6th International Symposium on Andean Geodynamics (ISAG 2005, Barcelona), Extended Abstracts: 346-349

The Interandean Quindío-Risaralda Basin in Central Colombia and its Pleistocene infill by stacked fluvio-volcanic mass flows derived from the Central Cordillera

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INTRODUCTION

The cities of Pereira (Risaralda Province) and Armenia (Quindío Province) in the Colombian "Eje cafetero" are located on a Pleistocene sequence of stacked fluvio-volcanic mass flows forming a major topographic fan (Figs. 1A and 1B). Following the dramatic earthquake of Armenia in 1999, detailed sedimentological, geomorphological and tectonic studies have been undertaken to better understand the geology of this area. In particular, special attention has been paid to the formation and deposition of the fluvio-volcanic fans.

The area studied lies west of the Central Cordillera: the Quindío-Risaralda basin where the fluvio-volcanic fans accumulated is limited westward by the Tertiary sediments of the Serranía de Santa Barbara, which were folded during the late Tertiary Andean tectonic phase and separate the area under study from the Cauca Valley (Figs. 1B and 1C). Several SSW-NNE trending major fault lineaments dissect the area west of the Central Cordillera, particularly the Romeral Fault System (Fig. 1C). The latter is associated with the activity of the Ruiz-Tolima volcanic system, where originated the material deposited in the fans.

This study has a twofold objective: 1) to analyze geomorphologically and sedimentologically the sequence of mass flows in the Quindío-Risaralda basin, especially in their proximal location. This phase of the study has been completed; 2) to identify the network of major and subordinate active faults in the area and analyze its relationship with the deposition of the fluvio-volcanic fans. This phase of study is still in progress. Ultimately, it is hoped to better understand the mechanisms associated with the formation of the Quindío-Risaralda basin.

RESULTS: Geology of the fluvio-volcanic fans in the Quindío-Risaralda basin

These fans consist of a sequence of stacked fluvio-volcanic mass flows sourced from the Central Cordillera. Geographically, they can be subdivided from south to north into the Quindío, Pereira and Cartago Fans (Fig. 1B). According to their stratigraphic succession, lateral continuity, genesis and sedimentological and petrographic parameters, several individual units can be distinguished within these deposits (Espinosa, 2000; Guarin, 2002; Guarin et al., 2004). Sedimentological observations show a transition with the increasing water/sediment ratio from debris avalanches to debris flows, transitional flows, hyperconcentrated flows and finally normal streamflows (nomenclature after Smith & Lowe, 1991). This gradation permits the subdivision of the fans into proximal, intermediate and distal parts (Fig. 1B). The imbrication of the different, terrace-forming units permits their relative dating. The older units are more compacted and present a more mature drainage

pattern. Thicknesses vary from more than 200 meters in the proximal part to less than 50 meters in the most distal parts.

In the distal part of the fans, particularly along the La Vieja River and in the Cartago Fan in the north (Fig. 1B), fluvio-volcanic mass flows are interbedded with fluvio-lacustrine sediments of the Zarzal Formation, present mainly in the Cauca Valley, but also encountered east of the Serranía de Santa Barbara in the Quindío-Risaralda basin (Suter et al., 2005 in this Symposium; Neuwerth et al., submitted). Palynological data from clay layers in the Zarzal Formation on both sides of the Serranía de Santa Barbara indicate an age of less than one million years for the latter formation. Therefore, the interbedded mass flows of the Quindío, Pereira and Cartago Fans, and presumably the largest part of the latter, are of Pleistocene age (see depositional model in Suter et al., 2005 in this Symposium). These datings await confirmation from radiometric data.

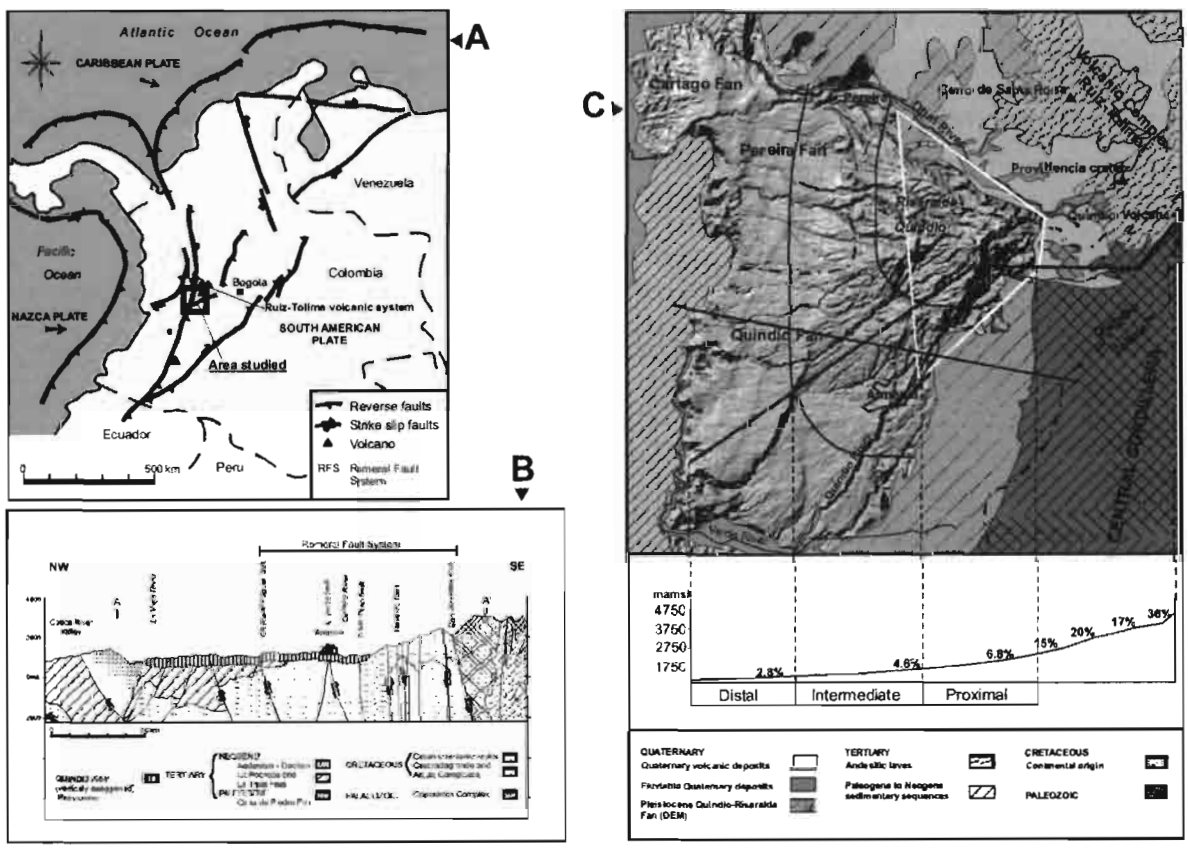

Fig. 1: A) Location of study area; B) simplified geological map of studied area. The fluvio-volcanic mass-flow infill of the Quindío-Risaralda basin (subdivided into the Quindío, Pereira and Cartago Fans) is illustrated by a Digital Elevation Model (DEM) based on radar photographs (USGS, 2004). The zone framed in white underwent detailed field studies. The profile below the map shows the present-day surface slope of the Quindío Fan up to the Quindío volcano; C) geological cross-section through the Quindío-Risaralda basin; see Fig. 1B for location.

RESULTS: Relationships between tectonics and the fluvio-volcanic infill of the Quindío-Risaralda basin

The Cauca Depression between the Western and Central Cordilleras has been exposed to a regional oblique compressive regime which has generated different pull-apart basins along the Cauca-Romeral Fault System (James, 1986). The strike-slip component changes from senestral to dextral south of 4° N latitude (Taboada, 2000).

So far, the origin of subsidence in the Quindío-Risaralda basin can not be clearly explained. Nevertheless, in this basin, a sum of observations can be collected linking the active fault patterns, the present-day drainage pattern and the distribution of fluvio-volcanic units. This can be achieved using topographical maps, aerial photographs and digital elevation models (DEM), complemented by field data.

Figure 2 shows some observations carried out in the Quindío Fan. The Quindío-Risaralda basin bears the expression of three major fault trends observed at a more regional scale on DEM: the N-S trending Cauca-Romeral System, the E-W trending Salento System and the SW-NE trending Palestina System. The present-day drainage pattern of the Quindío Fan has been heavily influenced by the vertical throws along the transpressional fault systems. The interaction of this transpressional multiple active system led to the formation of localized pull-apart basins that became depositional lows for the fluvio-volcanic units. The use of colour anaglyphs derived from aerial photographs permits the identification of such features.

Finally, the change in depositional direction of the fluvio-volcanic units may have been partly controlled by this tectonic activity. The oldest units (e.g. north of Filandia in Figure 2) were deposited in an E-W trending direction, aligned with the Salento Fault System. The younger units (e.g. south of Circasia in Figure 2) are aligned in a SW-NE trending direction and infill depressions possibly related to the activity of the Palestina Fault System.

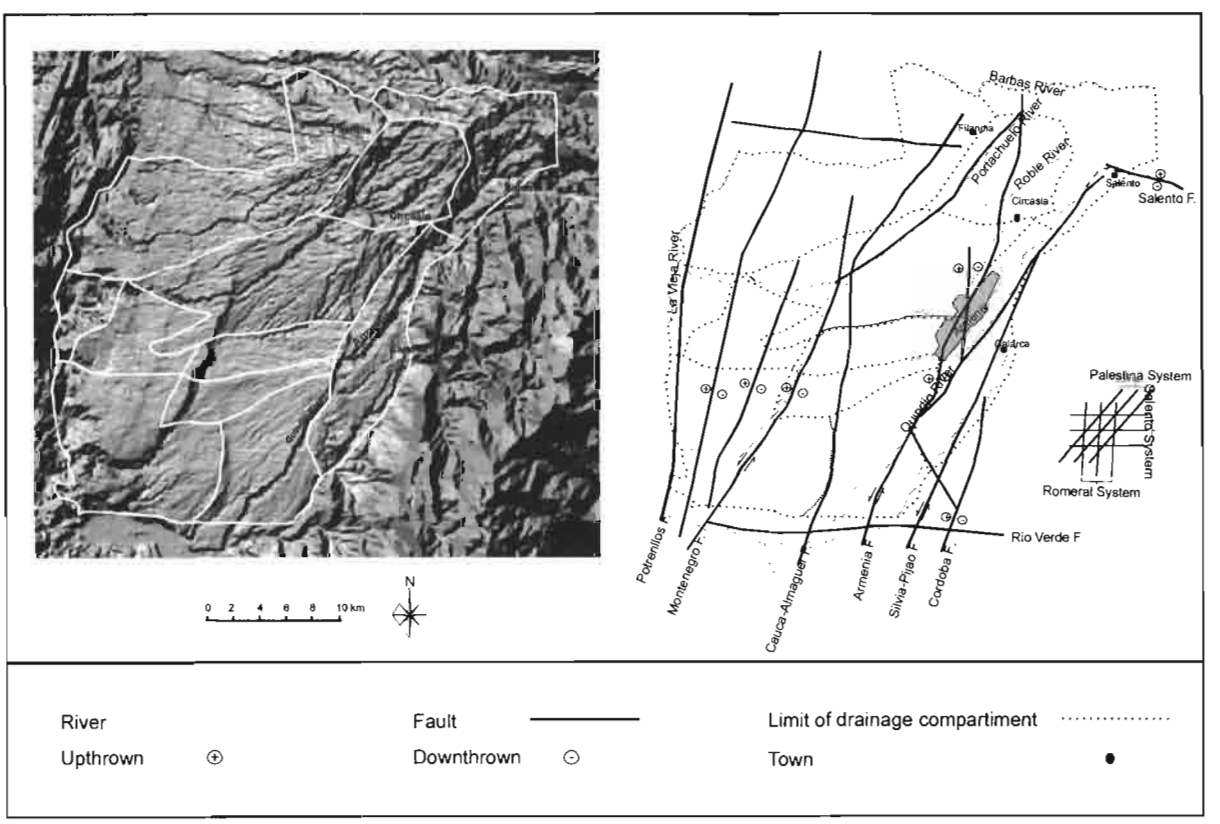

Fig. 2: Radar-based DEM (USGS, 2004) and interpretation of active faults and drainage patterns in the Quindío Fan (i.e., the lower part of Figure 1B). The limits of drainage compartments are shown as dotted lines on the interpretation at the right handside and as white lines on the DEM. Note the close relationship existing between the active fault lineaments and the drainage pattern. The three major fault trends observed both at local and regional scales are shown at the right handside.

CONCLUSIONS

The Quindío-Risaralda basin has been infilled over the last million of years by a succession of stacked fluvio-volcanic mass flow units derived from the Ruiz-Tolima volcanic complex in the Central Cordillera of Colombia. The sedimentology of these deposits shows an increasing water/sediment ratio in a distal direction, where mass flows become interbedded with fluvio-lacustrine sediments of the Zarzal Formation (Suter et al., 2005 in this Symposium).

The Quindío-Risaralda basin is dominated by a regional oblique compressive regime and bears the imprint of three active fault trends also known at a more regional scale: the Cauca-Romeral, Palestina and Salento Fault Systems. Although, so far, the origin of subsidence in the Quindío-Risaralda basin can not be unequivocally demonstrated, observations derived from DEMs, aerial photographs, field work and spatial distribution of fluvio-volcanic fan units point to the strong influence of this transpressional multiple active fault system on the deposition of the fluvio-volcanic units. Transpressional forces seem to have led to the formation of localized pull-apart basins used as depocentres by the fluvio-volcanic units. Pull-apart basins are known further south in the Cauca Depression.

The study of the Quindío-Risaralda basin is integrated with that carried out in the Zarzal Formation at the western edge of the fluvio-volcanic fans and in the Cauca Valley (Suter et al., 2005 in this Symposium). It is hoped to come up with an integrated interpretation of the dynamics of this interandean region.

This research is supported by the Swiss National Science Foundation (grant no. 21-67080.01)

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