Dynamic evolution of Oligocene - Neogene sedimentary series in a retro-foreland basin setting: Oriente Basin, Ecuador

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INTRODUCTION

In the past decade, a debate was raised concerning the Neogene deposits and landscape evolution of Western Amazonia (*e.g.* Hoorn, 1993; Hoorn *et al.*, 1995; Räsänen *et al.*, 1995; Vonhof *et al.* 1998; Wesselingh *et al.*, 2002). These studies mostly focused on the Peruvian, Colombian, and Brazilian parts of the Amazonian basin. At the same time, the Ecuadorian Oriente basin, where Neogene deposits record a huge humid tropical alluvial fan ("Pastaza Megafan"; Räsänen *et al.*, 1992), was poorly investigated, with the exception of Christophoul *et al.*, 2002 and Ruiz, 2002. The Neogene infill of the Oriente basin was essentially studied much earlier in the 20th century (Tschopp, 1953; Bristow and Hoffstetter, 1977; Baldock, 1982). It crops out in a great area of the Pastaza megafan. In this contribution, we propose a model of stratigraphic architecture and geodynamic evolution for the retro-foreland basin in Ecuador (Oriente basin, Fig. 1) throughout the Late Oligocene to Neogene times. This model is based on outcrops data, with an actualized chronostratigraphy. It is replaced in the Western Amazonian foreland context.

STRATIGRAPHY AND SEDIMENTOLOGY

Four Neogene formations have been generally recognized (Fig. 2) and approximately dated: the Chalcana Formation; the Arajuno Formation; the Chambira Formation and the Curaray Formation in the east of basin. The Neogene sediments as a whole are unconformably overlaid by the Pleistocene Mesa-Mera Formation, which corresponds to the top of the modern Pastaza Megafan. The scarcity of outcrops, the lateral and vertical variations of facies and the lack of biostratigraphic markers turned the correlations in time and space difficult (Tschopp, 1953; Campbell, 1970; Bristow and Hoffstetter, 1977; Baldock, 1982; D.G.G.M., 1986). Nevertheless, recent investigations, including new outcrops (Fig. 1A) in the Subandean zone and Amazonian lowland, led us to refine the correlations and the definition of stratigraphic architectures. The description of fluvial deposits is based on the nomenclature of lithofacies and architectural elements proposed by Miall, 1996.

Chalcana Fm. (Late Oligocene), is dominated by fine sediments (Fl, Fr, P facies) corresponding to floodplain environments (FF arcitectural element) and minor sadstones and conglomerates exhibiting Sl, Sr, Gt, Gp and Gh facies, grouped in LA (lateral accretion), CR (crevasse channels) and CH (channels).

Arajuno and Chambira formations exhibit coarser sediments than Chalcana. The major part of the Arajuno Fm. corresponds to sandstones and conglomerates, with Gh, Gt, Gp, St, Sh facies (SB, CH, DA/LA elements). Floodplain deposits are well preserved, this preservation can be interpreted as resulting of aggrading rivers in a subsiding area (Burgos *et al.*, 2004). In the Subandean zone (vicinity of Santa Clara town, Fig. 1A) they are present deposits with sedimentary structures type "herring bones" which show bidirectional flux in a tidal influenced environment, this interval can be comparable with the Curaray Fm. In the lower part of Arajuno Fm. was reported a single especimen of *Echitricolporites maristellae,* a fossil guide for the late Early Miocene Zone 27 (Late Aquitanian – Late Burdigalian), representing a ~22 - 16.2 Ma range (Fig. 2; Muller *et al.*, 1987; Rull, 2002). This age is consistent with the ~22 Ma apatite and zircon fission track dating (AFT age 19.3 ± 1.5 Ma; ZFT age 23 ± 1 Ma) near of the base of the Arajuno Fm. (Fig. 2; Ruiz, 2002).

The type locality of Chambira Fm. is on the Bobonaza River, 13 Km east of the Canelos village (Fig. 1A). In its type locality, the Chambira Fm. consists of sandstones and quartz pebble conglomerates without any red bed, characteristic of the underlying formations. The Chambira Fm. is not observed in the Napo and Cutucú uplifts, but it crops out in the Pastaza Depression in the south plunge of the Napo uplift (Talag syncline, Fig. 1A). The type locality is poorly known due to its difficult access. Thus, this formation is usually described on the basis of the Talag syncline outcrops (Christophoul *et al.*, 2002). Chambira Fm. was classically considered barren in fossils. In samples from about; and in the type locality on the Bobonaza river were reported palinological evidences. For example in JB.22.05.04.03:. *Polypodiaceoisporites pseudopsilatus*; (late Early Miocene – Pleistocene); JB.23.05.04.02: *Cyatheacidites annulatus*, *Psilatricolporites divisus;* (late Middle Miocene – Pliocene); Labogeo, 2004. *Crassoretitriletes vanraadshoovenii* occurs in the Arajuno/Chambira interval of the Villano-2 well (Edwards, 1993); this occurrence points out a Middle Miocene age (Zone 28; Muller *et al.*, 1987). *C. vanraadshovenii* ranges throughout the D-E Zones defined by Hoorn (Hoorn, 1993: Fig. 5), which means a Middle to earliest Late Miocene range. Preliminary apatite fission track (AFT) data suggest that the base of Chambira Fm. was deposited approximatly to **25.1 ± 2.1 Ma** (JB.23.05.04.1) and **23.1 ± 2.4 Ma** (JB 24.05.04.1), uppermost in the section, an AFT age of **14.6 ± 1.9 Ma** (JB.22.05.04.2) was obtained where we consider the "middle Chambira". In the Bobonaza river, we could not continue studing the section for security/political reasons; thus the "upper Chambira" member is based in the Talag syncline section. According to available data, the Chambira Fm. from Ecuador ranges from the later Oligocene to the Late Miocene, possibly until Pliocene.

DISCUSSION AND CONCLUSIONS

With the recently obtained ages, we can considerer the Arajuno and Chambira formations how contemporanous, at leats partly. Besides, they are equivalent to the Curaray Fm. in the east of basin.

The study of lithofacies and architectural elements of the Chalcana Fm. shows these sediments correspond fundamentally to great flood plain deposits, with presence of meandering rivers which load principally sands and something of milky quartz pebbles originated from the reworking of previous sediments and possibly the erosion of metamorphic bodies of the Cordillera Real. The fluvial system of the Chalcana Fm. can represent poor basin deformation, and probably a weak tectonic activity in the chain.

From the later Oligocene, uplift in the Cordillera Real led to tectonic and topographic loads, and therefore flexural subsidence in the retroarc foreland basin. This subsidence was enhanced by sedimentary loading of the Arajuno/Chambira formations., which correspond to a molasse dominated by fluvial deposits supplied by the erosion of the Cordillera Real. From ~25 Ma, the Arajuno/Chambira formations recorded the re-onset of both the uplift-loading phase by the Andes and the flexural subsidence of the western Amazonian basin. Such a foreland basin system continued to develop until the Pliocene, evolving from an underfilled to an overfilled foreland basin (Jordan, 1995) with an increasing discharge of sediments and an eastward propagation of the depozones. The Curaray Fm. (eastern part of basin) is time and facies equivalent to the Pebas Fm. of Peru and the Solimões Fm. of Brazil. The Pebas and Solimões deposits have been dated on several occasions and range between at least the late Early Miocene and the early Late Miocene (c. 17 - 10 Ma, see: Hoorn, 1993, Vonhof *et al.,* 1998). Wesselingh *et al.*, 2002; dated the Pebas Fm. including the La Tagua Beds of southern Colombia at ~20 - ~10 Ma. Hoorn, 1993; recognized perimarine conditions in the Early-early Middle Miocene and the late Middle-early Late Miocene (Pebas/Solimões); yet only the latter interval contains marine incursion levels corroborated by perimarine mollusks, foraminifera, barnacles; and stable isotopes data (Hoorn, 1995; Vonhof *et al.*, 1998).

The fauna from the Curaray Fm. indicates aquatic environment with some brackish influx, in a low energetic environment. At leats, the upper part of the Curaray Fm. reflects a marine influenced wetlands environment as confirmed by the yielded fossils. The tidal influenced deposits reported in the Arajuno Fm. can reflect the influence of previous marine incursions reaching the central part of the actual Subandean zone.

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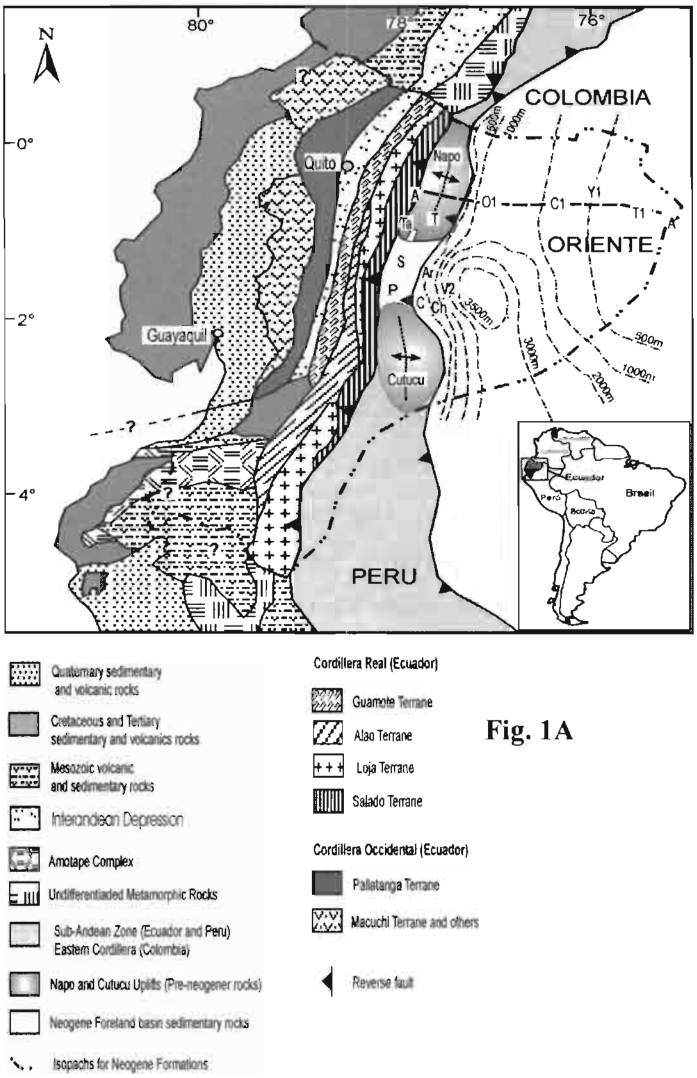

Fig. 1A

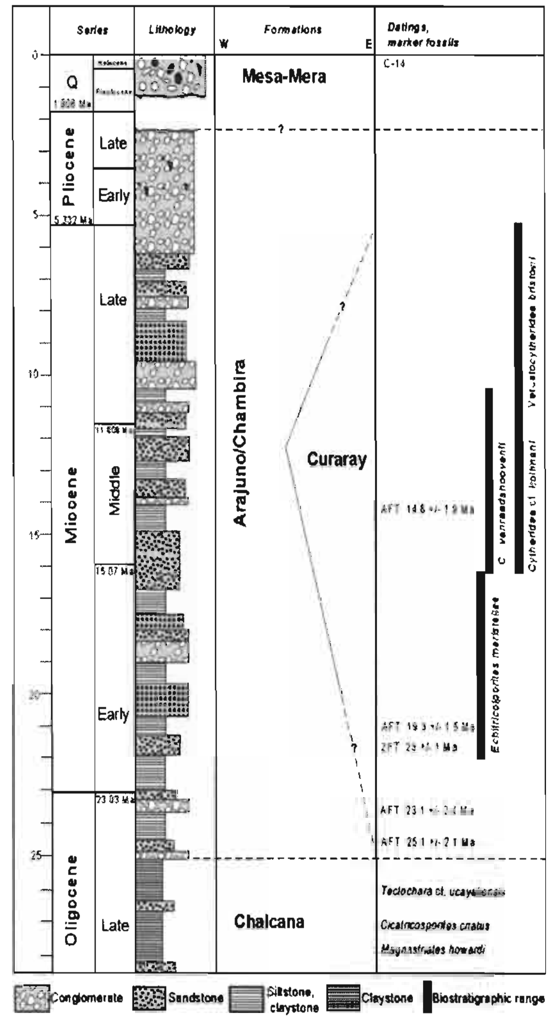

Fig. 2

Fig. 1B

Figure 1. (A) Simplified geological map of Ecuador. Isopach for Late Oligocene – Neogene formations in the retro-foreland basin are shown. Localities: P, Puyo; S, Santa Clara; T, Tena; Ta, Talag; C, Canelos; Ch, Chambira; Ar, Arajuno. Wells: C1, Capirón-1; O1, Oso-1; T1, Tiputini-1; V2, Villano-2; Y1, Yuturi-1. (B) W-E structural cross-sections in the Oriente basin showing the present geometry of the retro-foreland basin system: L.: Lower; U.: Upper; E.: Early; M.: Middle; L.: Late.

Figure 2. Generalized chronostratigraphic column from the Late Oligocene to Quaternary interval in the Oriente retro-foreland basin. Datations have been made by different authors: Carbon-14 (Bès de Berc, in press); apatite and zircon fission track (AFT/ZFT) analysis (Ruiz, 2002; this work); biostratigraphy (Tschopp, 1953; Bristow and Hoffstetter, 1977; Edwards, 1993, Labogeo, 1992, 1999, 2004).