The Andean Cordillera of Ecuador: timing and mode of orogenic growth as revealed from sediments in the Amazon Basin (heavy minerals and detrital zircon fission-tracks)

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The Ecuadorian Andean Cordillera represents a double-vergent orogenic belt, which generally comprises accreted oceanic plateau and arc series in the Cordillera Occidental (CO), and metamorphic continental basement and sedimentary series in the Cordillera Real (CR) (e.g. Spikings et al. 2001, 2005). The Andean Amazon Basin (AAB) of Ecuador developed to the east of the evolving Andean chain and to the west of the Amazon craton (Guyana Shield) from the mid-Cretaceous to the Recent. At least since the Maastrichtian (Tena Fm.), the basin shows the typical characteristics of a variable, very shallow marine to continental facies retro-arc foreland basin with respect to the growing orogen. Detrital provenance analyses (heavy minerals), and fission track (FT) thermochronology of detrital zircons (source rock exhumation ages) are used for monitoring the long lasting history of the supplying Andean chain and adjacent regions. The investigated samples are derived from the northern and southern Subandean zone (including the Napo and Tena uplift areas, respectively) and proximal parts of the Oriente Basin.

In the mid- to Late Cretaceous sediments (Hollin and Napo fms.), zircon-tourmaline-rutile dominated heavy mineral spectra (ZTR association) imply that the basin was supplied from non- and very low-grade metamorphic granitic source rocks (referred to as shallow continental crust provenance). Since the Maastrichtian (Tena Fm.) and during the Paleogene, an increasing amount of detrital medium-grade metamorphic grains (epidote-group, chloritoid and garnet) is observed. This is culminating with the further occurrence of high-grade metamorphic grains (kyanite, sillimanite) during the Neogene. This trend shows the continuous exhumation of deeper crustal levels in the supplying CR. The additional appearance of mafic minerals (augite, hypersthene, diopside, chromian spinel, olivine) infers that oceanic basement rocks in the CO started to contributed to the clastic supply since the Late Oligocene (post-dating a major accretionary event in the forearc). From other circumstantial arguments, it can be suggested that since the Late Miocene an orographic situation similar to today has existed.

The exhumation age of the detrital zircons was measured in the same sandstones as used for the heavy mineral analysis in the northern Subandean Zone (e.g. Ruiz et al. 2004). Various populations of detrital zircon FT ages were discriminated by statistical methods in the sandstone samples. The calculated lagtime (cooling/closure age minus depositional age), in assuming negligible time of transport of the grains into the basin, describes the time necessary for exhuming the source rocks from depth (ca 260°C) to the surface with subsequent re-sedimentation. Typical lagtimes are in the range between 0 My to 400 My (Fig. 1). The absence of lagtimes shorter than depositional ages proves that no post-depositional heating at the zircon FT annealing temperature has occurred.

The zircon FT age populations describe distinct population paths in time (D1-n in Fig. 1); the youngest population path (D1) is believed to portray closely the tectonic activity in the sediment source terranes. This is corroborated by the combined heavy mineral analysis. In considering two extreme cases: (1) decreasing lagtime, going even to zero is associated with increasing supply from metamorphic source rocks, and (2) increase of lagtime correlates with change to a new source blocks, which have experienced earlier cooling. However, a steady lagtime at frequent changes of sources is observed during the last 10-15 Ma of the orogenesis (Fig. 1).

The orogenic growth of the Andean cordillera in Ecuador is summarized as follows: The Early Cretaceous Peltetec compressive tectonic event has given rise of deep erosion of the earlier Misahualli volcanic arc, and the creation of a primordial CR. The subsequently forming Amazon Basin (Hollin and

Napo fms.) was supplied from the very slowly exhuming Amazon craton (D1), from Paleozoic-Early Mesozoic magmatic/volcanic and sedimentary rocks (D2), and from the moderately exhuming CR (D3) (Fig. 1). Decreasing lagtimes to zero during upper Napo and Tena time (Santonian-Maastrichtian) correlate with starting exhumation of medium-grade metamorphic source rocks in the rapidly exhuming CR, and with the vanishing of the Amazon cratonic source to the east, i.e. the CR became the main source of detrital material in proximal parts of the AAB. The corresponding decrease of lagtimes in path D2 corroborates that these supplying rocks also were situated in the rapidly exhuming CR. From Eocen until Oligocene, the exhumation of very high-grade metamorphics, the frequent changes of source rocks/drainage, respectively, and the radical decrease of lagtimes in path D2 infers a major phase of orogenic growth in the CR. Since ca 15-20 Ma (Miocene) the constant lagtime (30-40 My) associated with frequent change of source rocks represents preferential erosion of different blocks, that were being exhumed, but not sufficiently for the reset zircons to reach the surface. The relatively long lagtime, also seen in the modern river sediment, is possibly due to a regional exhumation event in the Late Eocene-Early Oligocene. Hence, the younger history of the Andean chain is rather characterized by moderate, but generalised uplift.

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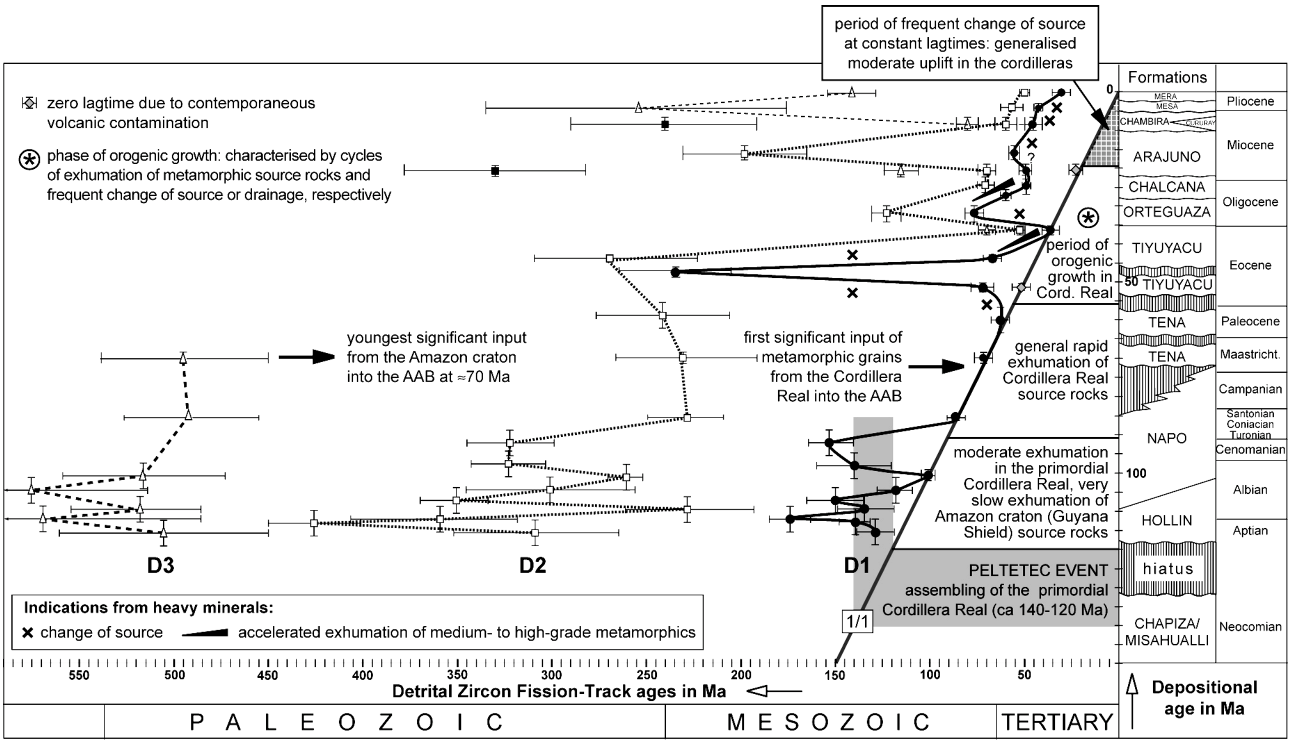

Figure 1. Detrital zircon fission track age populations correlated with heavy mineral variations in the proximal Andean Amazon Basin, including the interpretation of the active source areas and dynamics. 1/1 represents the stratigraphic correlation line, D1-D3 are population paths of the detrital zircon FT ages in time. Modified from Ruiz et al. (2004).