FLUVIAL TERRACE FORMATION ON THE PERUVIAN COAST CONTROLLED BY PRECESSIONAL FORCING AND LOWER CRUSTAL FLOW

W. Viveen[1,2*], J. Sanjurjo-Sanchez[1,2], M.A. Rosas[1,3], V. Vanacker[3]

[1]*Grupo de Investigación en Geología Sedimentaria, Especialidad de Ingeniería Geológica, Departamento de Ingeniería, Pontificia Universidad Católica del Perú, San Miguel, Lima, Peru. *wviveen@pucp.pe*
[2]*Grupo interdisciplinar de Patrimonio Cultural y Geológico, Instituto Universitario de Geología "Isidro Parga Pondal", Universidad de A Coruña, ESCI, Campus de Elviña, 15071 A Coruña, Spain*
[3]*Earth and Life Institute, Georges Lemaître Centre for Earth and Climate Research, Université catholique de Louvain, Belgium*

The ~2200 km-long Peruvian coast is characterised by large river systems that originate in the high Andes mountains and that flow towards the Pacific Ocean thereby traversing the Western Cordillera and the forearc plain. The fluvial terrace sequences of those river systems have hardly been investigated, despite that the region experiences short-term and long-term climate variability that is registered in the terrace record [1, 2, 3]. The coastal areas also experience intense tectonic deformation [4], especially in southern Peru where subduction of the Nazca Ridge has uplifted the coast and formed well-developed marine terraces [5]. No attention has been paid so far to fluvial terraces as recorders of these crustal movements. In order to fill this knowledge gap we present the preliminary results of a study on the fluvial terrace record of the Cañete River, located at 14° S latitude. The terraces were mapped along an 80-km-long transect that traverses the entire terrestrial forearc and part of the Western Cordillera. Three terrace levels were mapped at ~5 m (T1), ~15 m (T2) and ~30 m (T3) above floodplain level (+FP). InfraRed Stimulated Luminescence (IRSL) and post IR IRSL (pIR IRSL) dating of nine terrace sediment samples was carried out to evaluate the behaviour of five different signals ($IRSL_{50}$, $IRSL_{110}$, $IRSL_{180}$, $IRSL_{225}$ and pIR $IRSL_{290}$). The results showed that the $IRSL_{50}$ and the $IRSL_{225}$ signals often overestimated the age. The $IRSL_{110}$ and $IRSL_{180}$ signals, and in five samples also the $IRSL_{50}$ signal, gave coherent ages. Terrace ages of ~0.9 ka were obtained for the current floodplain (FP); ages of ~11-14 ka for T1; ages of ~22-31 ka for T2 and T3 was estimated to have formed ~30-47 ka ago. The ages of the FP, T2 and T3 are in agreement with the last three positive, or transitions between positive and negative, phases of the precession cycle, whereas T1 coincides with the last negative phase of the precession cycle. It has been shown that positive phases of the precession cycle result in increased precipitation in the Andes and rising lake levels [6] resulting in an estimated five-fold increase in fluvial discharge [2]. Fluvial sedimentation may therefore be climate-controlled as in other parts of the Peruvian Andes [7]. The number of terraces, their ages and the inferred climate control agree with published data from the nearby Pisco River [1].

Based on terrace surface elevation and age, uplift rates were estimated at ~0.4-0.7 mm a^{-1}. These rates are much higher than the highest, reported uplift rates for the southern Peruvian coast, which are < 0.5 mm a^{-1} maximally at the location of the subducting Nazca Ridge [5, 8] and < 0.2 mm a^{-1} away from the Nazca Ridge [5]. The Cañete River is situated north of the area that is being uplifted by the Nazca Ridge and ridge subduction can therefore not be directly responsible for the high uplift rates in the Cañete River valley. The forearc is currently subsiding and in transtension, which should pose unfavorable conditions for terrace formation [4]. The Western Cordillera obtained most of its current elevation during the late Miocene [9], so subduction of the Nazca plate is most likely not responsible for the anomalous uplift rates either. Instead, exhumation ages based on apatite fission-track and (U-Th)/He analysis shows increasingly younger ages when going from the Nazca Ridge axis northward towards the Cañete River basin [10]. Seismic recordings of the lower crust and upper mantle show that at the location of the Cañete River valley the Moho is situated ~10-20 km higher than in other parts of the southern Peruvian coast where ridge subduction occurs [11]. This was explained through a possible mechanism where Nazca Ridge subduction creates lower crustal flow towards its flanks [11]. We therefore hypotesise that the rapid uplift in the Cañete River valley may be related to lower crustal flow.

References

1. Steffen, D., Schlunegger, F., Preusser, F., 2009. Drainage basin response to climate change in the Pisco valley, Peru. Geology 37 (6), 491–494.

2. Litty, C., Duller, R., and Schlunegger, F.: Paleohydraulic reconstruction of a 40 ka-old terrace sequence implies that water discharge was larger than today, Earth Surf. Proc. Land. 41, 884–898.

3. Litty, C., Schlunegger, F., Akcar, N., Delunel, R., Christl, M., Vockenhuber, C., 2018. Chronology of alluvial terrace sediment accumulation and incision in the Pativilca valley, western Peruvian Andes. Geomorphology 315, 45–56.

4. Viveen, W., Schlunegger, F., 2018. Prolonged extension and subsidence of the Peruvian forearc during the Cenozoic. Tectonophysics 730, 48–62.

5. Hsu, J.T., 1992. Quaternary uplift of the Peruvian coast related to the subduction of the Nazca Ridge: 13.5 to 15.6 degree south latitude. Quaternary International 15/16, 87-97.

6. Baker, P.A., Rigsby, C.A., Seltzer, G.O., Fritz, S.C., Lowenstein, T.K., Bacher, N.P., Veliz, C., 2001. Tropical climate changes at millennial and orbital timescales in the Bolivian Altiplano. Nature 409, 698–701.

7. Viveen, W., Sanjurjo-Sanchez, J., Baby, P., González-Moradas, M.d.A., 2021. An assessment of competing factors for fluvial incision: An example of the late Quaternary exorheic Moyobamba basin, Peruvian Subandes. Global and Planetary Change 200, 103476, 1-24.

8. Saillard, M., Hall, S.R., Audin, L., Farber, D.L., Regard, V., and Hérail, G., 2011. Andean coastal uplift and active tectonics in southern Peru: 10Be surface exposure dating of differentially uplifted marine terrace sequences (San Juan de Marcona, ~ 15.4°S): Geomorphology 128, 178–190.

9. Sundell, K. E., Saylor, J. E., Lapen, T. J., Horton, B. K., 2019. Implications of variable late Cenozoic surface uplift across the Peruvian central Andes. Sci. Rep., 9-4877.

10. Wipf, M., Zeilinger, G., Seward, D. and Schlunegger, F., 2008. Focused subaerial erosion during ridge subduction: impact on the geomorphology in south-central Peru. Terra Nova, 20 (1), 1-10

11. Bishop, B.T., Beck, S.L., Zandt, G., Wagner, L., Long, M., Antonijevic, S.K., Kumar, A., Tavera, H., 2017. Causes and consequences of flat slab subduction in southern Peru. Geosphere 13 (5), 1392–1407.