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ONGOING INVESTIGATION OF HOLOCENE GLACIER FLUCTUATIONS IN THE CORDILLERA VILCABAMBA OF SOUTHERN PERU

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INTRODUCTION

The role of the tropics in triggering, transmitting, and amplifying interhemispheric climate signals remains an unresolved and fundamental issue in understanding global climate change. Tropical glacier fluctuations are among the most valuable indicators of regional climatic trends and forcings because these mountain glaciers respond sensitively to small-amplitude climate changes (Alley et al., 2003; Oerlemans, 2005). Over 99% of all present-day tropical glaciers are located in the Andes, and more than 70% are in the Cordilleras of Peru (Kaser and Osmaston, 2002). The Peruvian Andes contain extensive and well-preserved geomorphic features indicating former glacier expansion (Clapperton, 1983). Accurate chronologies of Peru's recent glacial history are key indicators of tropical paleoclimates and are thus critical for evaluating mechanisms of global climate variability and linkages (Cane and Clement, 1999; Chiang and Koutavas, 2004; Leduc et al., 2009).

RESEARCH STRATEGY AND INITIAL RESULTS

Ongoing work by our research group is aimed at establishing precise cosmogenic 10Be surface exposure ages of well-preserved moraine sequences in the Cordillera Vilcabamba (13°20'S latitude), located in the outer tropics of southern Peru. Development of these new glacial chronologies provides an essential foundation for quantifying the sensitivity of Holocene glaciers to climate changes, with the ultimate goal of elucidating Holocene climate variability and controls in the tropics. Initial geomorphic mapping and isotopic results from valleys near Nevados Salcantay and Tucarhuay (Figure 1; Licciardi et al., 2009; Taggart, 2009) have revealed the dominance of two major glacial culminations and associated climatic shifts, including an early Holocene episode and a less extensive glaciation late in the 'Little Ice Age' (LIA). On a regional scale, these events are consistent with the timing of glaciations recognized elsewhere in the Andes (Rodbell et al., 2009; Jomelli et al., 2009; Masiokas et al., 2009). On a global scale, results from the Vilcabamba establish temporal relationships between Holocene glacier chronologies in the tropics, New Zealand (Schaefer et al., 2009), and Europe (Nesje and Dahl, 2003; Holzhauser et al., 2005; Ivy-Ochs et al., 2009), indicating a sequence of events that is broadly correlative with glacial records in Europe but distinctly different from the New Zealand record.

The correspondence of LIA glacial records in Peru and Europe suggests climate teleconnections between the tropics and the North Atlantic region. Climate forcings involving southward migration of the Atlantic Intertropical Convergence Zone and associated atmospheric circulation patterns over continental South America are hypothesized to explain concurrent latest Holocene glaciations in tropical South America and northern high latitudes (Licciardi et al., 2009), but the influence of other climate drivers such as the El Niño/Southern Oscillation may have also played a role.

Estimated differences between equilibrium-line altitudes (ELAs) on modern and paleo-glaciers in the Vilcabamba reveal an ELA rise of 165-200 m since the LIA, suggesting that temperatures 1.1-1.3°C cooler than present could have sustained glaciers at their LIA maximum positions if temperature was the only control (Taggart, 2009). However, further work with glacier modeling is required to characterize the likely role of precipitation changes. These new Peruvian glacier chronologies and ELA reconstructions complement ice core (Thompson et al., 1986) and lacustrine (e.g., Baker et al., 2001) paleoclimate records in the vicinity, thereby increasing spatial and temporal coverage for identifying patterns of Holocene climate change in the tropical Andes.

WORK IN PROGRESS

Valleys emanating from high glacier-clad peaks in the expansive Cordillera Vilcabamba contain numerous additional and as-yet undated moraine sequences, as identified from high-resolution satellite images and aerial photos. Two recent field expeditions were conducted in October 2009 and July 2010, with efforts focused on the upper Yanama valley on the south side of Pumasillo and in additional valleys near Salcantay. Geomorphic mapping indicates that moraine sequences in the Yanama valley resemble those near Salcantay-Tucarhuay (Figure 1), but the Yamana moraines preserve additional details not recognized in other valleys. Numerous samples collected from moraine boulders during these expeditions are currently being processed for 10Be measurements to expand on the pilot exposure-age chronology (Licciardi et al., 2009).

Geomorphic mapping reveals the presence of bogs situated between moraines in several glaciated Vilcabamba valleys. Analyses of sediments in these bogs is a high priority in ongoing work because they contain organic material suitable for radiocarbon dating, thus supplementing the 10Be moraine chronologies, and can also provide continuous records of paleoclimate proxy data that will augment the morainal record of glacier fluctuations. Exploratory sediment cores have been recovered from a bog located between the 10Be-dated outer (8.6 ± 0.3 ka) and inner (AD 1810 ± 20) moraines in the Rio Blanco valley emanating from Nevado Salcantay (Licciardi et al., 2009). Preliminary analyses of diatoms in the sediment cores identified the presence of at least 70 taxa, with diatom abundance varying from rare to common. Recovery of additional sediment cores is planned in subsequent field expeditions, with efforts aimed at developing diatom records (cf. Tapia et al., 2003) and other paleoclimate indices extending through much of the Holocene.

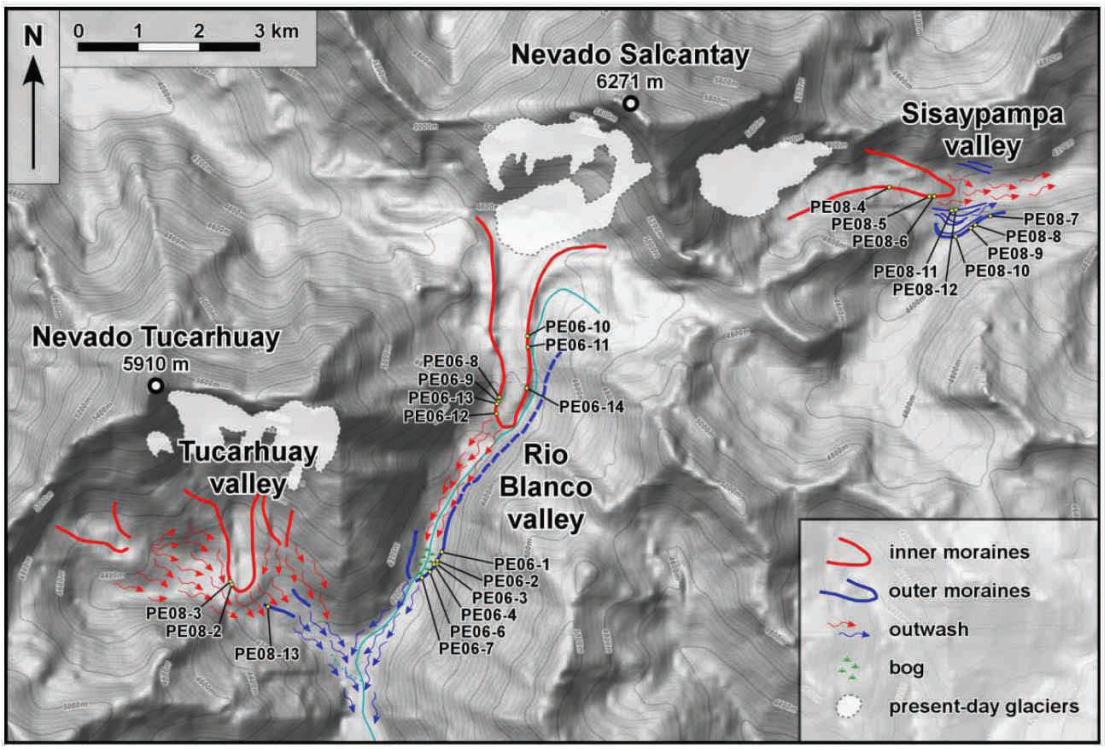

Figure 1. Geomorphic map of initial field sites (modified from Licciardi et al., 2009). Labels indicate locations of 25 boulders sampled in pilot work. Base map from Google Maps.

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