XVIII Peruvian Geological Congress

Cenozoic intramontane piggyback Calipuy basin: evidence of a major west verging thrusts system, north Peru.

Alice Prudhomme[1], Patrice Baby[2], Alexandra Robert[3], Ysabel Calderon[4], Leonardo Ramirez[5], Edward Cuipa[6]

[1] Géosciences Environnement Toulouse, Université Paul Sabatier, 31400 Toulouse, France (alice.prudhomme@get.omp.eu)
[2] Géosciences Environnement Toulouse, IRD, 31400 Toulouse, France (patrice.baby@ird.fr)
[3] Géosciences Environnement Toulouse, Université Paul Sabatier, 31400 Toulouse, France (alexandra.robert@get.obs-mip.fr)
[4] PERUPETRO S.A., Lima, Peru (ycalderon@perupetro.com.pe)
[5] PERUPETRO S.A., Lima, Peru (lramirez@perupetro.com.pe)
[6] PERUPETRO S.A., Lima, Peru (ecuipav@gmail.com)

1. Introduction

The Andean orogeny is currently displayed as a typical example for mountain-building in a subduction context, associated with low-relief surfaces at high elevation, as the Altiplano plateau. Surface uplift above subduction zone are often related to the initiation of slab-flattening, triggered by positive buoyancy of subducted oceanic plateaus. Indeed, it has been show that slab-flattening increases interplate friction, generates shortening in the overriding plate, which in turn decreases trenchward velocity of the Nazca plate (Espurt et al., 2008; Gutscher et al., 2000; Smalley et al., 1993; Jordan et al., 1983). Moreover many authors describe a migration of volcanic arc away from the trench or a complete cessation of volcanism (Pilger, 1981; McGeary et al., 1985) with a delay of ~7 Ma after the subduction of the buoyant oceanic lithosphere (Espurt et al., 2008).

Along the Andes, the slab geometry and mountain belt architecture vary considerably and exhibit a certain axial symmetry on both sides of the Altiplano plateau, corresponding to the hinge zone of the Andean orocline. The Bolivian orocline is the most developed part of the Andes with a lateral growth of 750 km wide and a crustal thickness reaching 70 km. The total shortening undergone by the hinge zone was estimate by many authors and varies from ~200 to 530 km (Baby et al., 1997; McQuarrie, 2002). Conversely, the Andes are much less developed in northern Peru (3°-15°S) and in central Chile (28°-33°S), despite the modern flat-slab since the Middle Miocene (Rosenbaum et al., 2005) and the Pliocene (Martinod et al., 2010) respectively. Indeed, the both lambs of the Andean orocline have a horizontal extend of ca. 250 km wide and a crustal thickness of ca. 55 km.

Many authors are interested in the formation of the huge Altiplano-Puna plateaus in the most developed part of the Andes, however few studies show interest for the low-relief-surface of high elevation located in the northern and southern segments. One of the best place to study processes responsible for surface uplift in the early stage of the orogeny is the Western Cordillera in northern Peru (~8°S). Indeed, remarkable low-relief surface of ~3500 m high is preserved at ~40 km from the coast near to Trujillo, corresponding to the Calipuy basin made of volcano-sedimentary rocks. Moreover this region is an under-studied field concerning structural and geomorphological analysis, although it is subject to numerous geochemical investigations on the Cenozoic volcanism (Chávez et al., 2013; Ordóñez et al., 2013).

In this study we want to highlight the processes which triggered such surface uplift along the coast, and thus the structural architecture of this low-relief surface. To resolve its internal structure a crustal balanced cross-section was carried out through the NNW-SSE trending coastal fold-and-thrust-belt. Two field works in this region were achieved to describe large scale deformation in the upper crust, and several sampling were analyzed for vitrinite reflectance, U-Pb zircon dating and biostratigraphy at key-points between lithological units. We include as well previous thermochronological, geochronological and vitrinite analysis to comprehend the timing of surface uplift and potential deformation.

2. Geological setting and evidences for syn-tectonic deposits

In the region of the Libertad, a notable low-relief surface of ~3500 m high is located at ~40 km from the coast (Fig. 1). It extends over a N150-trending 120 km × 70 km surface. The western edge of this plateau corresponding to the border of the Calipuy basin, describes an exceptionally sharp escarpment, ranging from 1 to >3 km over a distance of ~10 km.

[Figure 1]

The Calipuy Formation is an Eocene to Miocene volcanic sequence composed of basaltic and andesitic rocks (80%) and a minority of sedimentary rocks (20%) (Hollister and Sirvas, 1978). This volcanic arc was active from 40 to 17 Ma (Eude, 2014). The lower part of the Calipuy Formation, also called Huaylas Formation, hardly appears along the eastern border of the basin and into the deep valleys. It is characterized by a significant amount of breccias and conglomerates composed of granodioritic and quartzitic clasts, with an apparent thickness of ~200 m. These conglomerates deposed syn-tectonically in growth strata on folds involving Cretaceous strata. The upper part of the Calipuy basin forming the high plateau is characterized by sub-horizontal dips usually tilting toward the center of the formation. This upper part unconformably overlaps the south-western most part of the Marañon fold-and-thrust-belt, comprising the Jurassic Chicama shales and Cretaceous sediments along the northern and eastern borders of the basin. On the western side, the Coastal Batholith composed of diorite, granodiorite and granite mainly outcrops along the slope of the escarpment with occasionally Jurassic and Cretaceous sediments. This huge batholith intrude the Mesozoic sequence between 50 and 34 Ma, synchronously with the end of the major deformation phase in the Western Cordillera (Eude, 2014). The steepest dips of the Calipuy Formation are found closest to its western contact. Therefore the Calipuy basin seems to be parallel to the contacts and dips decrease inwards, which show evidence for a syn-tectonic basin development and filling. However, the basal composition of the Calipuy Formation remains largely unknown, as well as its total thickness, reaching at least 3000 m in the middle by stratigraphic projections (Hollister and Sirvas, 1978).

3. The coastal escarpment and west verging thrusts system

In this coastal region, many geomorphological features are consistent with the presence of western verging contractional structure, and compatible with experimental modelling results of Graveleau et al. (2015) on general active thrust systems. Indeed, the large escarpment of NNW-SSE trending direction is roughly linear and parallel to another smaller escarpment located at 25 km to the west of the plateau. This type of topographic signal is generally generates when deformation reaches surface, and may corresponds to fault nucleation. Moreover, numerous fluvial terraces are perched at different altitudes in the main and deep valleys, as the valley Moche. Graveleau et al. (2015) have demonstrated that formation of terraces above an active thrust appears mainly controlled by narrowing and incision of the main channel through the uplift hanging-wall. Furthermore debris cone including metric blocs are largely observable at the base of the main escarpment.

[Figure 2]

During the field works, we attempted to discern any structure along the escarpment, which is a hard job considering its steepness. Indeed, many studies were carry out through the Moche valley which deeply incised the plateau, however such structures are erased by the smoothing of topography along the valley. At the closest part of the plateau to the coast and the steepest scarp zone, large-scale folds are remarkable (Fig. 2). These folds highlight a west verging thrusts system that may be the key structure to comprehend its development.

4. Conclusion

We will present a crustal balanced cross-section through the Calipuy basin which forms a low-relief surface at high elevation in the Western Cordillera in northern Peru. Geological, structural and geomorphological features seem to be consistent with a main west verging thrusts system development. We proposed that the lower part of the Calipuy Formation infill corresponds to a piggyback basin due to a major west verging thrust of the western flank in the Western Cordillera. The undated conglomerates of the lower part of the Calipuy Formation should be older than 40 Ma and formed in response to a major tectonic event. This shortening pulse is posterior to the Upper Cretaceous Peruvian event observed in the Coastal belt, corresponding to the Eocene major pulse. No slab-flattening geometry was described at these times, however the major shortening in the Western Cordillera is followed by the considerable Calipuy volcanism. Indeed, the upper part of the Calipuy Formation composed of many volcanic centres and collapsed calderas seal the deformation.

Gratefulness

This project resulted from a research convention between IRD and PERUPETRO S.A.. and we thank them to have largely contributed to the several analysis. We thank also the anonymous reviewers for their constructive comments.

References

Arriagada, C., Roperch, P., Mpodozis, C., and Cobbold, P.R., 2008. Paleogene building of the Bolivian Orocline: tectonic restoration of the Central Andes in 2-D map view. Tectonics, v. 27.

Baby, P., Rochat, P., Mascle, G., and Herail, G., 1997. Neogene shortening contribution to crustal thickening in the back arc of the Central Andes. Geology, v. 25, p. 883-886.

Chávez, L., Navarro, P., and Mamani, M., 2013. Características geoquímicas del volcanismo cenozoico (Grupo Calipuy) en el cuadrángulo Santiago de Chuco, norte del Perú. Boletín de la Sociedad Geológica del Perú, v. 107, p. 36-40.

Eude, A., 2014. La croissance des Andes centrales du nord du Pérou (5-9S): Propagation d'un prisme orogénique dans un contexte d'héritage tectonique et de subduction plane. PhD Thesis, Université de Toulouse, France, 323 pp.

Espurt, N., Funiciello, F., Martinod, J., Guillaume, B., Regard, V., Faccenna, C., and Brusset, S., 2008. Flat subduction dynamics and deformation of the South American plate: insights from analog modeling. Tectonics, v. 27.

Graveleau, F., Strak, V., Dominguez, S., Malavieille, J., Chatton, M., Manighetti, I., and Petit, C., 2015. Experimental modelling of tectonics–erosion–sedimentation interactions in compressional, extensional, and strike–slip settings. Geomorphology, v. 244, p. 146-168.

Gutscher, M.A., Spakman, W., Bijwaard, H., and Engdahl, E.R., 2000. Geodynamics of flat subduction: seismicity and tomographic constraints from the Andean margin. Tectonics, v. 19, p. 814-833.

Hindle, D., Kley, J., Oncken, O., and Sobolev, S., 2005. Crustal balance and crustal flux from shortening estimates in the Central Andes. Earth Planet. Sci. Lett., v. 230, p. 113-124.

Hollister, V.F., and Sirvas, B., 1978. The Calipuy Formation of the northern Peru, and its relation to volcanism in the northern Andes. Journal of Volcanology and Geothermal Research, v. 4, p. 89-98.

Jordan, T.E., Isacks, B.L., Allmendinger, R.W., Brewer, J.A., Ramos, V.A., and Ando, C.J., 1983. Andean tectonics related to geometry of subducted Nazca plate. Geol. Soc. Am. Bull. 94, p. 341-361.

Kley, J., and Monaldi, C.R., 1998. Tectonic shortening and crustal thickness in the Central Andes: how good is the correlation? Geology, v. 26, p. 723-726.

Martinod, J., Husson, L., Roperch, P., Guillaume, B., and Espurt, N., 2010. Horizontal subduction zones, convergence velocity and the building of the Andes. Earth and Planetary Science Letters, v. 299, p. 299-309.

McQuarrie, N., 2002. Initial plate geometry, shortening variations, and evolution of the Bolivian orocline. Geology, v. 30, p. 867-870.

Ordóñez, E., Chávez, L., Navarro, P., Pajuelo, D., and Mamani, M., 2013. Relación entre la geoquímica y las anomalías de Bouguer para el volcanismo cenozoico (Grupo Calipuy) y el batolito de la Cordillera Blanca. Boletín de la Sociedad Geológica del Perú, v. 107, p. 41-45.

Rosenbaum, G., Giles, D., Saxon, M., Betts, P.G., Weinberg, R.F., and Duboz, C., 2005. Subduction of the Nazca Ridge and the Inca Plateau: Insights into the formation of ore deposits in Peru: Earth and Planetary Science Letters, v. 239, p. 18-32.

Smalley, R., Pujol, J., Regnier, M., Chiu, J.M., Chatelain, J.L., Isacks, B.L., Araujo, M., and Puebla, N., 1993. Basement seismicity beneath the Andean Precordillera thin-skinned thrust belt and implications for crustal and lithospheric behavior. Tectonics, v. 12, p. 63–76.

Illustrations

Figure 1: Geological map of the Libertad region in northern Peru and location of the balanced cross-section. Modified after 1:100,000 INGEMMET geological map.

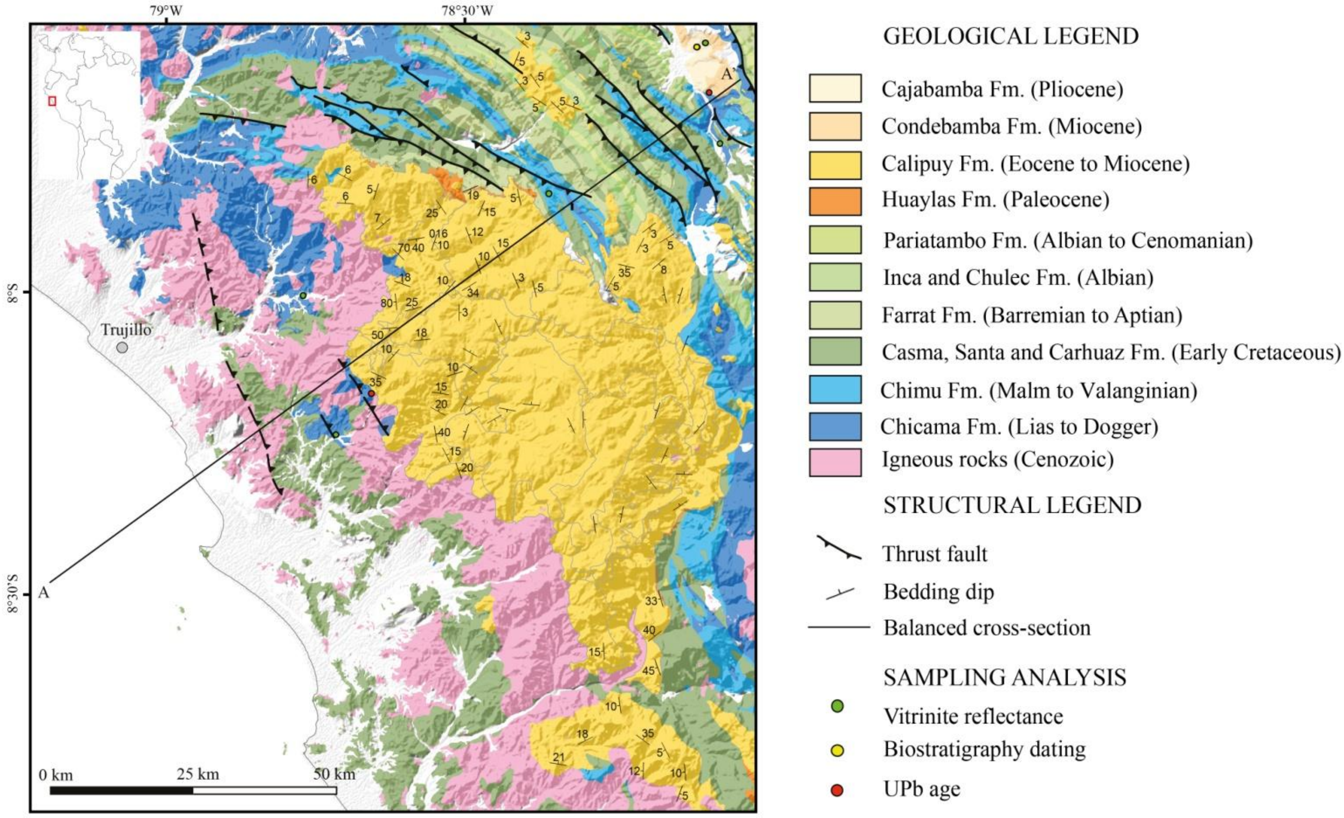

Figure 2: Google Earth satellite image showing large-scale folds above a detachment fault, highlighting a west verging thrusts system located at the western edge of the high plateau.