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Depositional model for the Quaternary Zarzal Formation (Colombia) and its stratigraphic relationship with the fluvio-volcanic mass flows derived from the Central Cordillera

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INTRODUCTION

The Cauca River in Central Colombia (Fig. 1A), which flows northwards between the Western and Central Cordilleras, shows an atypical longitudinal profile: it forms a large meandering floodplain before flowing northwards by cutting through higher reliefs and finally joining up with the Magdalena River. The interandean depression where meanders are encountered corresponds to a deep sedimentary basin called the Cauca Depression, extending north up to the studied area (Figs. 1B, C) and filled by approximately 6000 meters of sediments ranging in age from Early Tertiary to recent. The presence of folded Tertiary sequences demonstrates that this basin has been exposed to synsedimentary compressional as well as extensional tectonic phases (James, 1986).

This research attempts to establish the mechanisms which may have led to the opening of such an interandean basin. The Zarzal Formation (Keiser et al., 1955 in Van der Hammen, 1958; De Porta, 1974) being the first sedimentary succession to be associated with the latest distensive phase, its detailed study should bring key elements to the problem. This paper presents a sedimentary model illustrating the relationship between the Zarzal Formation and the volcaniclastic mass flows derived from the Central Cordillera to the east and which form the vast fluvio-volcanic fans of Quindío, Pereira and Cartago (Fig. 1C; Mc Court, 1984; Guarin et al., 2004; Guarin et al., 2005).

TECTONIC AND GEOMORPHOLOGICAL SETTINGS

The Cauca Depression has been exposed to a regional oblique compressive tectonic regime which has generated different pull-apart basins along the Cauca-Romeral fault system (James, 1986). The latter defines the boundary between continental and oceanic basements (Cline et al., 1981 ; González & Núñez, 1991 ; Paris & Romero, 1994 ; Taboada, 2000). The strike-slip component changes from senestral to dextral south of 4° N latitude (Taboada, 2000), i.e. south of the studied area.

The studied area extends in a N-S direction between the municipalities of Zarzal and La Virginia. From west to east it comprises the foothills of the Western Cordillera, the Cauca River valley, the folded Tertiary sediments of the Serranía de Santa Barbara and the La Vieja River valley (Fig. 1). The Serranía de Santa Barbara forms a natural barrier between the western (Valle del Cauca) and eastern (Quindío) parts of the basin, which coalesce in the Cartago Fan. In the western part, the Zarzal Fm exhibits very eroded gentle hills, largely covered by recent alluvial sediments of the Cauca River. In the La Vieja Valley it forms elevated, more or less rounded erosion

terraces (Suter, 2003). Between Cartago and La Virginia its morphology is that of the fluvio-volcanic Cartago Fan (Fig. 1B).

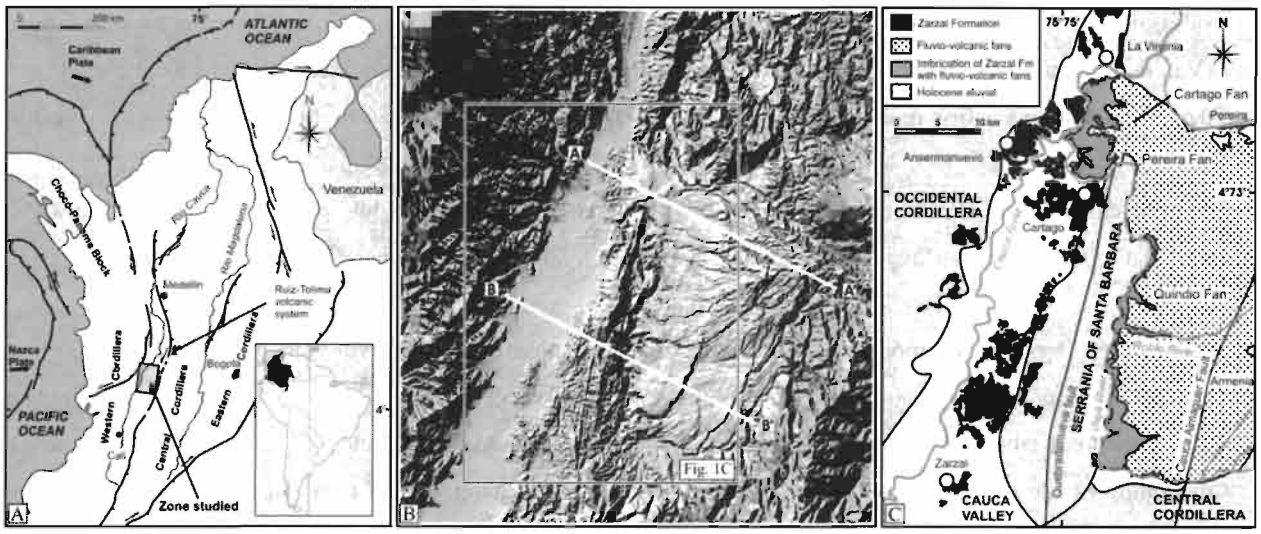

Fig. 1. A) Location of study area. B) Digital Elevation Model (DEM) of the studied area and its surroundings based on radar photographs (USGS, 2004). Location of profiles AA' and BB' shown in Figure 2. C) Simplified geological map of studied area.

RESULTS: Geology of the Zarzal Formation

The lithology and stratigraphy of the Zarzal Fm has been so far poorly studied (Keiser et al., 1955, in Van der Hammen, 1958 ; De Porta, 1974 ; McCourt, 1984 ; Cardona & Ortiz, 1994 ; Nivia et al., 1995). Without much evidence, a Pliocene age has been attributed to this unit (Van der Hammen, 1958). So far, the most relevant observations are those of Cardona & Ortiz (1994), who noted that the Zarzal Fm sediments show a westward decrease in granulometry and volcanic influence from the Central Cordillera foothills up to the Cauca River basin.

In the eastern part of the basin and in the Cartago fan up to Ansermanuevo (Fig. 1C), the clayey to conglomeratic fluvio-lacustrine sediments have a clear volcanic origin. The dark-coloured sands contain orthopyroxene, quartz, feldspar, amphibole and zircon grains with lithoclasts of vacuolar volcanic glass, volcanic rocks with fine microcristalline matrix, and chert. They rework gravel-sized fragments of diatomite. Conglomerates exhibit the same composition with soft pebbles of diatomite. These sediments are interbedded with volcanic mass flows, the granulometry of which depends upon the initial volume, energy and distance from the source.

In the western part of the basin, between Zarzal and Cartago, the Zarzal Formation is sourced from the Tertiary sediments of the Serranía de Santa Barbara and from the Western Cordillera (Fig. 1B). It exhibits feldspars, lots of quartz and a few amphiboles grains with fragments of chert, quarzite, andesite and some rare volcanic clasts.

The soft sediments of the Zarzal Fm uncomformally overlie the Lower to Middle Tertiary rocks forming the Serranía de Santa Barbara, and also probably both oceanic and continental basements of the Cordilleras. They are overlain in the western part by recent alluvial sediments of the Cauca floodplain and some relatively small alluvial fans derived from the Serranía de Santa Barbara and the Western Cordillera. East of the Serranía de

Santa Barbara and in the Cartago Fan the limit between fluvio-lacustrine sediments and volcanic mass flows is clearly transitional.

Preliminary palynological investigations in Zarzal shales have revealed the presence of *Alnus* pollen on both sides of the Serranía de Santa Barbara. Because the first record of this tree in Colombia dates back to 1 m.y. (Van der Hammen & Hooghiemstra, 1997), a large part of the Zarzal Fm is probably of Pleistocene age. These data are awaiting confirmation from ongoing palynological investigations and radiometric dating of volcanic ashes.

Sediments of the Zarzal Fm exhibit numerous soft-sediment deformations interpreted as seismites (Neuwerth et al., submitted), which prove the important seismic activity of this area since the Pleistocene.

RESULTS: Depositional model of the Zarzal Fm and relationship with fluvio-volcanic fans (Fig. 2)

The field data and palynological results allow the proposal of the following depositional model (Fig. 2). The latter does not take into account the tectonic activity nor the erosion, which play an important role in the modelling of the basin. The aim of this model is to explain the lithological differences encountered and the stratigraphic relationships between the different units.

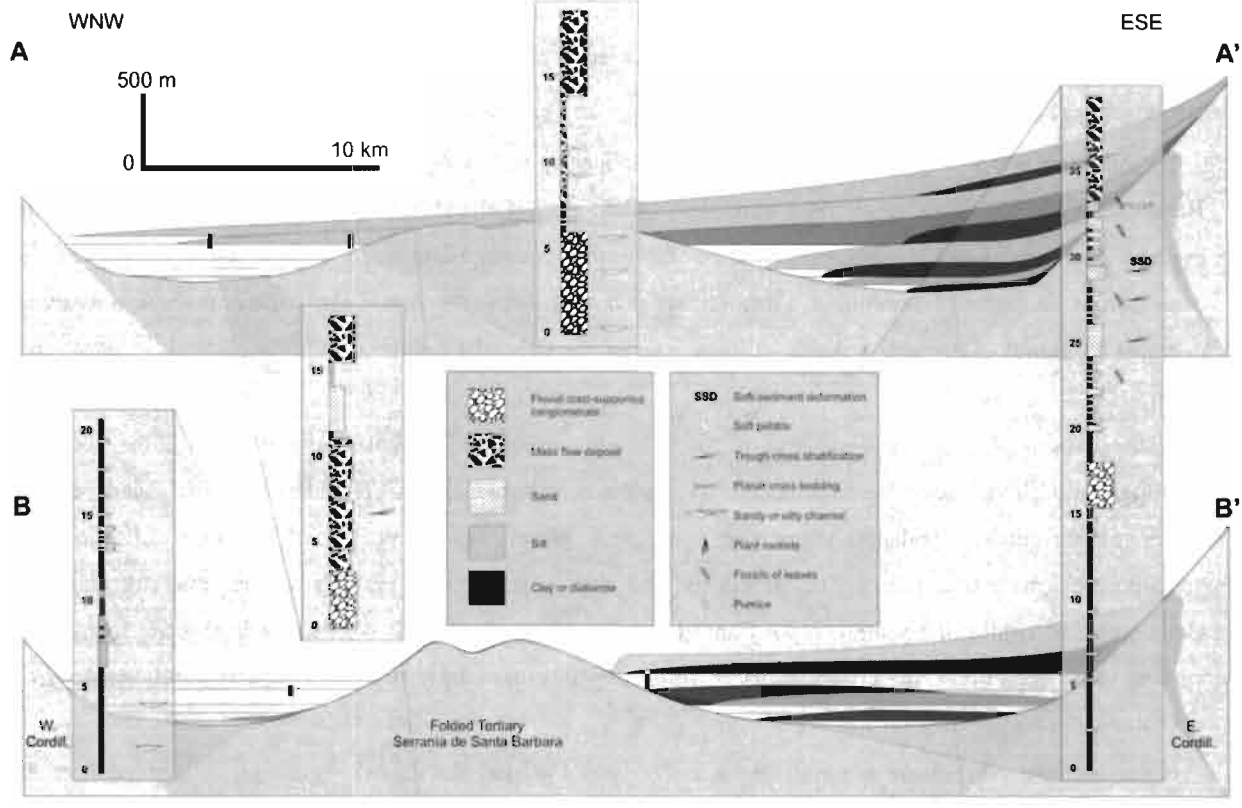

Fig. 2. Relation between field observations and the proposed depositional model (see figure 1B for location of profiles). Gravitational flows are represented in grey and black, fluvio-lacustrine sediments in white. This model does not take into account the tectonic activity. Moreover, the frequency of gravitational flows is schematic and underestimated.

The Andean tectonic phase caused the folding of the Serranía de Santa Barbara, thereby subdividing the basin into two parts. While the western part was infilled by the fluvial sediments of a paleo-Cauca River and by some in-situ diatomites formed in paleolakes, volcanic mass flows originating from the Central Cordillera

accumulated in the eastern part. Each of these mass flow unit behaved like a topographical barrier temporarily damming the basin and creating a lake, where very fine, reworked, mass flow sediments accumulated. Following the erosion of the damming mass flow, the lake dried out and turned into a floodplain, where the river could subsequently digs its valley. This cycle was repeated each time a new significant mass flow dammed the valley. This interpretation is supported by field observations of intercalations of volcanic mass flows with fluvio-lacustrine sediments (Fig. 2). The eastern basin continued to infill until the volcanic mass flows could flow over the lower-relief, northern part of the Serranía de Santa Barbara and spread into the Cauca Valley to form the Cartago Fan. In the last million years (see palynological data) subsidence rates in the western part of the basin (Cauca Valley) seem to have been higher than in the eastern part (La Vieja Valley) where outcrops of the Zarzal Fm interbedded with fluvio-volcanic fans are encountered at altitudes some 50 to 100m higher.

CONCLUSIONS AND RECOMMENDATIONS

These preliminary results have established the synchroneity of the deposition of the Zarzal Fm with that of the fluvio-volcanic fans. Within the last million years (palynological data), this area has been exposed to a lot of tectonic activity (evidenced by the widespread existence of seismites) and the western part of the basin (Cauca Valley) underwent a higher rate of subsidence. However, the whole area needs to be further studied from a tectonic and neotectonic point of view. Moreover, further datings are needed to refine the dynamic interpretation of this basin during the last million of years. This study is integrated with that carried out on the fluvio-volcanic fans to the east (Guarin et al., 2005 in this symposium)

Finally, this research has shown the need to revise the lithostratigraphic nomenclature of the area. One has to decide if a clear limit of the Zarzal Fm can be established in the field with respect to the fluvio-volcanic fans of Cartago, Pereira and Quindío to the east. If the transition from one type of deposits to the other is gradational, one might consider regrouping all the studied sediments into one single formation.

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