6th International Symposium on Andean Geodynamics (ISAG 2005, Barcelona), Extended Abstracts: 305-307

Uplift and exhumation of the northern Peruvian Andes

J. I. Garver [1], M. Montario [2], S. E. Perry [2], P. W. Reiners [3], & J. R. Ramage [4]

(1) Geology Department, Union College, Schenectady NY 12308 USA
(2) Dept of Earth and Atmospheric Sciences, ES 351, University at Albany, Albany NY 12222
(3) Geology and Geophysics, Yale University, P.O. Box 208109, New Haven, CT 06520-8109 USA
(4) Earth and Environmental Sciences, 31 Williams Hall, Lehigh University, Bethlehem, PA 18015, USA

Introduction

The north central Peruvian Andes (c. 9-11°S) are divided into the Cordillera Oriental and the Cordillera Occidental. Uplift of this part of the Andes has occurred since ~10-20 Ma, and since that time deep canyons have been incised (3-4 km of relief) and rugged ranges have been emerged along the crest of the uplift (peak elevations 5-7 km and relief of 3-4 km). High-relief ranges are distinct in the Cordillera Oriental, which has the highest peaks in Peru: these include Huscaran (6768 m) in the Cordillera Blanca, and Yerupaja (6634 m) in the Cordillera Huayhuash. These ranges represent the largest glaciated region in equatorial South America, and therefore glacial erosion rates are presumably higher than adjacent areas. Deep canyon incision has been profound in Pacific-draining rivers that have their source in this glaciated terrain. These deeply incised rivers include the Rio Santa, which drains the Cordillera Blanca, and the Rio Pativilica, which drains the Cordillera Huayhuash.

The timing of uplift and local intense exhumation varies along strike, but the majority of regional uplift is generally viewed as being Miocene to Plio-Pleistocene. We have focused our thermochronological studies on three areas in this region. 1) The Cordillera Blanca, along the Andean crest and which is bound on its western edge by the Active Cordillera Blanca Normal Fault; 2) the Cordillera Huayhuash, also along the crest of Andes, south of the Blanca, and 3) The Rio Pativilica, whose headwaters drain the Cordillera Huayhuash.

Cordillera Blanca

The Cordillera Blanca is an orogen-parallel, glaciated range with high relief and rugged topography that sits along the drainage divide of the Andes. The range is largely composed of granodiorites of Miocene Cordillera Blanca Batholith intruded at 2-4 Kb and were exhumed rapidly from the Pliocene to the Holocene. The Cordillera Blanca is bounded to the west by the Cordillera Blanca Normal fault (CBNF), which is a 200-km-long range-bounding, west-dipping, active normal fault. This fault accommodates extension nearly perpendicular to the orogenic belt and this extension in the high Andes coincides with contraction in the Sub-Andean fold and thrust belt in the same part of the system but at lower elevations. Sixty fission track ages on zircon (ZFT) and apatite (AFT) constrain the timing of footwall exhumation and thermal events in the hanging wall. Initiation of footwall exhumation occurred c. 5 to 6 Ma, and this exhumation coincides with the onset of sedimentation in the Callejon de Huaylas basin, which sits piggyback on the hanging wall. Exhumation has been fastest and most profound in the center of the range, where modern relief and topography is greatest. ZFT cooling ages decrease systematically away from the CBNF, and cooling ages also decrease from the central part of the range, southward to the termination of the fault where pre-orogenic cooling ages occur in cover rock. Based on $^{40}Ar/^{39}Ar$, ZFT, and AFT age in Llanganuco, exhumation appears to have been most rapid in this center part of the range from c. 4-2 Ma and then slower from c. 2-0 Ma, but these rates are difficult to resolve due to low precision of the cooling ages. This deceleration since c. 2.0 Ma, may be linked to a change in regional tectonic regime from extension to contraction between 2.0-2.5 Ma (Garver and Rodbell, 2002; Garver et al., 2003, Perry and Garver, 2004).

Cordillera Huayhuash

Cordillera Huayhuash is a north-south-oriented range that also sits along the drainage divide of the northern Peruvian Andes, but it is not fault bounded. The range has high topography with peaks in excess of 5500 m and the second highest peak in Perú, Nevados Yerupaja (6,617 m). Bedrock is dominated by folded Mesozoic miogeoclinal rocks unconformably overlain by mid-Tertiary volcanics intruded by late Tertiary granitic rocks and silicic dikes. Twenty-five fission track ages of zircon and apatite and helium ages on apatite (AHe) and zircon (ZHe) elucidate the thermal evolution of exhumed and uplifted rocks. ZFT ages from rocks in core of the range yield single mean reset age of c. 11 Ma. Together the ZFT and ZHe cooling ages near the core of the range indicate moderate to rapid post-intrusive cooling in the Miocene, and a high geothermal gradient (c. 40-50°C/km). This widespread cooling age represents a falling geotherm, not a period of significant exhumation. Estimation of the thickness of pre-exhumation cover-rock suggest nearly 5 km of unroofing has occurred since c. 6 Ma. Erosional exhumation was driven by valley incision initiated by uplift of this part of the Andes between 5-6 Ma. The high topography may have been formed by isostatic response to canyon incision. Assuming a geothermal gradient between 25 and 50°C/km, this cooling would imply exhumation rates of 250 to 1300 m/Myr from 10 to 6 Ma (Garver et al., 2004; Walker and Garver, 2004; Garver et al., 2005; Garver 2005; Bernet and Garver, in press).

Canyon Incision - Rio Pativilica

Since the Peruvian Andes have been uplifted to present elevations of 4 km, deep canyons (with 3 to 3.5 km of relief) have been incised along the western flanks of the range. Previous workers have demonstrated by regional mapping, that distinctive geomorphologic surfaces suggest two main erosional stages record the progressive uplift and erosion of the flanks of the Andes. Both of these surfaces cut the Puna surface, which is a flat erosional surface that is widely thought to predate uplift. The Vallé surface represents ~2-2.5 km of incision into the Puna Surface, and locally these valleys are filled with Late Miocene ignimbrites that we have dated as c. 6 Ma. The second phase of erosion is the Cañón Stage, which involves deep incision into the Puna and Valle surfaces. The Cañón incision phase represents ~2.5-3 km of further incision that follows Vallé stage erosion. The Rio Pativilca Valley, which has its headwaters in the Cordillera Huayhuash, cuts deeply into the edge of the uplift and its maximum incision is ~3.5 km. FT and Helium dates from thirteen samples from the Cretaceous Coastal Batholith provide insight into the link between uplift and progressive incision. Calculated erosion rates using AFT and AHe cooling ages suggest slow erosion rates (c. 50 m/Myr) up to about 18 Ma. From 18-6 Ma, rates increased to about 150 M/Myr and this is inferred to represent Valle stage of incision. From 6-0 Ma rates apparently increased to 300-400 m/Myr and this phase of incision is inferred to represent the Cañón stage of erosion and incision (Montario et al., 2005). Calculated erosion rates using AFT-AHE and AHE to Surface pairs from the Rio Pativilca of 75 m/myr indicate that the Puna surface is pre 17 Ma. Erosion Rates of ~200 m/myr indicate the Vallé stage or initial uplift is Miocene starting at 17-19 Ma and continuing until 4-6 Ma. Increased rates of 400 m/myr indicate the Cañón stage is Pliocene to Holocene starting at 4-6 Ma. (Montario et al., 2005).

Combined these three adjacent study areas provide an integrated view of uplift that was accompanied by exhumation of rocks along then crest of the Andes, and canyon incision along the flanks. These ages constraints suggest uplift here is slightly younger than uplift of the Altiplano-Puna farther to the south, thus supporting northward progression of uplift in this part of the Andes.

References

Bernet, M., and Garver, J.I., in press, Chapter 8: Fission-track analysis of detrital zircon, *In* P.W. Reiners, and T. Ehlers, (eds.), Low-Temperature thermochronology, Reviews in Mineralogy and Geochemistry Series.

Garver, J.I., 2005. Stability of fission tracks in radiation-damaged zircon from the Cordillera Huayhuash, northern Peru. Geological Society of America Abstracts with Programs, v. 37, n. 1, p. 76.

Garver, J.I., and Rodbell, D.T., 2002. Fission-track evidence for rapid tectonic exhumation of the Cordillera Blanca, Peru; Geological Society of America Abstract with Programs, v 34, n. 6, p. 376.

Garver, J.I., Reiners, P.R., Walker, L.J., Ramage, J.M., Perry, S.E., 2005, Implications for timing of Andean uplift based on thermal resetting of radiation-damaged zircon in the Cordillera Huayhuash, northern Perú, Journal of Geology, v. 113, n. 2, p. 117-138.

Garver, J.I., Schiffman, C.R., Perry, S.E., 2003, Rapid tectonic exhumation of the Cordillera Blanca, Geological Society of America Abstracts with Programs, v. 35, n. 6, p. 429.

Garver, J.I., Soloviev, A.V., Reiners, P.W., 2004, Field observations of the stability of fission tracks in radiation-damaged zircon, 10th International Fission track conference, Amsterdam, Abstract volume, p. 56.

Montario, M., Garver, J.I., Reiners, P., Ramage, J., 2005, Timing of canyon incision of the Rio Pativilica in response to uplift of the Andes in Northern Peru. Geological Society of America Abstracts with Programs, v. 37, n. 1, p. 76.

Perry, S.E., and Garver, J.I., 2004, Onset of tectonic exhumation of the Cordillera Blanca, Northern Perú, based on of fission-track and U+Th/He dating of zircon, Geological Society of America Abstracts with Programs, v. 36, n. 2, p. 92.

Walker, L.J., and Garver, J.I., 2004, Uplift and exhumation of the Cordillera Huayhuash, northern Perú, based on U+Th/He and fission-track dating of zircon, Geological Society of America Abstracts with Programs, v. 36, n. 2, p. 74