes corresponding to such scale (e.g., geomorphology, topographic barriers, volcanic chains, volcanic activity, large-scale climatic changes, intermittent connections, corridors). Factors that act at finer scales are related with the biota's life-history characteristics and it is only possible to associate them with evolutionary processes on a case-by-case basis and not as a general assessment. Hence, we believe that a thorough review, in which common genetic and phylogeographic patterns are highlighted and the interacting role of geologic factors is underlined, can help elucidate general patterns of the region's evolutionary history. Moreover, Quaternary researchers and readers from both biological and geological disciplines will benefit from gaining knowledge of how geologic information can be linked to other fields of study and also by the awareness of the current gaps in the study of the relationship between Central America geology, genetics and evolution.

The aim of this review is to examine how common genetic and phylogeographic patterns in Central America can be more thoroughly linked with geologic processes, for a more comprehensive understanding of the history of this region and the evolution and diversification of its biota. Most genetic information has been described for the Holocene onwards, and more specifically for the Quaternary. We

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start with a brief summary of the origin and development of Central America as a bridge connecting two landmasses (North and South America), based on different geologic and biogeographic studies, and describe the main geological events that ultimately affected the biota of the region. We next integrate information from a variety of systematic, phylogeographic and population genetic studies from different taxa, encompassing from the emersion of the region as a group of islands during the Miocene until the present, with emphasis on the Quaternary, to depict how some genetic and geological processes are linked in the evolutionary history of species. We do the latter by emphasizing the role of the corresponding large-scale geologic factors and briefly describe why others are less highlighted. Importantly, we show that there is an emerging pattern of differentiation, in which three main evolutionary groups can be linked to specific geological barriers such as mountain and volcanic chains, isthmuses and fault systems.

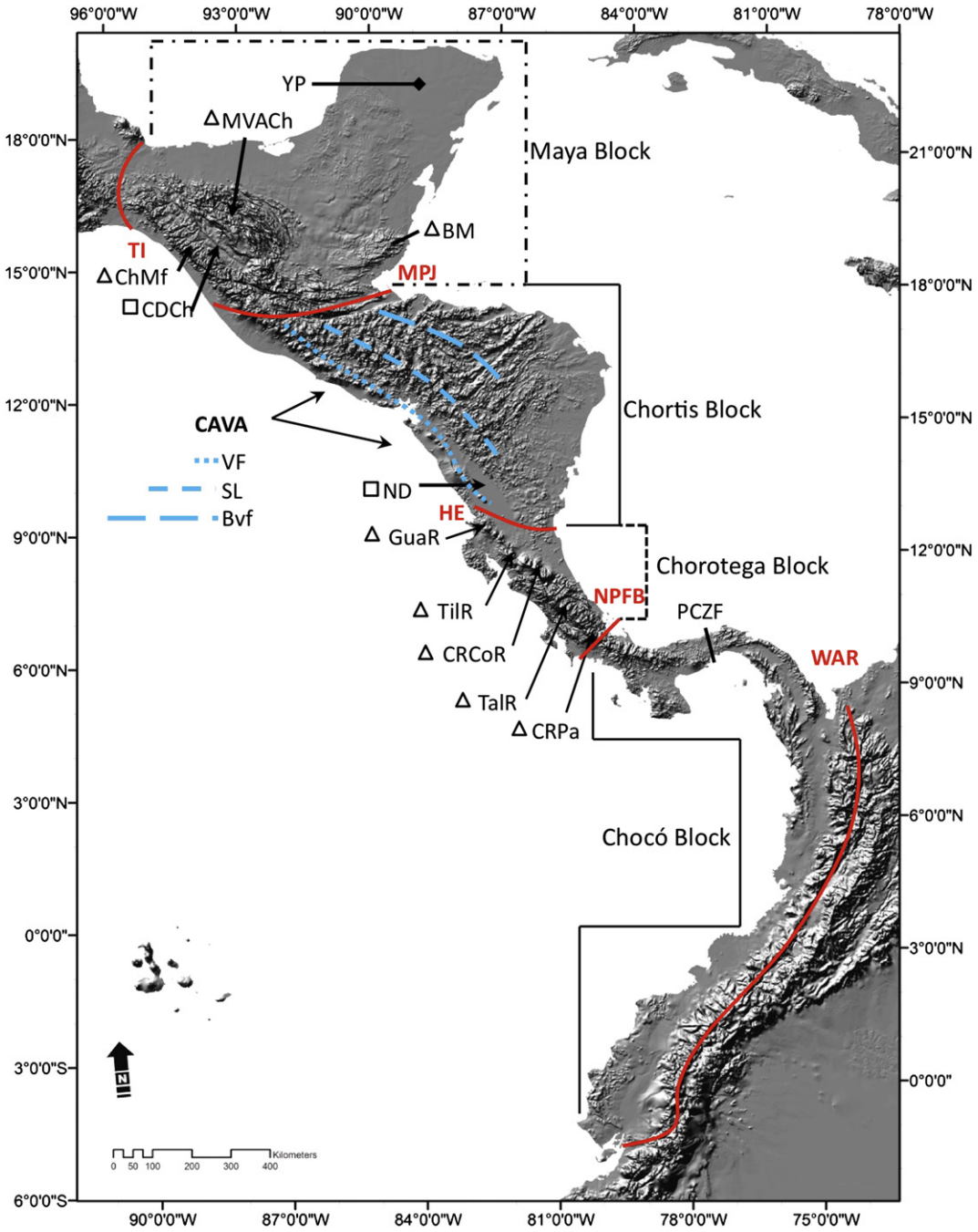

Figure 1. Summary of Central America's geology as used throughout the text, where main geological blocks, delimited by geological barriers, are shown. Abbreviations correspond to: BM = Belize mountains, CAVA = Central America volcanic arc, CDCh = Central depression of Chiapas, ChMf = Chiapas massif, CRCoR = Central range of Costa Rica, CRPa = Central range of Panama, GuaR = Guanacaste range, MVACh = Modern volcanic arc of Chiapas, ND = Nicaragua depression, PCZF = Panama channel zone fault, TalR = Talamanca range, TilR = Tilarán range, YP = Yucatan platform. Dashed (blue) lines indicate the three lines along the CAVA: Bvf = Behind the volcanic front, SL = Secondary line, VF = Volcanic front. Solid (red) lines depict the geological limits between each block, from north to south: IT = Isthmus of Tehuantepec, MPJ = Motagua–Polochic–Jocotán fault system, HE = Hess escarpment, NPFB = North Panama fracture belt, WAR = Western Andes range. Triangles indicate mountain ranges and squares depression areas and valleys.