Patterns of recent deformation of the western Maracaibo block, northern Colombia and western Venezuela, based on integration of geomorphic indices with regional geology

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Abstract

The Maracaibo block is a triangular, continental tectonic terrane that includes two isolated Andean ranges of northern Colombia and western Venezuela: the Sierra de Santa Marta Massif (SSMM; maximum elevation 5700 m) in the west and the Perija Range (PR; 3600 m) to the east. The Cesar-Rancheria Basin (CRB) is an intermontane basin that separates the two ranges. To establish patterns of recent deformation of this elevated region and to infer its tectonic mechanism, we have integrated the following results: (1) analysis of 350 stream profiles and calculations of geomorphic indices, including stream length-gradient(SL) index, ratio of valley-floor width to valley height (VF), and hysometric curves for 20 watersheds in both ranges and (2) interpretation of three seismic reflection profiles within the CRB and adjacent areas. We determine that the northeastern part of the SSMM is tectonically quiescent based on its concave stream profiles, low geomorphic indices, and few vertical-step knickpoints. In comparison, we find that the central, southern, and eastern parts of the SSMM show tectonic uplift and recent fault control based on slope-break knickpoints and values in steepness and geomorphic indices with possible additional controls from lithologies of varying erosional resistance. Correlations between steepness, SL indices, slope-break knickpoints, and topographic elevations of the SSMM and central PR all indicate recent deformation of these areas. We use seismic reflection profiles from the eastern part of the CRB to confirm the existence of late Quaternary faulting and folding in these geomorphologically active areas. We propose that active, southeastward shallow (approximately 10°–15°) subduction of the Caribbean plate along the base of the South American continental crust produces active crustal deformation within the southern and eastern SSMM. The central PR and eastern CRB are also being deformed by active strike-slip faults.

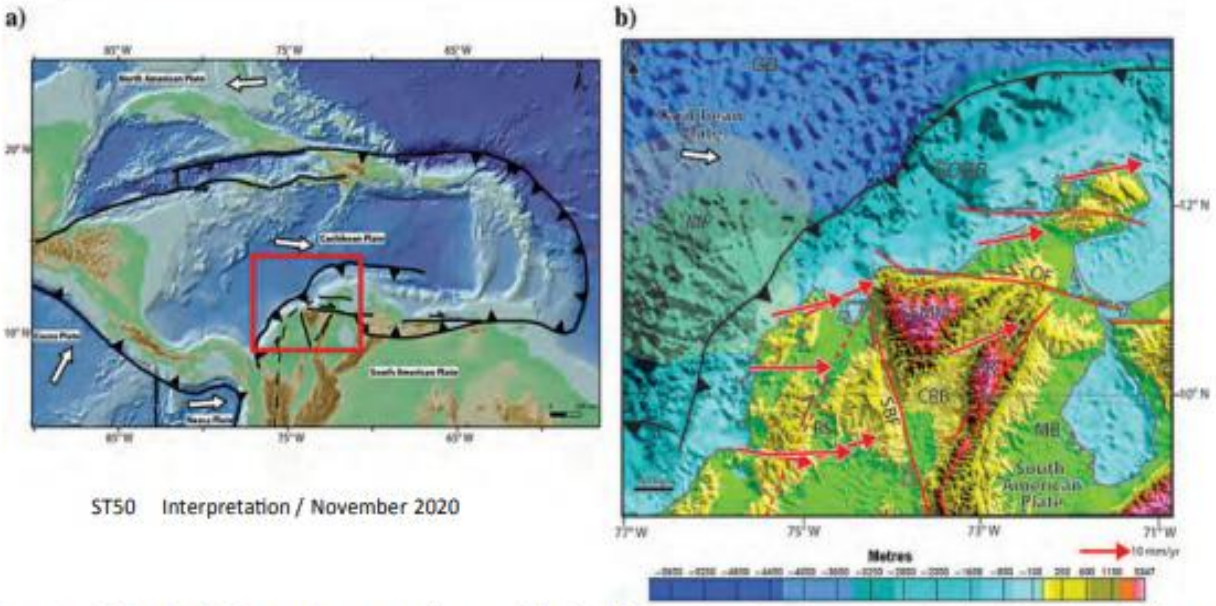

Figure 1. *(a) Regional bathymetric-topographic map of the Caribbean and northern South America showing major plate boundaries and plate motion directions. The red box outlines the area of the more detailed map of the study area in (b) of the northernmost Andes in northern Colombia and western Venezuela. The large white arrows show the directions of relative plate motion. (b) Topographic and bathymetric map of the study area (westernmost Maracaibo block) showing GPS vectors (the red arrows) relative to a fixed Caribbean plate from Calais and Mann (2009) and Mora-Páez et al. (2019); the large white arrow shows the subduction direction of the Caribbean plate relative to the South American plate. Key to abbreviations: CB, Colombian Basin; CF, Cuiza fault; CRB, Cesar-Rancheria Basin; MB, MaracaiboBasin; MF, Magdalenafan; OF, Oca fault; PR, Perija range; RS, Romeral suture; SBF, Santa Marta-Bucaramangafault; SCDB, South Caribbean deformed belt; SSMM, Sierra de Santa Marta massif; and TF, El Tigre fault.*

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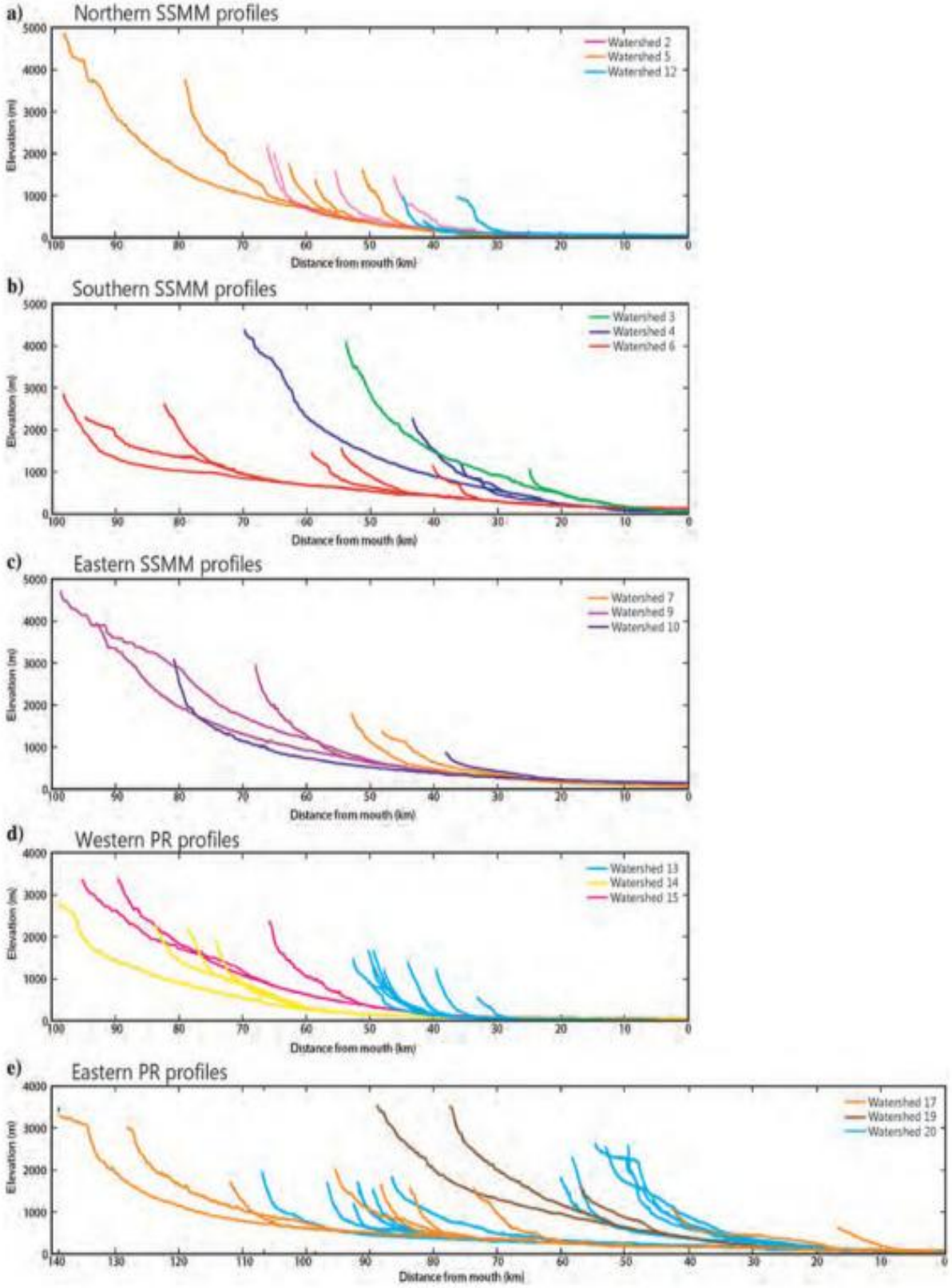

Figure 4. *Stream profiles extracted from several rivers in watersheds draining the flanks of the SSMM and PR. (a) Representative stream profiles of the northern SSMM, (b) representative stream profiles of the southern SSMM, (c) representative stream profiles of the eastern SSMM, (d) representative stream profiles of the western PR, and (e) representative stream profiles of the eastern PR.*

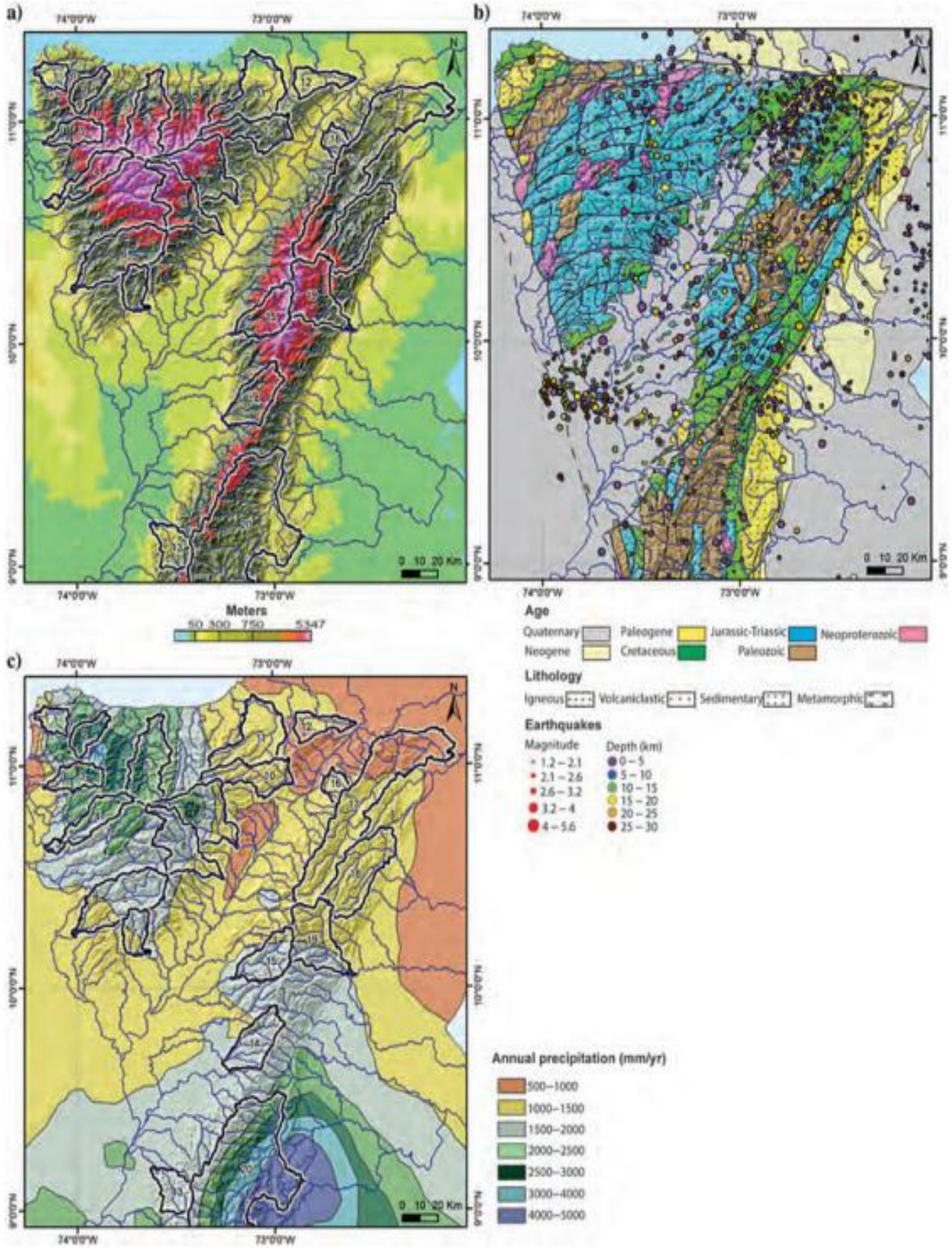

Figure 2. *(a) Topographic map of the SSMM showing all major rivers and streams and outlines of 20 watersheds (labeled 1–20) that were extracted for this geomorphic study, and (b) geologic map and shallow earthquakes (less than 30 km deep) of the SSMM (from the IRIS seismic event database: http://ds.iris.edu/ds/nodes/dmc/data/types/events/); geologic map compiled from Forero (1970), Tschanz et al. (1974), Caceres et al. (1980), Kellogg (1984), and Sanchez and Mann (2015). (c) Annual precipitation map modified from Hurtado-Montoya and Mesa-Sánchez (2014).*