DETRITAL PROVENANCE AND EXHUMATION IN THE ECUADORIAN SUB-ANDEAN ZONE: A KEY REGION LEADING TO THE UNDERSTANDING OF ANDEAN GEODYNAMICS

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INTRODUCTION

Tectonic activity at or near plate margins results in orogenic uplift and exhumation of rocks in the Earth's crust by erosion or faulting. Exhumation of a rock is accompanied by cooling and hence the genetic relationship between tectonic and geomorphic processes can be accurately investigated using low-temperature thermochronometers, due to their sensitivity to the movement of rocks through the uppermost, cooler crust. The temperatures of partial to full track annealing in apatite (60-120°C) and zircon (230-310°C) fission-track thermochronometers are particularly useful for this purpose. Since Naeser (1979), several workers have attempted to utilise changes in detrital fission-track grain ages through time to reconstruct the geodynamic development of the source region. This was a major innovative development because, in general, source regions tend to be continually overprinted in active margins and the only thermal record of relic exhumation of the source is in the site of deposition of the eroded material.

The timing and rate of the exhumation within source regions of the Ecuadorian Andean Amazon Basin (AAB; Fig. 1) during Cretaceous and Cenozoic times has been constrained on a regional scale through a thermochronology study of the Ecuadorian Andes (Spikings et al., 2000); whereas, the AAB is assumed to have originated during the Maastrichtian, when the main detrital supply from the Cordillera Real to the west became evident (Fig. 1). Fission-track methodology was thus applied to both (1) rocks constituting the substrate of the AAB in the northern Ecuadorian Sub-Andean Zone region (SAZ; Fig. 1), and (2) Aptian to Recent basin fill series of the AAB, to constrain and refine the geodynamic development of the Andean orogenic system.

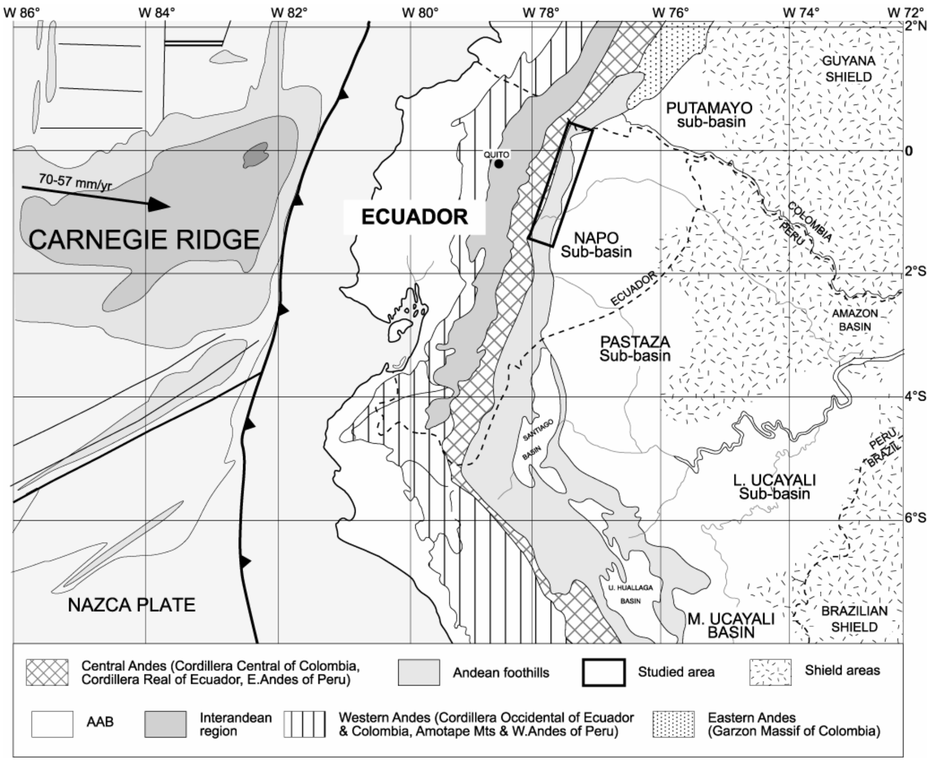

Figure 1: Simplified tectonic map of Ecuador.

RESULTS

-*Basement*: Approximately 40 fission-track ages have been determined from the Jurassic basement of the Andean Amazon Basin in the northern Ecuadorian Sub-Andean Zone (Fig. 1). Temperature-time envelopes reveal that several phases of cooling have occurred since the Middle Eocene (~ 50-35 Ma, 25-20 Ma, 12-0 Ma) and burial did not exceed ~ 4 kilometers (assuming a 30°C/km geothermal gradient).

-*Sediments*: Up to 30 siliciclastic sediments from the entire stratigraphic column across the Ecuadorian Andean Amazon Basin were separated and analysed. Reset apatite and zircon fission-track ages are restricted to a narrow depression within the Cordillera Real, whereas only one apatite fission-track (AFT) age from basin fill series east of the Andes exhibits an AFT age conspicuously younger than its assumed stratigraphic age. Therefore, it is reasonable to assume that the zircon fission-track ages of the sediments from the AAB preserve their detrital character. Seventy detrital zircon fission-track (DZFT) age populations from the Aptian-Albian to Recent basin fill series were extracted from 950 individual grain ages using statistical techniques (Brandon, 1992) and labelled as P_1, P_2… to P_n with increasing ages (Fig. 2). The DZFT age populations show a significant variation from 579 ± 65 Ma to 22.9 ± 1.2 Ma (1σ), and lagtimes vary from 450 to 0 My. The distribution in the cooling ages of detrital grains reflects the varied thermal histories of the source regions.

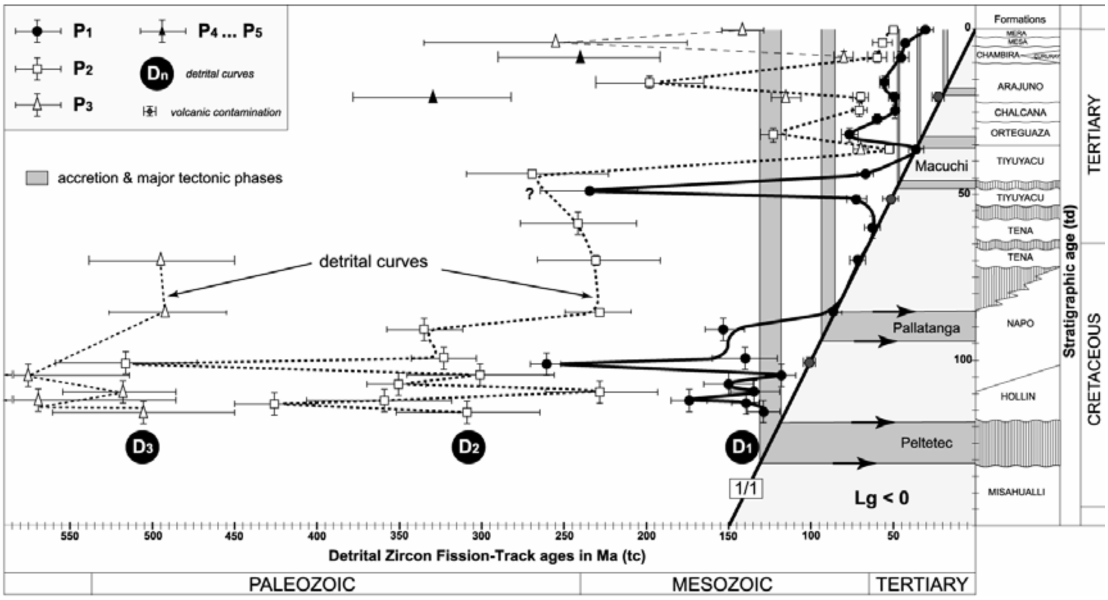

Figure 2: Detrital zircon fission-track age populations (DZFT) from the sedimentary formations of the northern Ecuadorian Subandean Zone. The y-axis represents the stratigraphic age (td) of the host sediment and the x-axis is the ZFT age (tc). Three detrital curves D_1, D_2 & D_3 linking the respective P_1, P_2 & P_3 DZFT age populations are drawn where possible.

Complementary constraints for the identification of source rocks, such as heavy mineral analysis (HM), also provide highly detailed information for diagnosing a large variety of source lithologies. Short-term cycles from ZTR (zircon-tourmaline-rutile) to metamorphic mineral grain dominance are observed stratigraphically upward within both members of the Eocene Tiyuyacu Fm., and the Oligocene Chalcana and Orteguaza Fms. These changes in the heavy mineral contents represent lithological variations within the source rocks from, reworked sediments or shields regions to (1) low to medium-grade, and even (2) high-grade metamorphic rocks. These observed cycles indicate the repeated exhumation and erosion of lower crustal levels that contributed, in variable proportions, to the sedimentary formations of the Ecuadorian AAB. Furthermore, the presence of older detrital zircon fission-track ages from the Tiyuyacu Fm. to the Orteguaza Fm. (Fig. 2) indicates a change of source region (Ruiz et al., 2002), which correlates with a change in the respective heavy mineral association.

CONCLUSIONS

1- The abundance of DZFT populations with Proterozoic and Middle Jurassic to Early Cretaceous ages in the Hollin Fm. (Aptian-Albian) suggests that several distinct source regions, which may have been significantly geographically dispersed, contributed to the early infilling of the AAB. The old populations indicate a probable sourcing in the Guyana-Brazilian Shield regions to the east (Fig. 1). Furthermore, the Early Cretaceous detrital zircon fission-track populations suggest a Late Jurassic-Early Cretaceous phase of exhumation along the Ecuadorian margin (Peltetec event?), which may be responsible for the 60 My hiatus between the Jurassic Misahualli volcanic arc and the overlying Middle Cretaceous AAB sedimentary sequence.

2- Rapid Coniacian/Santonian to Paleocene exhumation (>2 $mm.y^{-1}$) within the source region is coeval with the burial of the basement of the AAB in the northern SAZ. Exhumation during this period is synchronous with the accretion of the oceanic Pallatanga Terrane to the west and therefore may be considered as a minimum constraint for the accretion of the Pallatanga Terrane (e.g. Hughes and Pilatasig, 2002).

3- Distinct provenance changes during the Eocene were coeval with the deposition of proximal sedimentary facies in the AAB (Tiyuyacu Fm.), suggesting that the contemporaneous tectonic development along the Ecuadorian margin was more protracted. Rapid exhumation in the hinterland was restricted to the Middle to Late Eocene (Fig. 2), while lower crustal levels were eroding into the AAB. This phase probably ended with the final docking of the Macuchi oceanic island arc against the Ecuadorian margin where it currently constitutes part of the Cordillera Occidental (Fig. 1; Hughes and Pilatasig, 2002).

4- An almost constant lagtime of 25-35 My can be seen on the D_1 curve during the last 25 Ma (Fig. 2), which indicates that the sediments were being shed from relatively slowly exhuming regions. Therefore, the slow rise of the Eastern Cordillera during the Lower Miocene (Spikings et al., 2000), which was probably related to the break-up of the Farallon plate into the Nazca and Cocos plates at 27-25 Ma, may have sourced the AAB during the Miocene.

5- A clear change of provenance, characterized by the introduction of a pyroxene-olivine dominated heavy mineral assemblage, is observed between the Late Miocene Chambira Fm. and the Pliocene-Pleistocene Mesa and Mera Fms. Therefore, rocks with an oceanic affinity, such as those in the Western Cordillera and Interandean region, have been eroding into the AAB since the Pliocene suggesting a probable coeval exhumation of the region by this time.

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