6th International Symposium on Andean Geodynamics (ISAG 2005, Barcelona), Extended Abstracts: 705-708

(U-Th)/He - derived thermochronological constraints on the post - middle Miocene tectonic history of the Ecuadorian Andes

R. A. Spikings [1], P. V. Crowhurst [2], & W. Winkler [3]

1. Minéralogie, Université de Genève, Rue des Maraîchers 13, CH-1205 Genève, Suisse; spikings@terre.unige.ch
2. CSIRO Petroleum, PO Box 1130, Bentley WA 6102, Australia; Peter.Crowhurst@csiro.au
3. Geologisches Institut, ETH-Zentrum, Zürich CH-8092, Switzerland; winkler@erdw.ethz.ch

KEYWORDS: Northern Andes, (U-Th)/He Thermochronology, Interandean Depression, Ecuador

Introduction

Numerous apatite fission-track (AFT) monocompositional thermal history (t-T) reconstructions from the Andean cordilleras have identified a single period of continual, linear cooling during 9±1 - 0 Ma along the entire orogen. However, the lack of sensitivity of the AFT method at temperatures <~60°C (Laslett et al., 1987), coupled with ambiguity regarding the initial conditions of track annealing (e.g. the length of an unannealed fission track; Jonckheere, 1996) suggests the AFT method may have frequently failed to resolve post- 9 Ma cooling histories. Consequently, the post 9 Ma cooling and exhumation rates reported in many cases are under-estimates as they simply average rates from more than one event over a time which is longer than the cumulative time of the individual events. The aim of this contribution is to try to improve the resolution of the thermal histories during the Miocene and post-Miocene period from the central and northern Eastern Cordillera of Ecuador using the (U-Th)/He thermochronological method, which can provide precise quantitative information about the thermal histories of rocks at temperatures lower than ~ 90°C. An enhanced spatial knowledge of the timing and rates of cooling during the Miocene and later in the Ecuadorian Andes is useful for identifying and quantifying the driving forces responsible for the development of the contemporaneous Andean Orogen, including the prominent Interandean Depression in the Northern Andes.

Results, thermal modelling and interpretation

Apatite (U-Th)/He ages have been determined from six samples from the Alao, Loja and Salado terranes along a traverse across the central Eastern Cordillera between the towns of Baños and Puyo, and a single sample was analysed from the northern Eastern Cordillera, along the Colombian border (Fig. 1). The ages used in the interpretation are weighted mean ages of individual aliquots, where the ages yielded by each aliquot are indistinguishable .

The variation in age data along the traverse across the Eastern Cordillera between the towns of Baños and Puyo in central Ecuador (Fig. 1) follows no distinctive geographic trend. All of the (U-Th)/He ages lie within a narrow range (10.4±0.9 – 2.1±0.01 Ma) relative to the AFT ages obtained from the same samples (41±11 to 11±2 Ma; Spikings et al., 2000). The youngest ages were obtained from Paleozoic schists and Triassic granites (Tres Lagunas Granite) of the Loja Terrane, which range between 3.8 ± 0.1 – 2.1 ± 0.01 Ma. A Jurassic schist of the Alao Terrane yielded the oldest age of 10.4 ± 0.9 Ma and intermediate ages of 8.7 ± 1.2 to 4.9 ± 0.7 Ma were obtained from the Jurassic Azafran Batholith along the Baños – Puyo traverse in the Salado Terrane. The

Azafran Batholith also yielded an age of 9.1 ± 0.4 Ma at the Colombian border, which is indistinguishable from ages yielded by the same granite further south.

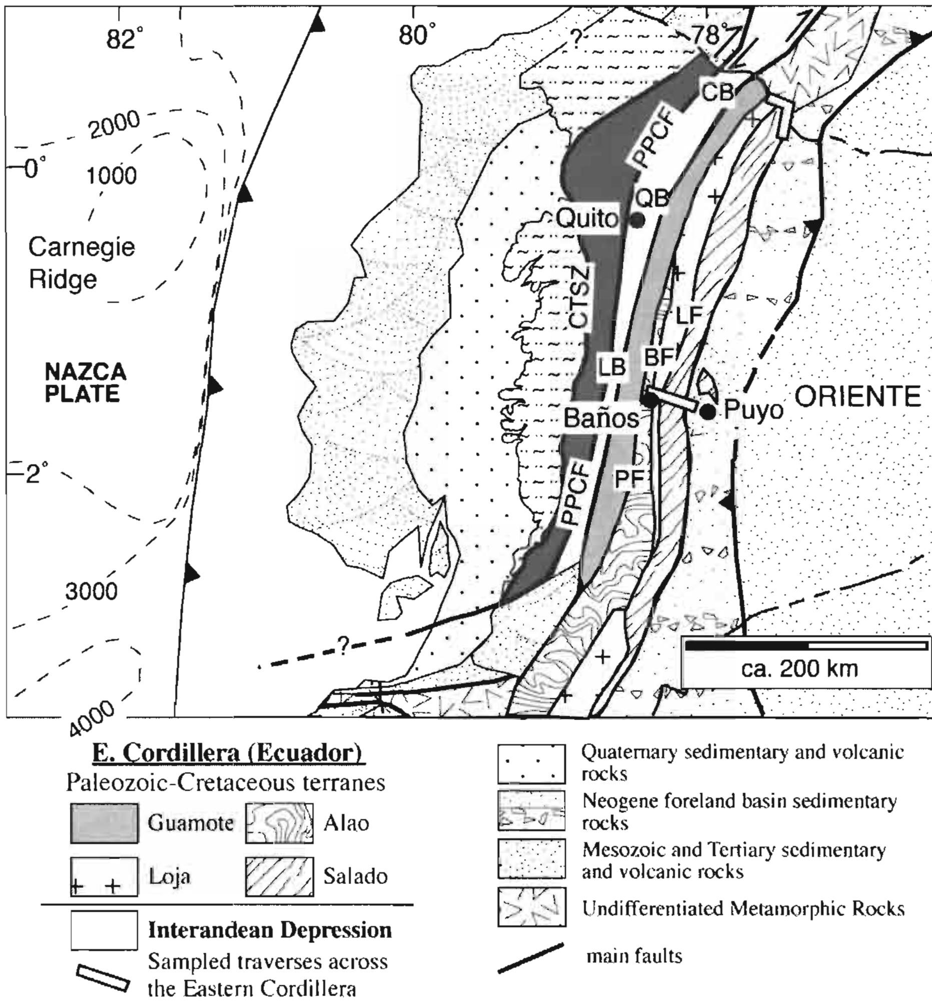

Figure 1. Faults - BF: Baños Fault, CTSZ: Chimbo-Toach Shear Zone, LF: Llanganates Fault, PF: Peltetec Fault, PPCF: Pujilí Fault. Basins: CB: Chota Basin, LB: Latacunga Basin, QB: Quito Basin

Forward modeling of the (U-Th)/He apatite age data (e.g. Farley, 2000; Spikings et al., 2004) from the Loja and Salado terranes in the central Eastern Cordillera suggests that cooling of the central cordillera since the early Late Miocene was not linear and occurred in discrete stages. Exhumation and cooling of the Loja Terrane commenced at sometime between 11 and 9 Ma and continued until ~ 3.2 Ma at rates of ~ 0.2 km/my (Fig. 2), which are comparable with those derived by the AFT data for the late Miocene – Recent (Spikings et al., 2000). However, exhumation rates in the westernmost Salado Terrane were significantly higher during 11 – 9 Ma and may have exceeded 1km/my. In contrast, fault blocks comprising the eastern Salado Terrane were thermally stable and hence probably tectonically quiescent during the late Miocene.

Moderately high exhumation rates were widespread throughout the sampled regions of the Loja and Salado terranes during a majority of the Pliocene. These elevated rates commenced during ~ 5.5 Ma to ~ 3.3 Ma and were typically ≤ 0.65 km/my (Fig. 2).

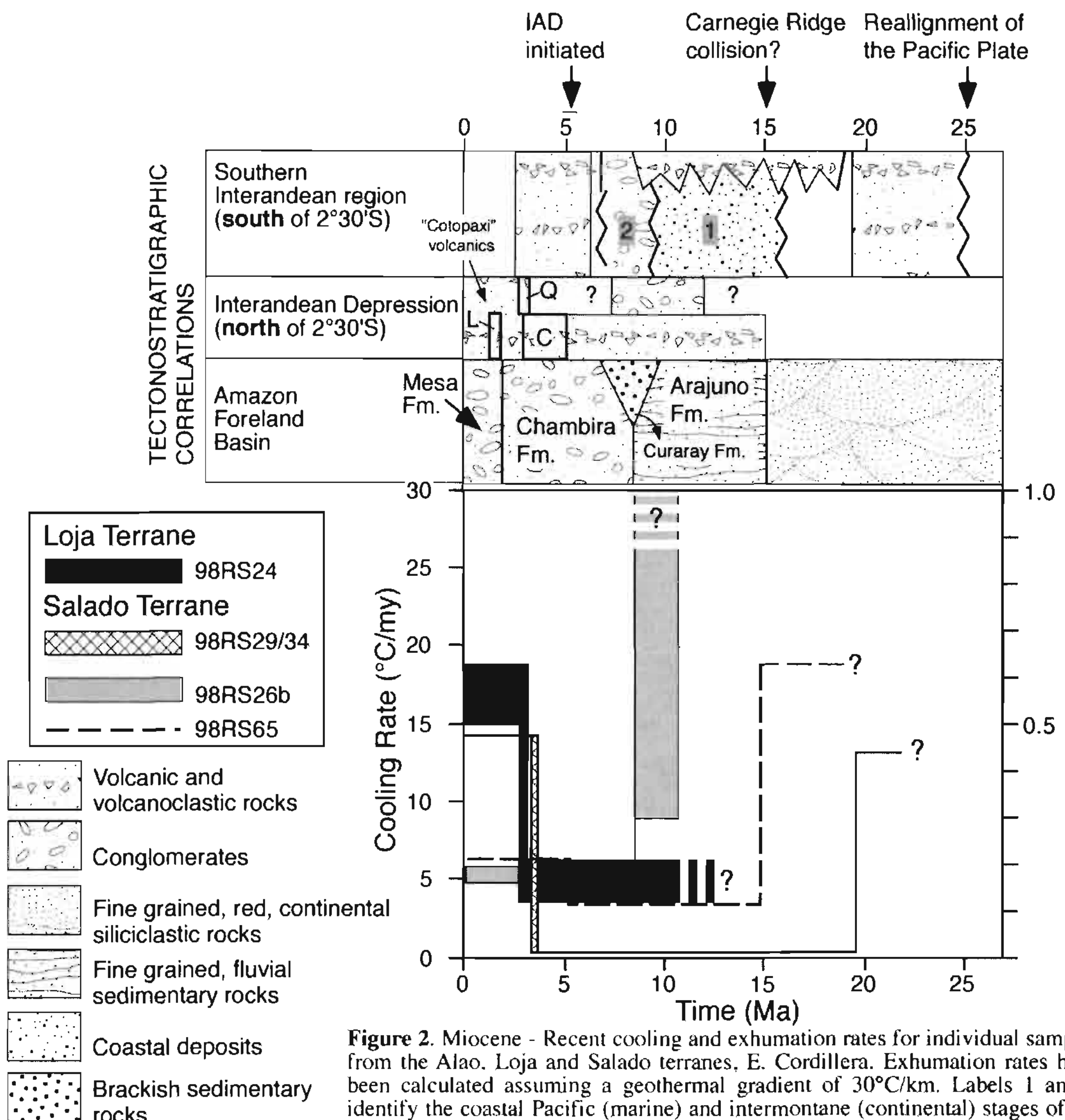

Figure 2. Miocene - Recent cooling and exhumation rates for individual samples from the Alao, Loja and Salado terranes, E. Cordillera. Exhumation rates have been calculated assuming a geothermal gradient of 30°C/km. Labels 1 and 2 identify the coastal Pacific (marine) and intermontane (continental) stages of the southern Interandean region (Steinmann et al., 1999). Labels C, L and Q note the basal sedimentary units of the Chota, Latacunga and Quito basins respecitvely.

Southward younging Pliocene cooling and exhumation ages in the Eastern Cordillera corroborate the trends in timing of inception of basins that reside in the Interandean Depression (Fig. 2), which juxtaposes against the Eastern Cordillera to the west (Fig. 1). From north to south, these basins (Fig. 1) are the Chota Basin (inception at 5.4±0.4 Ma; Winkler et al., 2002; Fig. 4), the Quito Basin (younger than 3.5±0.1 Ma; Barberi et al., 1988) and the Latacunga Basin (younger than ~2.7 Ma; Lavenu et al., 1992). Elevated Pliocene exhumation rates initially occurred in the northern cordillera at ~ 5.5 – 4.5 Ma whereas uplift and erosion of faulted blocks in the central Cordillera (same latitude as the Latacunga Basin) commenced after ~ 3.7 Ma. Therefore, the progressive southward uplift of the Cordillera during the Pliocene, matches the trend in inception of basins within the Interandean Depression. The Interandean Depression is believed to have been forming since ~ 6 Ma in a transcurrent setting, resulting in the progressive southward opening of the depression and uplift of the flanks from north to south, in a ramp setting (e.g. Winkler et al., 2002). Therefore, it is likely that the Pliocene exhumation ages from the Cordillera Real are a direct consequence of a transpressional tectonic regime, that lead to the formation of the Interandean Depression.

A comparison of the exhumation rates of individual samples in the Salado Terrane within the central cordillera suggests that exhumation of fault blocks propagated eastwards during the Late Miocene – Recent. Exhumation rates of fault blocks within the westernmost Salado Terrane progressively reduced throughout the late Miocene - Pliocene from ~ ≥1 - 0.5 km/my during 11 – 9 Ma to ~ 0.2 km/my during 9 – 3.7 Ma. Subsequently, exhumation rates have been greater in the central Salado Terrane since ~ 3.7 Ma. Foreland (eastward) propagating reverse faulting throughout the Salado Terrane in central regions of the cordillera may be a consequence of migrating zones of subducted high relief on the Carnegie Ridge. Alternatively, it may reflect the progressive widening of the transcurrent or pure thrust system that is responsible for generating the topography of the Interandean Depression.

A linear relationship between (U-Th)/He age and altitude within the Alao and Loja terranes suggests that they have defined a single, coherent fault bounded block since at least the middle Miocene. This region cooled at rates greater than those located further east in the Salado Terrane after ~ 3.3 Ma (Fig. 2). Consequently, reactivation of the Llanganates Fault, which separates the postulated coherent block from the Salado Terrane, was probably responsible for higher exhumation rates in the west than in individual fault blocks to the east. Assuming a geothermal gradient of 30°C/km and flat isotherms, we can calculate that a difference of 1.2 – 1.0 km of exhumation has occurred across the Llanganates Fault since 3.3 Ma. The lack of detectable vertical displacement across the postulated Baños Fault (which separates the Alao Terrane from the Loja Terrane; Fig. 1) supports the suggestion of Pratt et al. (2002) that the contact between the Alao and Loja terranes may in fact be intrusive, as opposed to faulted (Litherland et al., 1994).

References

Barberi, F., Coltelli, M. Ferrara, G., Innocenti, F., Navarro, J.M., Santacroce, R., 1988. Geological Magazine 125, 1 -14.

Farley, K.A., 2002. In: Porcelli, D., Ballentine, C. J. and Wieler, R. (Eds), Reviews in Mineralogy and Geochemistry 47, 819 - 843.

Jonckheere, R., 1996. International Workshop on Fission-Track Dating, Gent, Belgium, p. 62.

Laslett, G.M., Green P.F., Duddy I.R., Gleadow A.J.W., 1987. Chemical Geology 65, 1–15.

Lavenu, A., Noblet, C., Bonhomme, M.G., Egüez, A., Dugas, F., Vivier, G., 1992. Journal of South American Earth Sciences 5, 309 - 320.

Litherland, M., Aspden, J., Jemielita, R.A., 1994. Overseas Memoir 11, British Geological Survey, pp. 147.

Pratt, W., T., Duque, P., Ponce, M., 2002. 5th ISAG, Toulouse, France, 485 – 488. Spikings, R.A., Seward D., Winkler W., Ruiz G., 2000. Tectonics 19,649-668.

Spikings, R.A., Crowhurst, P.V., 2004. Journal of South American Earth Sciences 17, 239 – 251.

Steinmann, M., Hungerbühler, D., Seward, D., Winkler, W., 1999. Tectonophysics 307, 255 – 276.

Winkler, W., Spikings, R., Villagomez, D., Eguez, A., Tobler. S., Abegglen, P., 2002. 5th ISAG, Toulouse, France, 705 – 708.