Tectonic geomorphology, ^{40}Ar/^{39}Ar thermochronology, and sedimentology of the Cordillera Blanca normal fault, central Peruvian Andes

Melissa K. Giovanni (1), Brian K. Horton (1), Gilles Peltzer (1), Marty Grove (1), & Brendan McNulty (2)

(1) Dept. of Earth & Space Sciences, University of California Los Angeles, Los Angeles, CA, 90095 USA, (giovanni@ess.ucla.edu; horton@ess.ucla.edu; peltzer@ess.ucla.edu; marty@argon.ess.ucla.edu)
(2) Dept. of Earth Sciences, California State University Dominguez Hills, Carson, CA 90747 USA, (bmcnulty@csudh.edu)

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INTRODUCTION

The Cordillera Blanca is the highest range in the Peruvian Andes and poses a fundamental geologic problem. Despite regional ENE-WSW compression related to flat-slab subduction of the Nazca plate beneath South America, the Cordillera Blanca is bounded by an active low-angle normal fault. The spectacularly exposed fault is >250 kilometers long, strikes 330°, and parallels the Peru trench at 8.5-10°S. Fault scarps cutting glacial moraines show that the fault has been active during Quaternary time. The Cordillera Blanca normal fault dips 25-40° WSW and overlies a ~1-km-thick mylonite zone within a footwall composed of the late Miocene Cordillera Blanca granite batholith (McNulty and Farber, 2002). The hanging wall of the normal fault includes the Callejon de Huaylas supradetachment basin which contains 8.7-7.5 Ma volcanic rocks and an Upper Miocene-Pliocene succession of nonmarine sedimentary rocks. The key questions we hope to address are:

(1) What are the timing and magnitude of exhumation and fault slip in the Cordillera Blanca?

(2) What are the temporal and spatial variations in exhumation, fault slip, and basin development along the Cordillera Blanca normal fault?

(3) How are climate and erosion related to evolution of the Cordillera Blanca normal fault?

(4) What are the tectonic and geomorphic implications of the deep glacial valleys that incise the entire width of the batholith?

(5) How is evolution of the Cordillera Blanca related to Nazca – South America convergence and flat-slab subduction?

GEOLOGIC SETTING

The Cordillera Blanca forms the highest topography in the Peruvian Andes. The range is extensively glaciated, with major valleys oriented perpendicular to the NNW-striking, range-bounding fault (Fig. 1). The footwall contains the Cordillera Blanca granodiorite batholith emplaced at ~8.2 Ma (U-Pb zircon ages; McNulty et al., 1998) and Jurassic-Cretaceous metasedimentary rocks. ^{40}Ar/^{39}Ar cooling histories for granite samples obtained from traverses normal to the fault, both along the exposed fault scarp and along glaciated valleys, help delineate the exhumation history of the footwall. The hanging wall contains nonmarine clastic fill and volcanic rocks attributed to fault-induced subsidence. The Callejon de Huaylas supradetachment basin is exposed only as isolated outcrops of the upper Miocene-Pliocene Lloclla Formation along the southern segment of the fault.

Along the northern segment of the fault, the hanging wall has no exposures of the Lloclla Formation but contains the upper Miocene Yungay volcanic deposit. Total offset along the fault is poorly constrained but may exceed 10 kilometers, based on an estimated granite emplacement pressure of 3 kbar (Petford and Atherton, 1992; McNulty and Farber, 2002). Kinematic indicators for the footwall mylonite and brittle fault both show consistent down-to-the-west dip slip with some oblique slip.

RESULTS

Thermochronologic data for the Cordillera Blanca indicate rapid along- and across-strike variations in late Cenozoic exhumation. Potassium feldspar ages increase away from the fault. Results from the Quebrada Honda transect are shown in Figure 2. ^{40}Ar/^{39}Ar age spectra were modeled with multi-domain diffusion (MDD) models to produce cooling histories. The youngest sample (HON1) underwent the most recent and rapid cooling at ~5-3 Ma. Samples in the footwall interior (HON3 and HON6) experienced rapid cooling at ~8-5 Ma, prior to HON1. These results are consistent with footwall tilting during faulting. Samples from northern and southern transects are currently being analyzed with similar across-strike cooling histories. Determining the along-strike variations is the next step.

The sedimentology of the Callejon de Huaylas supradetachment basin is represented in a ~1300-m-thick succession of nonmarine clastic sediments. The upper Miocene-Pliocene Llocla Formation is exposed along the central to southern fault segment (L in Fig. 1). A basal tuff yields an ^{40}Ar/^{39}Ar biotite age of 5.35 ± 0.10 Ma, constraining initial basin evolution. The lower levels of the section are dominated by lacustrine, fan-delta, and distal alluvial facies; upper levels contain coarse-grained, proximal alluvial-fan facies. We attribute the onset of clastic sediment accumulation to initial motion along the basin-bounding Cordillera Blanca normal fault. However, the northern segment of the hanging wall lacks outcrop of the Llocla Formation and contains the 8.7-7.5 Ma Yungay volcanic rocks (Y in Fig.1). With no significant clastic sedimentation to the north, extensional basin development seems to have been limited to localized regions along the fault. This implies that there is no direct correlation between slip magnitude and sediment accumulation. However, the age of the Yungay volcanics do correspond to the timing of cessation of volcanism which McNulty and Farber (2002) attribute to the flattening of the slab beneath Peru due to subduction of the aseismic Nazca Ridge.

From the thermochronologic data, we tentatively interpret maximum slip in along the central fault segment with diminished slip to the north and south, but topographic profiles obtained from DEM data show a pronounced decrease in relief and increase in elevation southward along strike (Fig. 1). The fault dip is greatest in the north and decreases to the south. For example, transect 2 (Fig. 1) has the greatest amount of down-dip exposure of the fault (~2.5 km), while transect 9, while at higher elevations, has < 1 km of down-dip fault exposure. ASTER, DEM, and Landsat data are being used to analyze this along-strike variability in topography and to consider any links to the exhumational history of the fault. The large amount of relief to the north may be due to greater slip along the northernmost segment of the fault.

On the basis of the sedimentary record from the Llocla Formation and ^{40}Ar/^{39}Ar thermochronology of potassium feldspars from Quebrada Honda, we conclude that the Cordillera Blanca normal fault was active between 5-3 Ma.

References

McNulty, B.A., Farber, D.L., Wallace, G.S., Lopez, R., and Palacios, O., 1998, Role of plate kinematics and plate-slip-vector partitioning in continental magmatic arcs: Evidence from the Cordillera Blanca, Peru, *Geology*, v. 26, p. 827-830.

McNulty, B., and Farber, D.L., 2002, Active detachment faulting above the Peruvian flat slab, *Geology*, v.30, p. 567-570.

Petford, N., and Atherton, M.P., 1992, Granitoid emplacement and deformation along a major crustal lineament: the Cordillera Blanca, Peru, *Tectonophysics*, v. 205, p. 171-185.