# Reconstruction polyphased exhumation histories using detrital thermochronology, an example from the zircons of the northern Ecuadorian Sub-Andrean Zone

**Report**

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# *Reconstructing polyphased exhumation histories using detrital thermochronology, an example from the zircons of the northern Ecuadorian Sub-Andean Zone.*

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Abstract: Foreland basins developed along the eastern Andean margin as a response to the interaction of the subducting Nazca plate and the South American Craton. These basins contain sediments that were eroded from the cratons as well as the rising Cordilleras. Because information cannot be accurately traced within the orogens, an advanced thermochronological methodology based on changes in lagtime upwards in the stratigraphic column, combined with heavy mineral analysis, allowed events in the source regions to be distinguished. A detrital zircon fission track study of sediments from the Andean Foreland Basin in Ecuador, reveals in detail the distinct tectonic phases that affected the source regions- they are 140 - 125 Ma, 90 - 85 Ma, 55 - 52 Ma, 37 - 33 Ma and possibly 48 - 46 Ma.

Keywords: thermochronology, detrital, basin, exhumation, geodynamic.

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The study of the provenance of detrital material in sedimentary basins provides important clues in defining source regions and their development through time. Heavy mineral and modal sandstone composition analyses, preferably combined with palaeocurrent indicators, are examples of powerful methods that have often been used. Several workers (e.g. Zeitler et al., 1986, Cerveny et al., 1988) used changes in detrital grain ages through time in order to reconstruct the geodynamic development of the source region. This was a major innovative development because the source region has itself been eroded yet; information could be thus obtained on the tectonic development of the hinterland through dating of the eroded material. Many thermochronometers can be applied toward such investigations, ranging from the relatively high temperature thermochronometers $^{40}Ar/^{39}Ar$ on biotite, K-feldspar, hornblende or muscovite, through to fission-track on sphene, zircon or apatite, and, to the even lower temperature thermochronometer U-Th/He on apatite. Further, two or more of these radiometric methods can be combined but the results should be interpreted with care as complications can arise.

The aim of the study was to investigate the polyphased evolution of the Ecuadorian Andean margin through the study of the Ecuadorian Andean Amazon Basin (AAB) with particular reference to the region of the northern Ecuadorian Sub-Andean Zone (SAZ). Various post Late Jurassic accretionary events have been identified in the Andean Cordilleras, which were the potential sources for the SAZ sediments. However, information about the timing and exhumation rates during these events is not well constrained and it is now difficult to trace in the Cordilleras themselves because the record has since been removed by erosion. In a preliminary study, the thermal history of the basement from the northern SAZ was constrained using fission-track analysis on both zircon and apatite. The results reveal that the substratum of the sediments within the northern SAZ, dominantly Jurassic igneous sequences, has never undergone temperature higher than 100°C. Therefore, fission-track dating on zircons from the covering Cenozoic sediments provides true detrital ages. Detrital zircon fission-track age populations within the Cenozoic sedimentary pile were extracted from raw data using Gailbraith and Green's algorithm (1990).

Because ages vary upward within the stratigraphic column with conspicuous patterns, and because detrital ages cannot merely be restricted to the calculation of single temporal exhumation rates, we decided to investigate the meaning of such patterns. How do they vary upward within the stratigraphic column? What are the possible patterns within simple but characteristic tectonic settings? As a result, an empirical model based on variation in both lagtime (Naeser et al., 1979; Cerveny et al., 1988) and time of closure was envisaged. Five characteristic paths, i.e. type 1 to 5 were defined based on potential patterns of change with time (Fig. 1). This new methodology was used to interpret the detrital zircon fission-track

populations dataset from the northern SAZ, and consequently to constrain the geodynamic development of the Ecuadorian margin system. The results show that main accretionary events to the west of the AAB can be correlated with typical change of source region in the Detrital Zircon Fission-Track curves (type 1, Fig. 1 & 2) and are also associated with change in the heavy mineral content. Type 5 paths often follow accretionary events and correspond to acceleration of denudation within the source region (Fig. 2) that can reach values greater than 2 $km.my^{-1}$. On the basis of the shortest lag time, clear thermal events occurred in the source region during the following periods: 140 - 125 Ma, 90 - 85 Ma, 55 - 52 Ma, 37 - 33 Ma and possibly 48 - 46 Ma. This confirms known events with increased precision but additionally points to previously unknown tectonic pulses that we have been able to correlate to variations within the sedimentary column of the Andean Amazon Basin.

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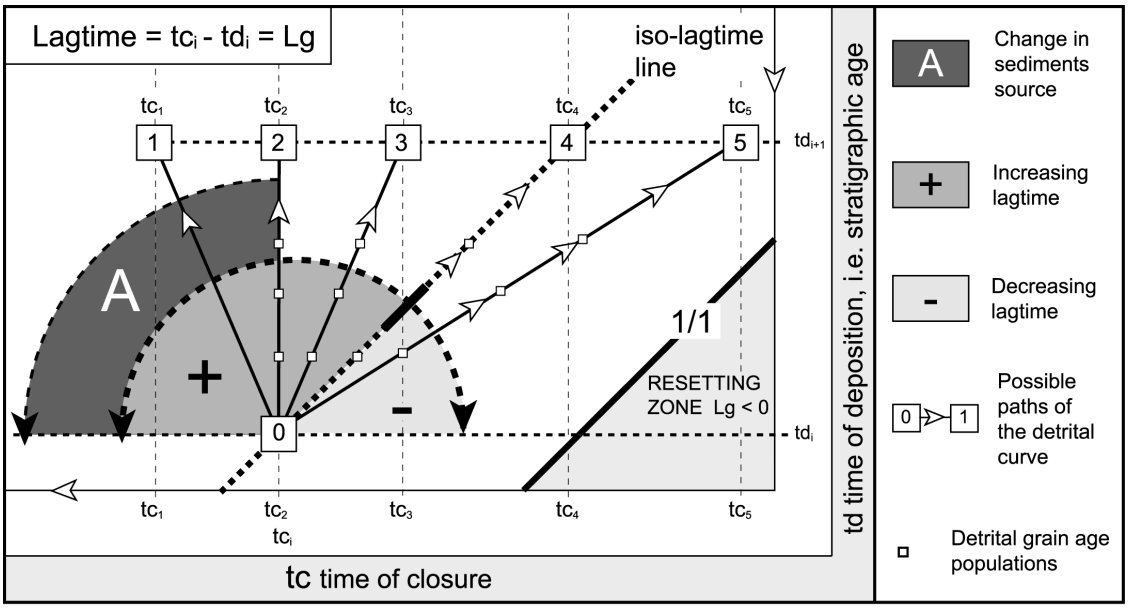


Figure 1: possible paths in the stratigraphic column within a detrital curve. Five paths are individualized on the base of variations in lagtime (Lg) and time of closure (tc). 0 [tci; tdi] is the starting point of all the paths that have the same incrementation within the stratigraphic column (tdi+1) to facilitate comparison. The 1/1 line and resetting zone are described elsewhere (Fig. 2).

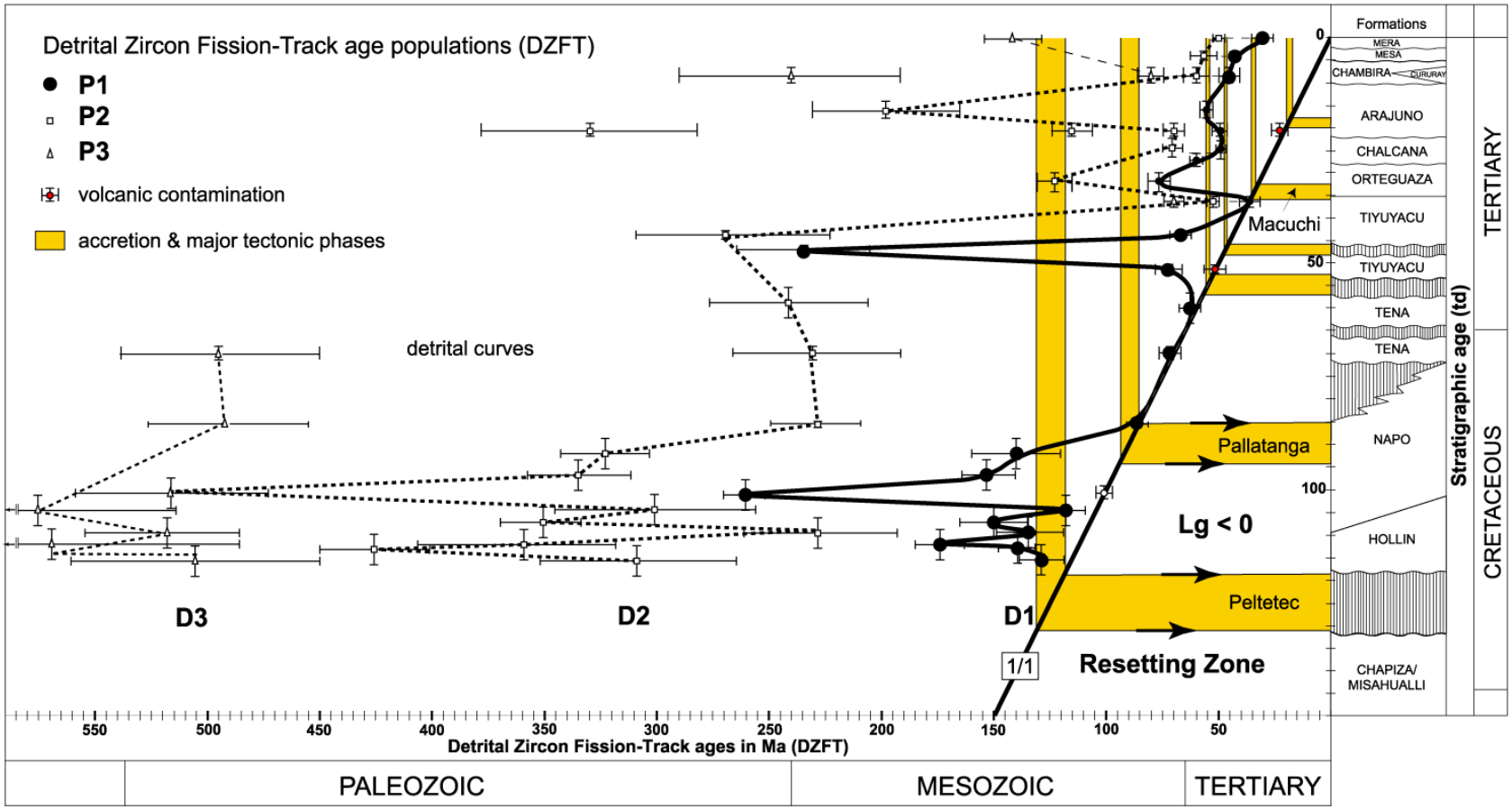


Figure 2: Detrital Zircon Fission-Track age populations (DZFT) from the sedimentary formations of the northern Ecuadorian Subandean Zone. The y-axis represents the stratigraphic age (td) of the hosting sediment when the x-axis is the ZFT age (tc). The dashed areas within the stratigraphic column are reported or supposed hiati. Three detrital curves D1, D2 & D3 linking the respective P1, P2 & P3 DZFT age populations are drawn when possible. The area right to the 1/1 correlation line corresponds to the resetting zone (Lg = tc - td < 0), i.e. a zone where a DZFT population should have been heated post-deposition of its hosting sediment.