THE DYNAMIC FOREARC OF SOUTHERN PERU

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Recently, there has been a renewed interest in models of active tectonic and climatologic processes along the Andean margin. While many new studies in the forearc regions of southern Peru and northern Chile have presented data constraining morphotectonic chronologies as well as the rates of surface process, there has yet to be a complete synthesis of these new data. As recently as ~5 years ago, the preferred working model was that most of the low-relief surfaces within the Atacama Desert were ancient relict surfaces abandoned >7Ma due to incision caused by periods of intense surface uplift (Tosdal et al., 1984), and that the western limb of the Altiplano is a passive monocline with no significant Neogene structures accommodating deformation (Isacks, 1988). Until recently, documented active deformation was limited to major strike-slip and normal faults in the Precordillera, that are respectively related to oblique subduction and gravitational collapse of the western margin of the Altiplano (Wörner et al., 2002). Extensional features, oriented both perpendicular and parallel to the coast, were also mapped (Hartley et al., 2000), however very little was known about the slip history, kinematics or rates of motion along these structures.

Using the combination of remote sensing with high-resolution data, in situ cosmogenic isotope concentrations and thermochronology, in recent years the scientific community has made important advances in addressing the rates, timings, styles, and locations of active deformation within the forearc of the Andean margin. Specifically, we see 1) ancient surfaces reflecting erosion rates as low as <0.1m/Ma (Kober et al., 2005; Nishiizumi et al., 2005; Hall et al., *to be published*) are well preserved in the forearcs of both Peru and Chile, 2) the existence of young (30ka-1Ma) low-relief pediment surfaces due to recent landscape modifications (Hall et al., *in press*), 3) active structures accommodating compressional, tensional, and shearing stresses in numerous localities within the forearc (Allmendinger et al., 2005a; Gonzalez et al., 2006; Hall et al., *in press*; Audin, et al., *in press*), 4) a consistent rate of river incision of ~0.3mm/yr along exoreic rivers (Hall et al., *to be published*), 5) uplift rates that been variable in time and space with pulses throughout the last 10Ma (Schildgen et al., 2007; Saillard et al., *in review*) and 6) instantaneous modern forearc rotation rates are similar to time integrated rates over the past 10Ma (Allmendinger et al., 2005b).

To first order, we find that the Andean forearc during the last 10Ma has been quite a dynamic region, both in terms of tectonics and climate. The coastal Atacama Desert is situated in a zone that has been hyperarid for at least the last 3My and this has contributed to the high degree of geomorphic surface preservation in this region (Hartley, 2003). Indeed, in an area spanning of over 11 degrees of latitude, erosion rates based on cosmogenic isotope concentrations are consistently less than 0.1m/Ma (Kober et al., 2005; Nishiizumi et al., 2005; Hall et al., *to be published*). On shorter timescales, changes in precipitation may enhance or dampen incision rates (i.e. during a glacial-interglacial transition the increased discharge and tools may enhance valley incision), however ultimately the amount of potential base-level change is set by surface uplift or sea level change. Thus, the exact timing of periods of more intense incision may correspond with climate events, but the total amount of incision over time is useful for tectonic interpretations. Based on zircon and apatite (U-Th)/He ages, Schildgen et al. (2007) interpreted periods of more intense canyon incision along the Rio Majes in southern Peru (16˚S). Specifically, from the period 5.1-2.3 Ma, 1.4 km of incision occurred yielding an incision rate of ~0.5mm/yr and an additional older period of 1 km of incision from 9-5.1 Ma yielding a rate of ~0.25mm/yr. Thouret et al. (2007) suggest incision rates of ~0.2mm/yr since 9Ma in a similar area of southern Peru. Our recent work suggests that these incision rates are very similar to measured time integrated rates since the Pleistocene on the major exoreic rivers (Hall et al., *in press*; Hall et al., *to be published*). Along the Rio Sama, Rio Locumba, and the Rio Osmore of southern Peru, we have mapped sequences of well-preserved strath terraces and dated (along the Rio Sama and Rio Locumba) these using cosmogenic ^{10}Be. Our work yields a consistent set of incision rates of ~0.3 ± 0.1mm/yr (Figure 1). Further, where these rivers are cut by active structures, the local incision rate determined near the knick-point reaches 0.8 mm/yr.

Along the three major drainages of southernmost Peru, we have mapped multiple flexures trending sub-parallel to the coast and the Western Cordillera. In many cases, these flexures correspond to abrupt changes in river incision and topography. Along the Rio Sama, the largest of these flexures is produced by a propagating hanging-wall anticline above a blind thrust (Figure 1). The youthfulness of this feature is suggested by the deflection of active channels around the propagating tip of the anticline and by young (~30-500ka) surface exposure ages on terraces along those active channels (Hall et al., *to be published*).

Schildgen et al. (2007) conclude that the pattern of apatite and zircon U-Th/He ages along the Rio Majes (16˚S) either supports the Isacks (1988) monocline hypothesis assisted mechanistically by lower crustal ductile flow or reflects distributed forearc deformation along multiple non-surface breaking, or un-mapped faults. While our work highlights role of contractile deformation in the southern Peruvian forearc, contractile structures trending sub-parallel to the range front have also previously been observed in Northern Chile (Oxaya anticline; Victor et al., 2004; Garcia and Hérail, 2005; Kober et al., 2005). While based on our mapping and chronologic data we cannot rule out a role for lower-crustal ductile flow in the forearc of southern Peru and northern Chile (Husson and Sempere, 2003; Hoke et al., 2007; Schildgen et al., 2007), our observations of surface breaking and blind reverse faults as well as active hanging-wall anticlines shows that a significant amount of uplift is accommodated in contractile structures in the Precordillera of southernmost Peru.

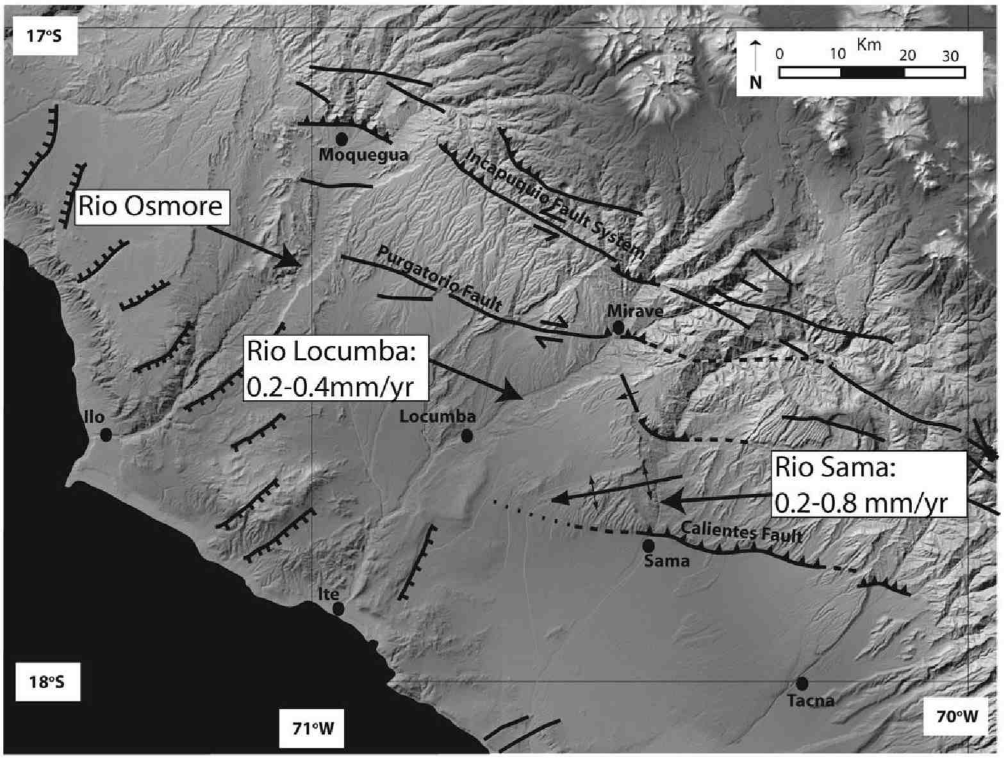

Figure 1. The forearc of southern Peru. Structures active during the Pleistocene include the Purgatorio Fault, the Incapuquio Fault System, and the Calientes Fault, in addition to some of the normal faults along the coast including the Chololo Fault (Audin, et al., *in press*) near the town of Ilo. Incision rates based on cosmogenic ^{10}Be concentrations are 0.2-0.4 mm/yr in major drainages and up to 0.8mm/yr near active structures (Calientes Fault). The vast incised late Pliocene and Pleistocene pediment surfaces north of the Purgatorio Fault suggest surface uplift has driven incision and abandonment of these surfaces during the past ~2Ma.

In this light, any additional as of yet unmapped active contractile structures reduce the need to call on lower-crustal ductile flow to accommodate surface uplift in this area. Given the limited number of field sites that have been studied in detail, it is not unreasonable to suggest there is a high likelihood that more active contractile structures exist in this region of the Peruvian forearc.

In summary, the geomorphic and structural features in this region of southern Peru provide strong evidence of distributed crustal deformation along range-sub-parallel contractile and strike-slip structures. The observation that Pleistocene incision rates are comparable with Late Miocene and Pliocene rates suggests to us that the rates and style of surface uplift within the forearc of southern Peru has been ongoing and consistent (on the timescale of 1 Myr) during the past 10Ma.

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