Paleoseismic assessment of the main strand of the Boconó fault in its central section, at Mesa del Caballo, Mérida Andes, Venezuela

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INTRODUCTION

This paper presents the preliminary results of a trench excavated across the main strand of the Boconó fault, at Mesa del Caballo, located south of Apartaderos and west of Lake Mucubají (LM) in early 2004, in order to determine the recent seismic history of this fault strand in its central Mérida Andes portion. In addition, these trench results should complement those obtained by Audemard et al. (1999) on the northern and secondary strand, thus allowing a better understanding of the seismogenic behavior of both strands. This should shade light on the activation of both strands (independent and/or simultaneous) and whether the Apartaderos pull-apart basin functions as a "leaky" or a perfect geometric barrier to rupture propagation.

THE BOCONÓ FAULT

The Boconó Fault (BF) is a spectacular NE-SW trending right-lateral strike-slip (RLSS) fault that extends for about 500 km, between the Tachira depression, at the border between Colombia and Venezuela, and Morón - on the Caribbean coast of Venezuela-. In our study area, it essentially runs, although slightly oblique to the chain axis, along the backbone of the Mérida Andes (MA). This fault has been identified, mapped and characterized rather easily since the pioneering work of Rod (1956) by the large number of along-strike geomorphic features, among which: continuous series of aligned 1-5 km wide valleys and linear depressions, passes, saddles, trenches, sag ponds, scarps and sharp ridges (**Fig. 1b**). The alignment of valleys along the fault trace makes the fault easily distinguishable in radar (SLAR) images (**Fig. 1a**).

STUDY AREA

The study area partly lies in the northeastern end of the Apartaderos basin that forms at a releasing bend of the BF (Soulas, 1985; Audemard et al., 1999). In fact, this part of the BF has a slightly more easterly strike with respect to the overall NE-SW trend. Here, the BF is well preserved along a 3,500-m-high drainage divide that separates the SE-flowing streams (Orinoco basin) from the NW-flowing streams (Maracaibo basin). This divide is centred in the area of lake Mucubají (LM), belonging to the Sierra Nevada National Park. However, this high-altitude Apartaderos basin is being deeply dissected at present by both the Chama and Santo Domingo (SD) river headwaters, even though this depression seems to have accumulated a rather thick sequence of Pleistocene glacial deposits as those preserved at Mesas del Caballo and Julián (Audemard, 2003). The BF here comprises two conspicuous sub-parallel basin-bounding active strands located at about 1-1.5 km apart, both exhibiting magnificent geomorphologic expression preserved in latest Pleistocene and Holocene deposits (**Fig. 1b**). Even though the vertical component of slip appears to be significant at some localities (*e.g.*: near El Cerrito, in the village of Apartaderos, Los Zerpa and near Las Tapias), most of the fault geomorphology is typical of a RLSS fault (**Fig. 1b**). The BF exhibits is highest slip rate at this basin, where the southern and northern strands respectively carry about 75% and 25% of the 7-to-10 mm/a net slip rate measured in this sector (Audemard et al., 1999). Away from the LM area, the BF slip rate decreases.

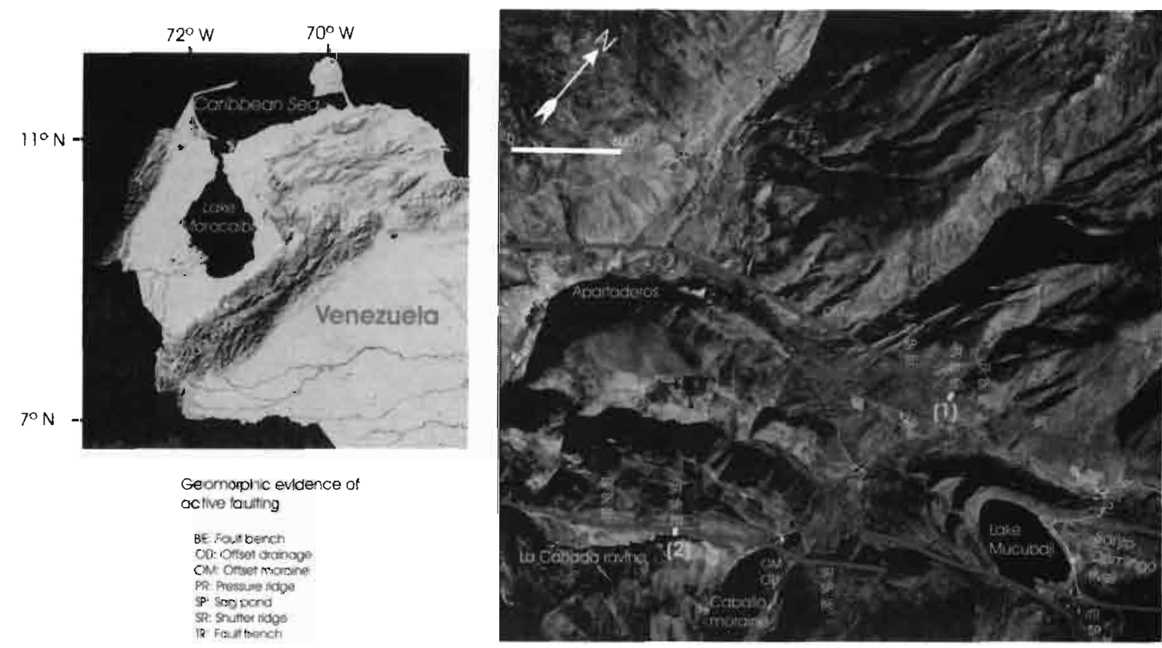

Fig. 1. A) Relative location of the study area in western Venezuela indicated by green open circle (Radar base image modified from Garrity et al., 2004). **B)** Aerial photograph showing both Boconó fault strands in the Mucubají area, as well as location of the two paleoseismic studies performed in this region: **(1)** Audemard et al. (1999), and **(2)** at Mesa del Caballo.

MESA DEL CABALLO TRENCH SITE

Mesa del Caballo is a flat top relief that lies west of the late Pleistocene LM moraine complex, and north of the La Cañada fluvio-deltaic sequence and the late Pleistocene Caballo moraine (**Fig. 1b**). The Mesa del Caballo seems to be built of older Pleistocene glacial deposits, probably ascribable to the early Mérida Glaciation or older, since Mahaney et al. (under review) report deposits older than 40 ka under the La Cañada deposits, which seem to be unconformably overlying the Mesa del Caballo deposits on the south. Very roughly, the main strand of the Boconó fault where the trench was excavated runs near the sedimentary boundary between those two units (La Cañada fan and Mesa del Caballo glacial deposits). In addition, the active strand, from the structural viewpoint, seems rather simple since it shows a single trace (**Fig. 1b**). This trace, at the selected trench site, comprises a set of en echelon synthetic Riedel shears of several tens of meters in length. The Riedel shears are connected by modest (few meter long) pop-ups.

TRENCH EXCAVATION AND MAIN RESULTS

The trench at Mesa del Caballo was excavated across a Riedel shear and its related pop-up in April 2004 (**Fig. 2**). In fact, this pop-up structure acts as a small shutter ridge, behind which a 15-20-m-across sag pond forms. This site selection ensured not only the accumulation of young but also datable materials. On the other hand, the southern flank of the pop-up is affected by regressional erosion along a ravine named La Cañada. Consequently, the trench was hand-dug along the N15°W direction –normal to the Riedel shear-, extending from the sag pond into the ravine crown, across a single Riedel shear and the related shutter ridge. No machinery could be used following owner's request, although access to the trench site was excellent for any type of vehicle during the entire study (March-April, corresponding to the end of the dry season). Final dimensions of the hand-dug trench were 14 m long, 2.5 m deep and 0.75 m wide at the trench bottom. As manual excavation progressed, the trench walls were scrapped clean from top to bottom. Trench drainage was ensured by the gentle dipping of its bottom into the ravine located at the trench south end (**Fig. 2**)., although rain was almost completely absent during excavation except for very fine occasional drizzling.

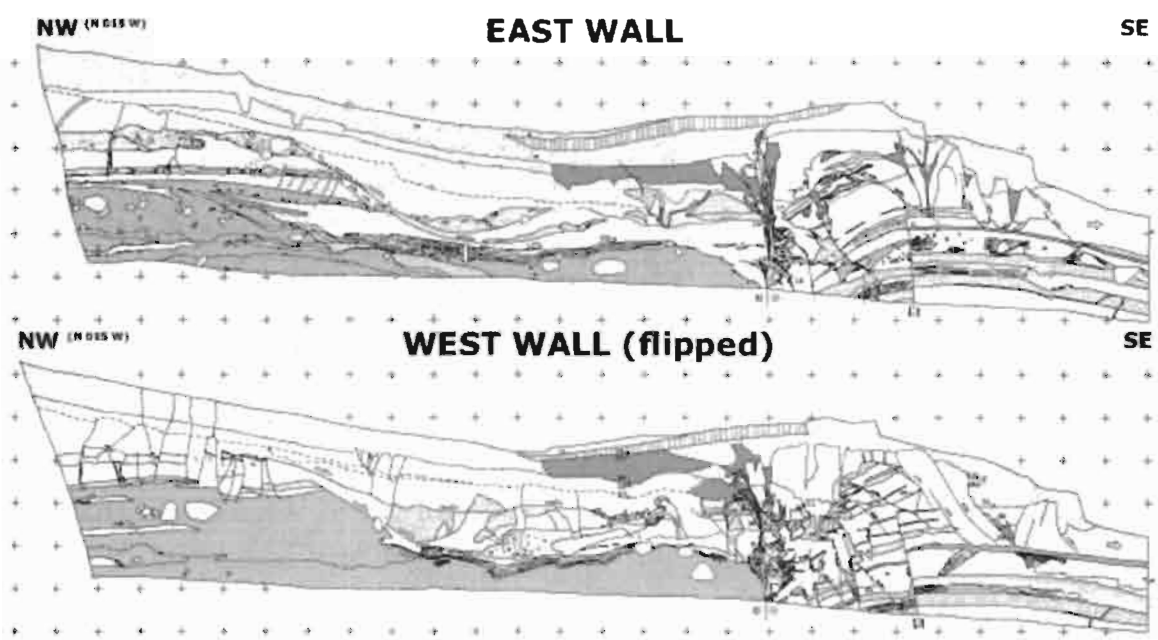

Fig. 2. Logs of trench walls showing the main Boconó fault strand at Mesa del Caballo, Mérida state, Venezuela.

This trench study is considered highly satisfactory, as evidenced by **Fig. 2**. Furthermore, it displays a complete set of features never seen in Venezuela before. Besides imaging a main fault plane, liquefaction features and sliding have also been observed and described. The main fault plane –well corresponding to the surface break between the pop-up and sag-pond, where the Riedel shear was inferred-, has functioned as an open crevasse which contains more than 6 different vertical slices of paleosoils squeezed inside. This is evidence of a record of as many paleo-earthquakes. As mentioned above, other soft-sediment deformations are reported not only in the open crevasse but all along the trench walls. Sand dykes, flame structures, sequence blocks or clay plugs floating in well sorted structureless sands, and convoluted bedding are unequivocal evidence of earthquake-triggered liquefaction. These structures were recognized in finely laminated pond deposits as well as in the fluvial sequence of which the pop-up is built. Sedimentation also attests to a complex evolution in a Holocene tectonically active environment since two different sag pond sequences were identified, and several organic-rich paleosoils. Besides, a coarse colluvial sequence resting on the older sag pond deposits (or interfingered between the two sag ponds) were affected by water-rich sliding, implying that the nearby fault plane also triggered syn-sedimentary slope instabilities. In addition, the free face of the pop-up also shows sliding towards the ravine, which would not seem to have occurred in dry conditions (as it happens nowadays), because sliding surfaces root in a same softly deformed layer, implying that they are not currently moving by regressional erosion but had by shaking during older earthquakes. This seems supported by the fact that paleosoils atop sliding masses are also "down-faulted", and they occasionally exhibit sort of colluvial wedges inside the organic-rich paleosoils. Definitely, all these deformations confirm that this is the other Holocene active trace of the Boconó fault bounding the Apartaderos pull-apart basin (**Fig. 1b**), as proposed by Audemard et al. (1999).

Finally, the earthquake chronology of this main strand is awaiting the radiocarbon dating of 23 out of 34 collected samples, which we hope to be able to present during this *VI ISAG*.

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