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New insight on the recent tectonic evolution and uplift of the southern Ecuadorian Andes from gravity and structural analysis of the Neogene-Quaternary intramontane basins

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ABSTRACT

The sedimentary basins of Loja, Malacatos-Vilcabamba and Catamayo belong to the Neogene-Quaternary synorogenic intramontane basins of South Ecuador. They were formed during uplift of the Andes since Middle-Late Miocene as a result of the Nazca plate subduction beneath the South American continental margin. This E-W compressional tectonic event allowed for the development of NNE-SSW oriented folds and faults, determining the pattern and thickness of sedimentary infill. New gravity measurements in the sedimentary basins indicate negative Bouguer anomalies reaching up to −292 mGal related to thick continental crust and sedimentary infill. 2D gravity models along profiles orthogonal to N-S elongated basins determine their deep structure. Loja Basin is asymmetrical, with a thickness of sedimentary infill reaching more than 1200 m in the eastern part, which coincides with a zone of most intense compressive deformation. The tectonic structures include N-S, NW-SE and NE-SW oriented folds and associated east-facing reverse faults. The presence of liquefaction structures strongly suggests the occurrence of large earthquakes just after the sedimentation. The basin of Malacatos-Vilcabamba has some folds with N-S orientation. However, both Catamayo and Malacatos-Vilcabamba basins are essentially dominated by N-S to NW-SE normal faults, producing a strong asymmetry in the Catamayo Basin area. The initial stages of compression developed folds, reverse faults and the relief uplift determining the high altitude of the Loja Basin. As a consequence of the crustal thickening and in association with the dismantling of the top of the Andes Cordillera, extensional events favored the development of normal faults that mainly affect the basins of Catamayo and Malacatos-Vilcabamba. Gravity research helps to constrain the geometry of the Neogene-Quaternary sedimentary infill, shedding some light on its relationship with tectonic events and geodynamic processes during intramontane basin development.

1. Introduction

Ecuador is located in western South America and belongs to the Pacific Ring of Fire, a very active belt of volcanism and seismicity. Its territory is N-S crossed by the Andes mountain range, and nearby, in the Pacific Ocean, the active Galapagos ridge separates the Cocos and Nazca plates (Fig. 1a). The Mesozoic-Cenozoic Andean orogenic cycle is characterized by the subduction of the oceanic Nazca plate beneath the South American plate along a trench bounding Ecuador's continental margin. This subduction, which led to the formation of the Andes relief, is generally the source of an overall compressive tectonic regime and arc magmatism. Currently, the direction of convergence between the Nazca and South American plates is N83°E; its rates vary from 58 mm/yr at latitude 5°S, to 55 mm/yr at 2°N (Trenkamp et al., 2002; Kendrick et al., 2003; Nocquet et al., 2009).

The Ecuadorian Andes comprise two parallel chains, the

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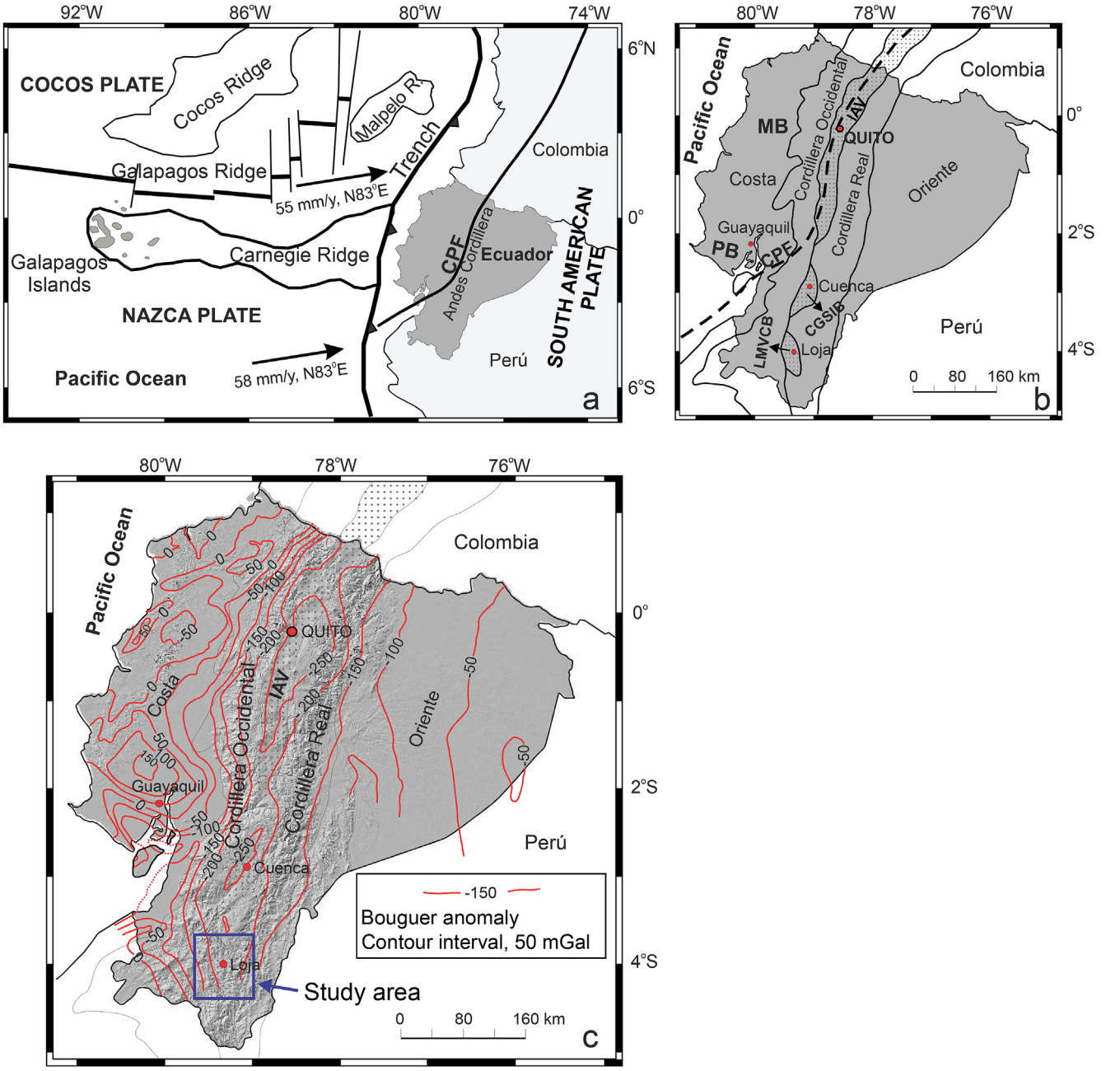

Fig. 1. Tectonic setting of the Ecuadorian Andes. (a) Plate tectonic sketch. (b) Main Ecuadorian Andes orographic features. (c) Bouguer Gravity Anomaly of Ecuador (after Feininger and Seguin, 1983). PB, Progreso Basin; MB, Manabí Basins; CPF, Calacalí-Pallatanga Fault; IAV, Inter Andean Valley; CGSIB, Cuenca-Girón-Santa Isabel Basin; LMVCB, Loja, Malacatos-Vilcabamba and Catamayo basins.

Cordillera Occidental and the Cordillera Real, both elongated mainly ~ N10°E, with a central depression between the two (Fig. 1b). The northernmost basins, at over 3000 m a.s.l. (e.g. Inter Andean Valley, IAV), are filled by volcanic deposits related to stratum volcanoes whose activity does not extend to the south. Southwards of Ecuador this main depression is closed, and a set of widespread intramontane Neogene-Quaternary basins develop: Azogues-Cuenca-Nabón, Loja, Malacatos-Vilcabamba and Catamayo (Figs. 1 and 2). They are filled with Middle Miocene to Quaternary sediments reaching thicknesses up to 5 km intruded by igneous rocks (Lavenu et al., 1992, 1995). During the Paleogene, the pre-Cretaceous metamorphic basement underwent erosion and probably some uplift. In any case, marine fossils indicate that some areas remained below sea level up to 15 to 10 Ma (Hungerbühler et al., 1995; Hungerbühler et al., 2002), then underwent fast uplift. Hungerbühler et al. (2002) and Winkler et al. (2005) suggest that most of these basins were bounded by pre-Cenozoic faults, reactivated during recent transpression.

Kennerley and Almeida (1975a, b) and Hungerbühler et al. (2002) present stratigraphic and sedimentological research that constrain the evolution of the Loja, Malacatos-Vilcabamba and Catamayo basins. However, the deep structure and distribution of sediments in these basins —along with their evolution and relations with the tectonic structures in their metamorphic basements— are poorly understood, as there is insufficient reliable data on subsurface geology to corroborate interpretations.