GEOMORPHIC EVIDENCES OF RECENT TECTONIC ACTIVITY IN THE FOREARC, SOUTHERN PERU

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ABSTRACT

As the Andean forearc is not concentrating as much tectonic shortening as the foreland (since Middle Miocene) and as GPS measurements can not inform on the long-term deformation but rather describe the elastic response of the Andean forearc (Nazca-South American convergence), little is known about the active deformation in the Central Andes Pacific lowlands. However, geomorphic evidences of recent tectonic activity are observed from the Coastal Cordillera to the piedmont of the Western Cordillera. In this paper we analyze this Quaternary tectonic activity in the southern Peruvian forearc, from 17°S to 18°30'S. Examination of aerial photographs and satellite data, and focused field work not only confirms that there is recent tectonic activity but also has revealed the presence of additional active structures that should be taken into account in the description of Andean deformation. In response to active tectonics, these tectonic structures affected very young terraces and Quaternary pediments in the southern Peruvian forearc. We discuss some of the strong geomorphic signatures, such as active fault traces, scarplets, sag ponds, river terraces and some major and minor landslides, which are indicative of active tectonics in this area. Mapping of fault trace geometry and identifying recent surface offsets are used to determine the key places where active tectonics can be involved in the deformation of the forearc, either through normal faulting, strike-slip faults or thrust faults. Among those major tectonic features, some are likely due to seismic crustal activity (along the ongoing Andean tectonic processes) and some to relaxation processes of the stress imposed on the outer forearc area after each major subduction earthquakes.

Keywords: *Southern Perú, forearc, active tectonics, geomorphic features.*

RESUMEN: *Evidencias geomórficas de actividad tectónica reciente en el Antearco Perú sur.*

Debido a que el antearco andino no está concentrando tanto acortamiento como el antepaís (desde el Mioceno Medio) y como las mediciones de GPS no pueden dar información de la deformación de largo plazo sino que más bien describe la respuesta elástica del anteraco andino (a la convergencia entre Nazca y Sudamérica), poco se sabe acerca de la deformación activa en las tierras bajas pacíficas de los Andes Centrales. Sin embargo, evidencias geomórficas de la actividad tectónica reciente son observadas desde la Cordillera de la Costa hasta el pidemonte de la Cordilera Occidental. En este trabajo analizaremos la actividad tectónica cuaternaria en el antearco del sur del Perú, desde los 17°S a los 18°30'S. La examinación de fotografías aéreas y datos satelitales, y trabajo de campo enfocado no sólo confirma que hay actividad tectónica reciente, sino que también ha revelado la presencia de estructuras activas adicionales que deberían tenerse en cuenta en la descripción de la deformación andina. En respuesta a la tectónica activa, estas estructuras tectónicas afectaron a terrazas muy jóvenes y a pedimentos cuaternarios en el antearco del sur del Perú. Se discuten algunas de las fuertes señales geomórficas, tales como trazas de fallas activas, escarpas, *sag ponds*, terrazas fluviales y algunos deslizamientos mayores y menores, los cuales son indicativos de la tectónica activa del área. El mapeo de la geometría de las trazas de falla y la identificación de dislocaciones en superficies recientes son usadas para determinar loslugares clave donde la tectónica activa está involucrada en la deformación del anteraco, ya sea a través de fallas normales, de desplazmiento de rumbo o corrimientos. Entre estos rasgos tectónicos mayores, algunos son aparentemente debidos a actividad sísmica cortical (como parte de los procesos andinos activos) y otros a procesos de relajación de los esfuerzos impuestos en el sector externo del antearco después de cada terremoto de subducción mayor.

Palabras clave: *Sur del Perú, antearco, tectónica activa, rasgos geomórficos.*

INTRODUCTION

The curved shape of the Central Andean orogen associated with the Bolivian Orocline exhibits a striking bilateral symmetry considering the underlying Wadati-Benioff zone and the topography (Gephart 1994). Tectonic activity and geomorphology in the forearc however vary along the margin from the northern side of the Arica Elbow in Peru to the southern side, in Chile. Emplacement of relief in the modern Central Andes occurred mostly during the Late Cenozoic (Isacks 1988, García and Hérail 2005; Von Rotz *et al.* 2005) when the shortening jumped eastward to the backarc region. The Andean orogen globally has evolved since the Mesozoic through Neogene. While northern Chile is the site of ongoing tectonic studies on active deformation processes (Muñoz and Charrier 1996, Gonzalez *et al.* 2003, Audin *et al.* 2003, Worner *et al.* 2002, Soto *et al.* 2005), the forearc in southern Peru has not been the

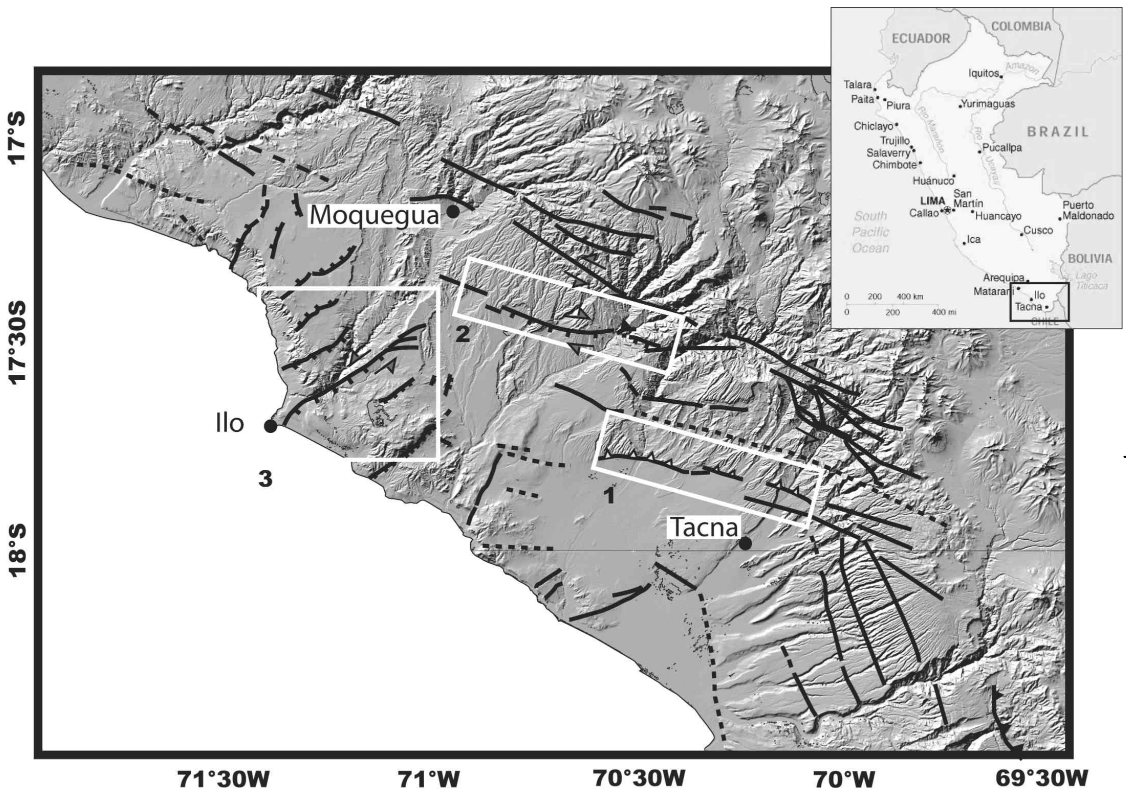

Figure 1: Mosaic of SRTM topographic images , northern part of the Bolivian Orocline, forearc of southern Peru: Large-scale morphotectonic map of the forearc in Southern Peru. Inset shows the location of studied area. Interpretation outlining main strands of Quaternary active faults.

site of neotectonic studies since the 1980's (Macharé *et al.* 1982, Sébrier *et al.* 1985, Ortlieb *et al.* 1996). The Andean forearc in southern Peru is comprised of three different morphological zones from East to West: the coastal cordillera, an NS elongated basin (the central valley) and the piedmont of the Western Cordillera. The whole region was the site of contractional, strike-slip and extensional deformation episodes from Late Miocene to Pleistocene (Sébrier *et al.* 1985, Semperé *et al.* 2002).

The Western Cordillera in the forearc of Southern Peru is constitued by a NW-SE range bounded by faults systems (one is known as the Incapuquio fault system) of which, the kinematics have not been explored (Fig. 1). The coastal cordillera is composed of by crystalline basement rocks (Cobbings *et al.* 1977) and affected by a system a normal faults trending perpendicularly to the coast (Audin *et al* . submitted; Fig. 1). The Coastal Cordillera is absent at the Peru/Chile border, appears 60km north of the border and runs in a NE direction, parallel to the western cordillera and the coastline, forming the western topographic boundary of the central valley. The Central Valley is a NS elongated basin that runs parallel to the Coastal Cordillera and the Western Cordillera. Miocene deformation led to a narrow, elongated basin. Deposits in the Central Valley and lowlands include multiple large alluvial fans issued from Andean Range erosion since the Eocene-Oligocene diachroneously. Much of those volcano-clastic deposits are part of the Moquegua Formation, that correspond to four major episodes of erosion (Semperé *et al.* 2004). The more recent deposits belong to the Moquegua D Formation (14-9Ma, Semperé *et al.* 2004) and Quaternary recent alluvial fans, alluvial terraces and pediments. Erosion prevailed largely since 2.7 Ma (Semperé *et al.* 2004). All the ages comes from interbedded ignimbrites and discontinuities analysis in the whole Moquegua Formation. In Chile, the developpment of frontal thrust developped topographic highs in the Central depression along the Western Cordillera (García and Hérail 2005) but in Peru it seems that other processes are involved in the building of the topography (Jacay *et al.* 2002).

The piedmont of the Western Cordillera in its lower parts and the central basin are exposed to low denudation due to the extremely dry climate, which has persisted for at least 5 Ma. As the arid climate allows for the preservation of geomorphologic evidence of tectonic deformation in the forearc of Southern Peru and Northern Chile, this study is based on field work and air photo analysis.

TECTONIC SETTING

The tectonic activity that produced the present relief in Central Andes is known, as a whole, to begin during the Miocene and to have accelerated during the Neogene (Dalmayrac *et al.* 1980, Sébrier *et al.* 1985), even if no detailed study focused on the tectonic structures themselves. The forearc area has maintained at least since at least the Eocene the same morphology as the present day one (Macharé and Ortlieb 1992). The piedmont makes up the eastern border of the closed desertic basin. Piedmont stratigraphy consists of weathered granite and volcanic bedrock overlain by 100 -1000m of Miocene and Pliocene basins and distal piedmont sediments that grade upward into poorly sorted gravel to alluvial-fan units of

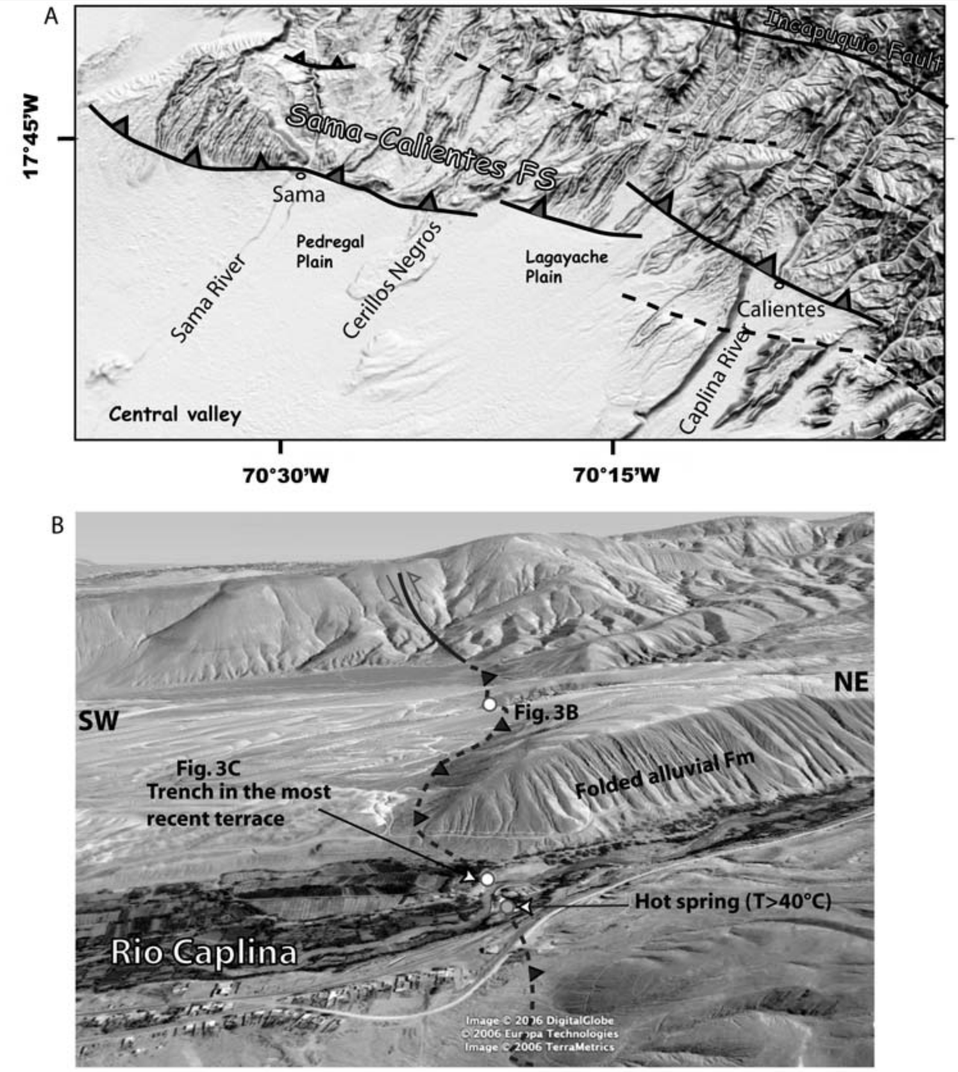

Figure 2: Shaded-relief image of 30 m spaced digital elevation model (DEM derived from SRTM data) from Sama Calientes Fault zone. Zone 1 on Fig. 1. Fault traces deduced from field and topographic surfaces traces.

Quaternary age. Structures with a northwest trend are prominent within the Incapuquio fault system (Jacay *et al.* 2002). Normal faults, fault-related folds, thrust faults with similar geometries and strike-slip structures, exist west to the major oldest Incapuquio fault set but were not studied yet. The Incapuquio fault system extends over about 200km as series of various segments and shows a complicated history, mainly with left lateral movement during the Oligocene but again nothing was known about its present day activity (Jacay *et al.* 2002). The SRTM DEM and aerial photography analysis indicates a very strong, straight and well delineated fault trace, which cuts through various relief, bedrock, and alluvial deposits. Recent studies issued from the installation of local temporal seismic network (David *et al.* 2004) indicates that crustal seismicty showing magnitude is located right on Incapuquio fault system up from Tacna and thus strongly suggest that this morphologic signature is due to ongoing tectonic activity of this old fault system. All of those observations suggest a near vertical fault reaching the surface, which is also typical of strike-slip deformation. Two type examples of fault segment associated with the Incapuquio fault system are discussed here with the Sama-Calientes fault zone and the Purgatorio fault. The coastal tectonic structures that can be observed in the morphology are trending northeast and are associated essentially with normal faulting: we will focus in this zone on the Chololo fault system.

GEOMORPHIC MARKERS OF DEFORMATION

The relationship between active faulting and the offset of recent alluvial surfaces or stream terraces has been successfully used to identifying active faults systems (Gaudemer *et al.* 1989, Jackson *et al.* 1996, Audin *et al.* 2003). This paper documents morphologic offsets and evaluates the potential tectonic activity at 3 sites (Fig. 1) where streams and terraces are developed along the piedmont of the western Cordillera or along the coastal area. Analysis of aerial photos, SRTM DEM and satellite

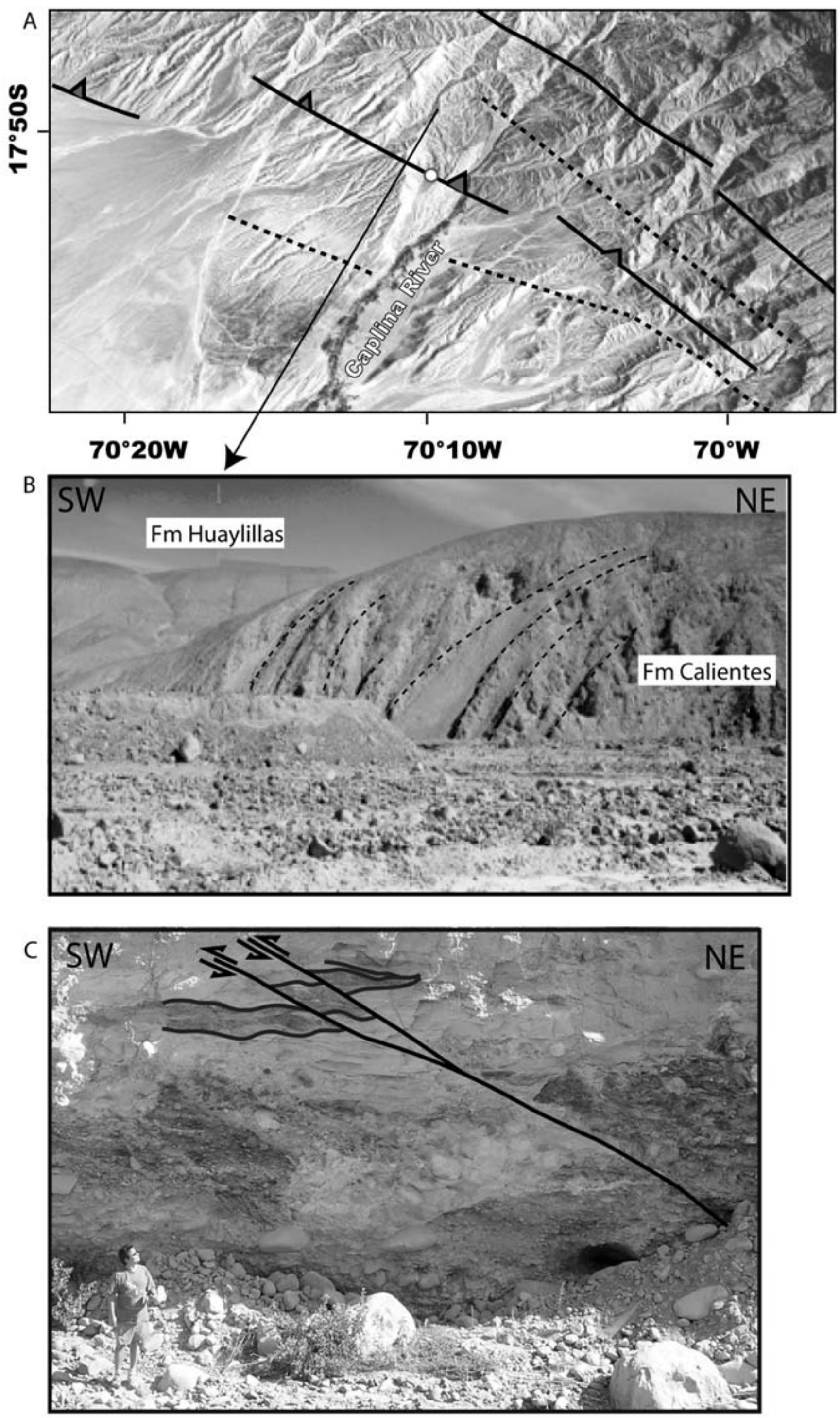

Figure 3: ASTER image and field photography of Calientes Site. See Figs. 1 and 2 for locations.

images allows us to identify the strong geomorphic expressions of these faults, which offset both Tertiary formations and Quaternary-Recent deposits.

THE SAMA CALIENTES FAULT SYSTEM

Site 1 is located near the cities of Sama and Tacna at the very southern end of Peruvian forearc (Figs. 1 and 2). The observed tectonic morphology marks the base of the hill front, near the town of Calientes, upstream from Tacna in the Caplina Valley. It cuts as well through the active flood plain of the Caplina River (Fig. 2), forming a nice emergent thrust (Figs. 2 and 3) over kilometers, also associated to major flexures in the Huaylillas Formation (25-9 Ma, Roperch *et al.* 2006). At this location, one of the last surface ruptures can be observed within the youngest river terrace near the village of Calientes and also within the Pedregal Plain (Fig. 3). Active faults are likely to cut the surface of alluvial or fluvial terraces as well as other landform, but several aspects of terraces make them useful to study active tectonics, date the deformation for example. Alluvial terraces are mostly flat, and due to the local aridity in Southern Peru, it also represents an approximate geomorphic time marker (Rockwell *et al.* 1984, Hall *et al.* in press). As the fault cuts the last well developed Caplina river terrace, then faulting is known to postdate the age of that surface. The Sama-Calientes fault zone is related to southernmost part of the Incapuquio fault systems. This fault system provides evidences of structural control on the deposition of at least Upper Cenozoic sedimentation units (Flores *et al.* 2004) and in some case show nice folding of the Calientes Formation (Fig. 3). The fault trace is about 50 km-long with various segments en-echelon disposed. However no lateral offset of the major drainage can be observed (see the alignment of Quebrada Sama) and thus the en echelon disposition must be mainly due to some segmentation of the front thrust system.

From Calientes to Sama, the rupture deviates from a north west trend to a west north west trend. The trace of the fault here follows some flexures, folds and reverse faults which offset terraces in the active drainages (dry secondary rivers) or the sediments of the Pliocene Calientes Formation (Fig. 3), Moquegua units (Oligocene to Neogene) or Huaylillas Formation (Early Miocene, Figs. 4a and b). Folding of the Calientes Formation along the fault trace indicates post Pliocene activity of the Calientes fault segment (Fig. 3). A well preserved scarp is observed along the foothill of Pedregal Plain (Fig. 4a), which dips ste-

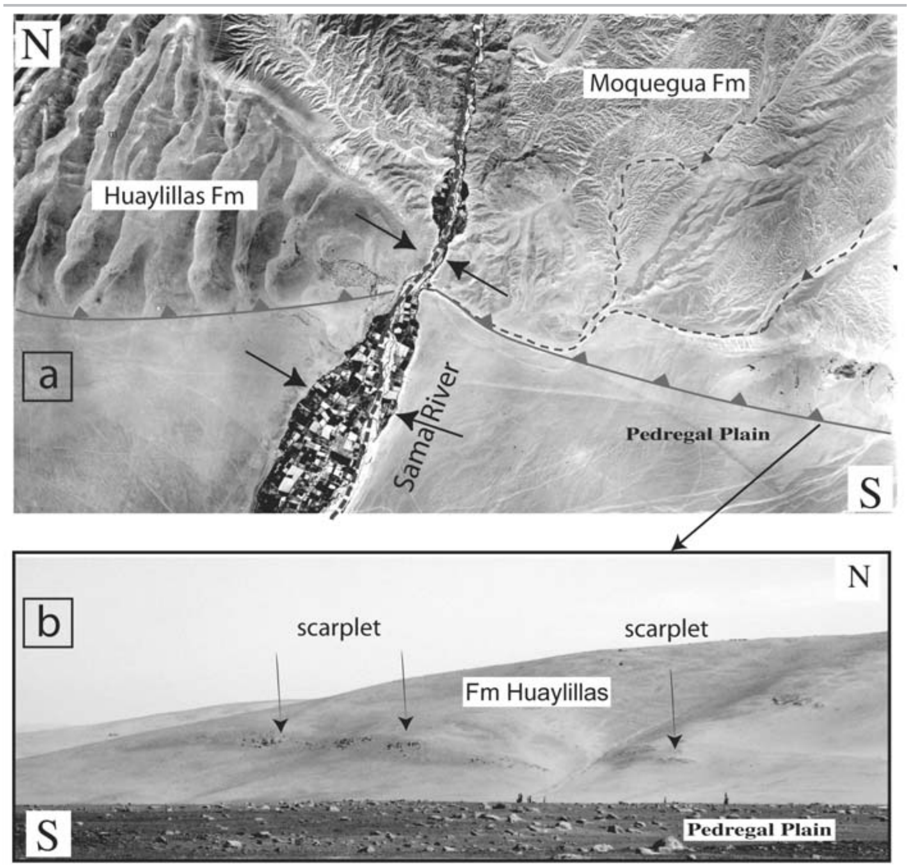

Figure 4: Aerial image. a) and field photography of Sama Area; b) with an example of the recent surface fault trace as a scarplet (b), river capture along the fault trace. The arrows show the scarp as a shadow visible along the active fault trace.

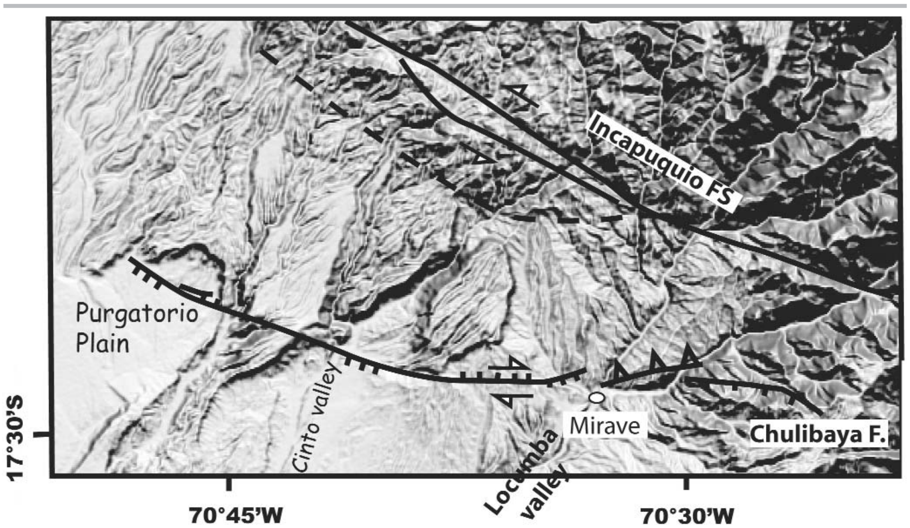

Figure 5: Shaded-relief image of 30 m spaced digital elevation model (DEM derived from SRTM data) from Purgatorio Fault zone. Zone 2 on Fig. 1.

eply to the south and affects the Huaylillas Formation. It is just barely followed through the Cerrillos Negros tongue of major rock avalanche coming from the Cerro Caquilluco giant landslide area uphill (Fig. 1). Some small landslides have occurred along the Sama fault segment east of Cerrillos Negros (Fig. 4c). The Sama river itself appears to be influenced as the associated alluvial plain is suddenly much larger to the south of the fault trace and much more incised to the north (Fig. 4a). Some dry valleys have been captured along the fault plane and mark the fault trace just east of the town of Sama (Fig. 4a). Over much of the length of the fault, the expression, in the form of recent scarps, appears and disappears from one plain to the other (Fig. 4b). When visible the scarp height is up to 1 to 2 meters. Last movement along the southern segment, the Calientes segment, occurred most probably in the last centuries as it's offsetting the active terrace of the Caplina river (Fig. 3a). A serie of colluvial wedges are observed along the fault trace itself cutting through the Holocene terrace and offsetting a serie of brown to white layers in a natural trench visible along the dry valley in Calientes town (Fig. 3c). The Sama Calientes fault is thus an emergent thrust.

THE PURGATORIO FAULT SYSTEM

Site 2 is located immediately east of the city of Moquegua, and lies at the piedmont of the western Peruvian cordillera. It is also part of the Incapuquio fault system. The fault trace can be followed as the southern rim of the relief. The eastern segment of the fault trends northwest while upon reaching the town of Mirave the rupture deviates from a northwest trend to an eastwest trend. The fault is probably also associated with the previously mapped Chulibaya normal fault (Fig. 5, Sébrier *et al.* 1985) and to the emergent thrust lying west of the Purgatorio fault system, in Mirave. The Purgatorio fault system does not cut through the Locumba valley but follows it in its western end (Fig. 5). The fault trace can be identified at various scales from the Landsat satellite images and SRTM DEM, to aerial photographs and field work with outcrop scale (Figs. 5 and 6). It is most obviously observed in the discontinuous topography where the surface trace cuts the southward-flowing dry network of desert streams in Purgatorio and Cinto Plains (Fig. 5). Although the stream terraces had been documented previously by INGEMMET (1:100 000, Instituto Geológico Minero y

Metalúrgico del Perú) as Tertiary Moquegua Formation and Quaternary deposits, our work suggests the presence of various recent fluvial terraces issued from the reworking the Tertiary Moquegua Formations such as Holocene debris flows, coarse gravels and alluvial sandy-silty recent deposits (Fig. 6). Hall *et al* . (in press) obtain very recent ages based on cosmogenic dating of planation surfaces and alluvial terraces (from 92 1.6ka to 215 38.5ka). The Quaternary depositional terraces, rising 0.5-2m above the present stream-bed exist within the small valleys crossing the fault (Fig. 7). The EW scarp dissects the gravels and sandy terraces of the Pampa Purgatorio in its western end to Mirave and the Lower Moquegua Formation and conglomerates in its eastern end. Some sag ponds and really vertical scarps are observed along the fault trace (Figs. 6 and 7). East of Mirave some thrusting of the Toquepala Formation over the younger Moquegua Formation indicates some compression. In addition, during the 2001 subduction earthquake (Arequipa event, June 23rd, Mw = 8.4) these fault traces were associated with open cracks in the Purgatorio Plain. Ruptures were located along the pre-existing scarps that face southward and while they did not show reliable vertical offsets, they did exhibit open cracks of about 20-30 cm. The Purgatorio-Mirave fault offsets the present day surface deposits along the base of the major landslide and shows either down to the north or down to the south facing scarps about 2 meters high (Fig. 6). One of these scarps is fed by a large resurgence emerging from the talus slope at the foot of the scarp, permitting the development of vegetation in this extremely arid area. An intermittent resurgence is observed where those small trees typical of desertic environments are observed aligned with the fault trace (Site A, Fig. 6). This fault seems to show long-lived activity with diverse movements and a complicated history, from dextral strike-slip to normal faulting (down to the south and down to the north) movements. The streams and terraces in the western part of the fault system shows the more expressive dextral offset of each streams and its terraces (Site B, Fig. 7a). Some sag ponds and scarps are also

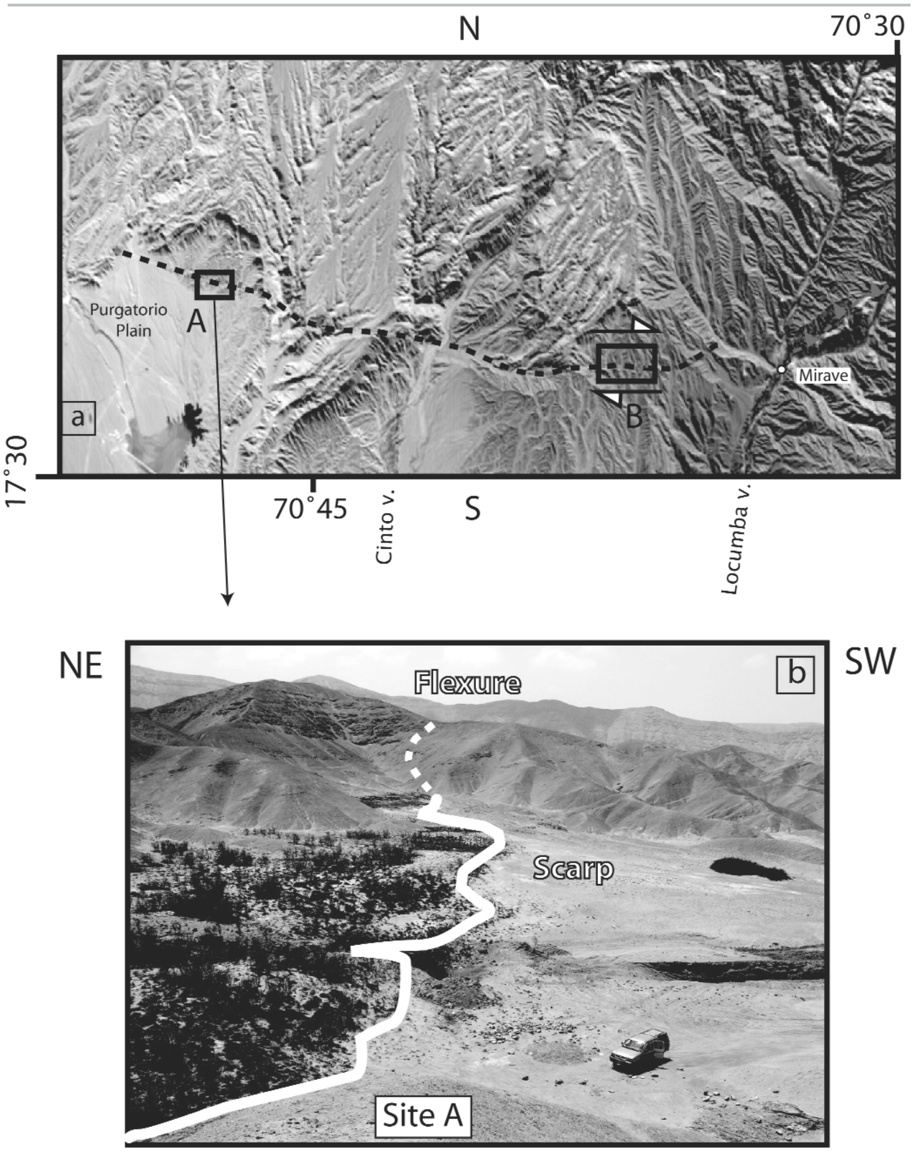

Figure 6: ASTER image and field photography of Purgatorio fault zone in Purgatorio Plain, Site A. View to northeast, along the fault trace, toward flexure zone developed into the Huaylillas Formation marked by aligned small trees and by vertical scarp.

observed sometimes indicating a normal dip slip recent movement (down to the north, Figs. 7b and c or to the south). But larger and older normal movements are also indicated by large vertical scarp dipping to the south, that also shows clear vertical striations. Aligned, narrow and linear valleys also mark the fault trace throughout the Cinto River that show some captured secondary streams (Figs. 6 and 7, Hall *et al.* in press). Just before Mirave village, the surface trace of the fault does not lie at the base of the range but north within the Moquegua formation, where the surface expression of the fault is narrowest and sharply defined. Offset streams are especially well preserved in this area (Fig. 7). The Purgatorio fault is thus a normal fault with a right lateral component.

THE CHOLOLO FAULT SYSTEM

Site 3 concerns a larger area of the Coastal Cordillera and the Ilo region. This region is characterized by large faults or fault systems that are easily observed on the SRTM DEM and Aster images (Figs. 8 and 9). This coastal area lies above the stretch of the subduction zone that has historically produced

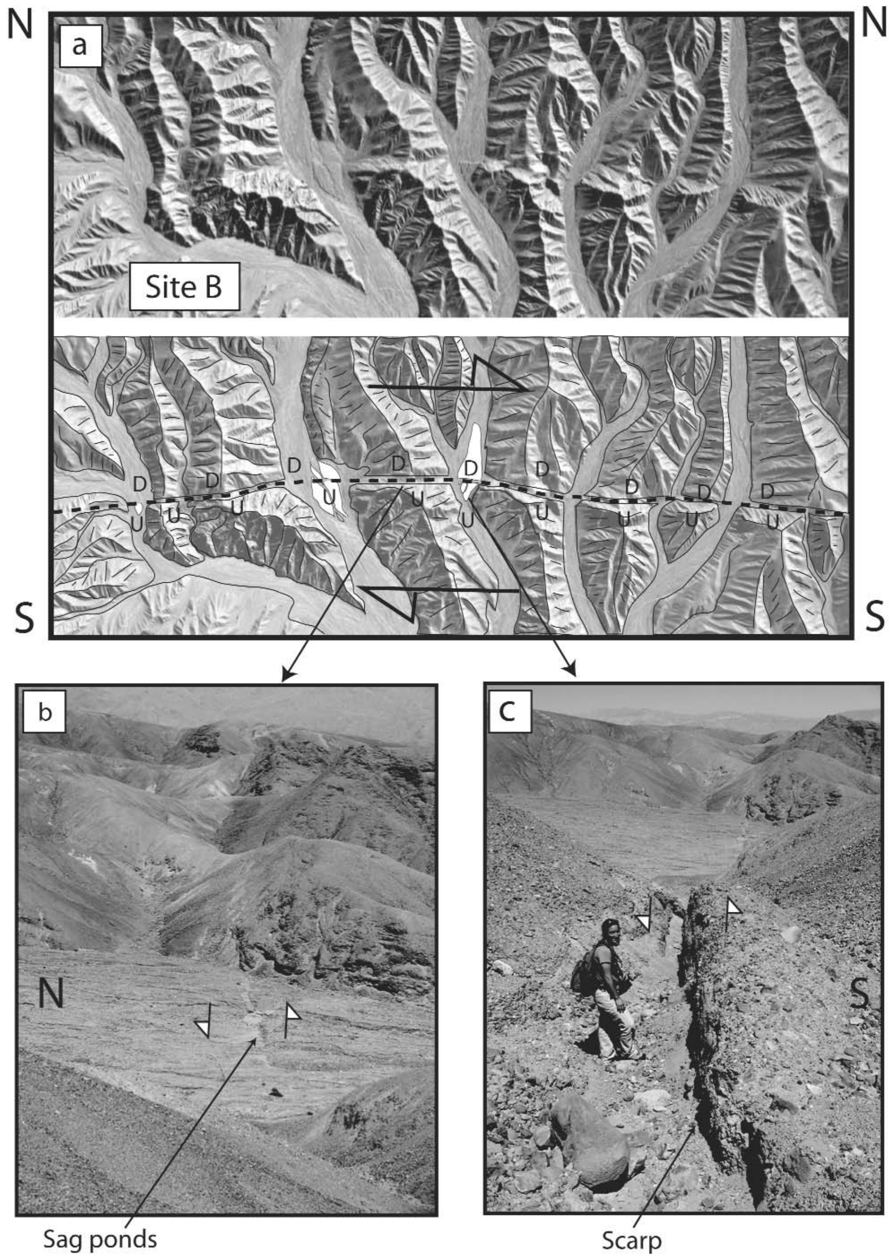

Figure 7: Map of fault traces and alluvial surfaces superimposed on aerial photography. Field photography of Purgatorio fault zone, Site B ; showing the vertical offset of Moquegua Formation and of the Quaternary alluvial fans inside the active channel (sag ponds and scarps). D: down. U: up.

major earthquakes (Mw = 8.4, June 23rd 2001 Arequipa event) and is thus the site of different deformation processes than sites 1 and 2. We will focus in this paper on the Chololo fault system that trends perpendicular to the coast from Ilo in the southeast to the valley of Moquegua river to the northwest. It consists of one main fault segment and secondary smaller sub-parallel faults. The fault strikes more or less to the northeast along a steep southeast facing wall. The Chololo fault system consists of various sub segments, the older and larger one being transtensional with major left lateral strike slip and normal movements and the smaller and lower ones showing normal movements (Fig. 10). The Chololo fault system as a whole has a surface trace of about 40 km from Punta Coles (Figs. 8 and 9) to the Panamericana to the north, eventually reaching Moquegua Valley. Some vertical offset of about 350 m is observed along the fault (Fig. 10) however, the more recent offsets along the fault show some left lateral strike slip motions of about 10 to 20 meters. The secondary segments show mainly normal offsets of 1 to 2 meters high (Fig. 11). The gentle triangular facets and the horizontal offset of the shallow gullies along the fault trace indicate some transtensional movements have occurred on this structure (Figs. 10 and 11). The top of the Cerro Chololo presents recent alluvial deposits that could be associated with the Last Moquegua sedimentary units or even more recent alluvium, , which suggest as much as 350 meters high vertical offset (Fig. 10). The normal scarps are facing to the southeast and offset either the bedrock at the piedmont or the recently active recent alluvial fans issued from the erosion of the major wall (probably due to the last historical large El Nino event). Additionally, some even more recent alluvial fans and eolian deposits are coalescing along the scarps at various sites along the fault trace. Near to the topographic profile line, offset ashes, most likely associated with the last Huaynaputina eruptions are observed along the scarp. It is typical fine grey ash (1,600 AD; de Silva and Zielinski 1998, Fig. 11). As the wind activity is really strong nowadays and that some of the last "El Niño" events are still in minds in Moquegua Valleys, it can be inferred that despite those, a really recent activity of Chololo fault system can be deduced from our observations. As in the case of the Purgatorio fault system, during the 2001 subduction earthquake the fault trace in Inalambrica Plain was underlined with open cracks. Ruptures were located along the pre-existing scarps and did not show reliable vertical offsets but rather open cracks of about 20-30 cm. Most of the houses aligned on this scarp, which corresponds to the southern horsetail termination of the Chololo fault in Punta Coles near Ilo, were destroyed during the earthquake. The Chololo fault is thus a normal fault with a left lateral component.

Numerous normal faults marks the coastal area north and south of the Chololo fault zone, which offset either the crystalline

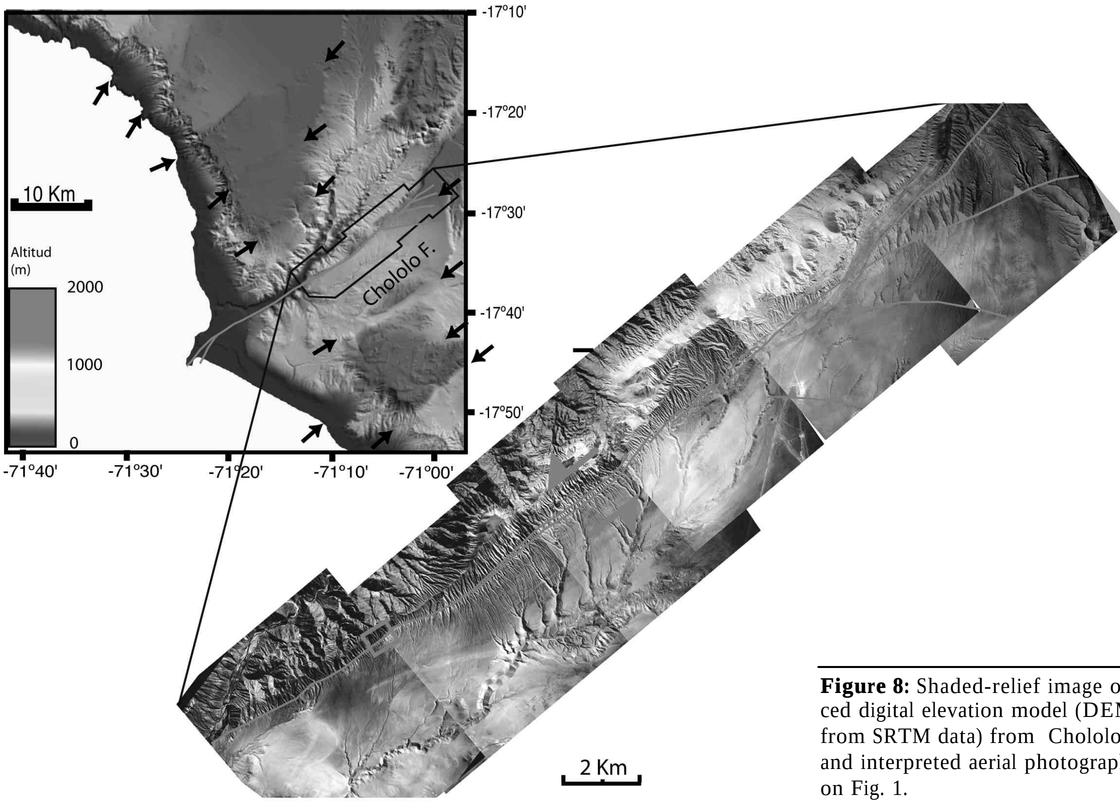

Figure 8: Shaded-relief image of 30 m spaced digital elevation model (DEM derived from SRTM data) from Chololo Fault system and interpreted aerial photography. Zone 3 on Fig. 1.

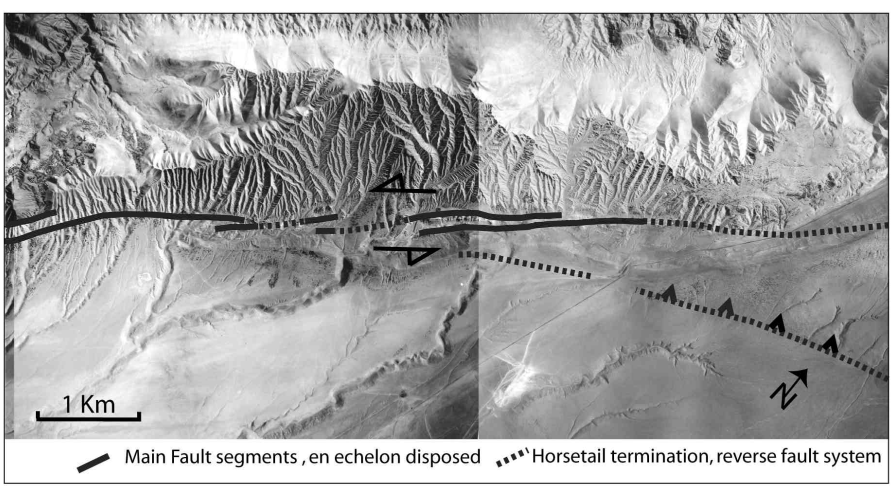

Figure 9: ASTER image and interpreted aerial photography of the central segment of the fault.

basement, the Neogene pediments or the Quaternary alluvial fans issuing from the hanging wall (Figs. 1 and 8).

DISCUSSION AND CONCLUSION

The purpose of this work is to show that prominent geomorphic markers exist along previously undescribed crustal fault systems in the forearc of southern Peru and present an abundance of evidence of recent tectonic activity. Some of these markers are robust enough to allow us to characterize the kinematics of movements along the faults, at least for the recent Quaternary period (Fig. 1). Deformation is comparatively small with the Andean uplift necessary to build the mountain range, while surface processes are a much weaker signal than the tectonic signal, with time they gently degrade traces of active tectonics possibly creating the segmented nature of the structures we observe in the forearc. We propose that despite the large degree of segmentation that is observed along the fault systems, this strongly suggest that some crustal seismic events can be expected to occur in this area of the Andean forearc. Many of these faults we have identified are capable of generating earthquakes, some small and local, others major and capable of impacting human activities. As already noted, these three fault systems show a complicated history of active surface deformation with reverse, strike-slip, and normal components on the same fault set (Fig. 1). Even if today we cannot calculate a recurrence interval, we can at least place bounds on this and we argue, that it should be less than historical times (~1000 yr). Recent studies based on cosmogenic dating show that Purgatorio fault system is cutting through. Moreover, both the piedmont of the Western Cordillera in its lower parts and the central basin experienced extremely low denudation rates, much of which is likely accommodated by mass movements trigge-

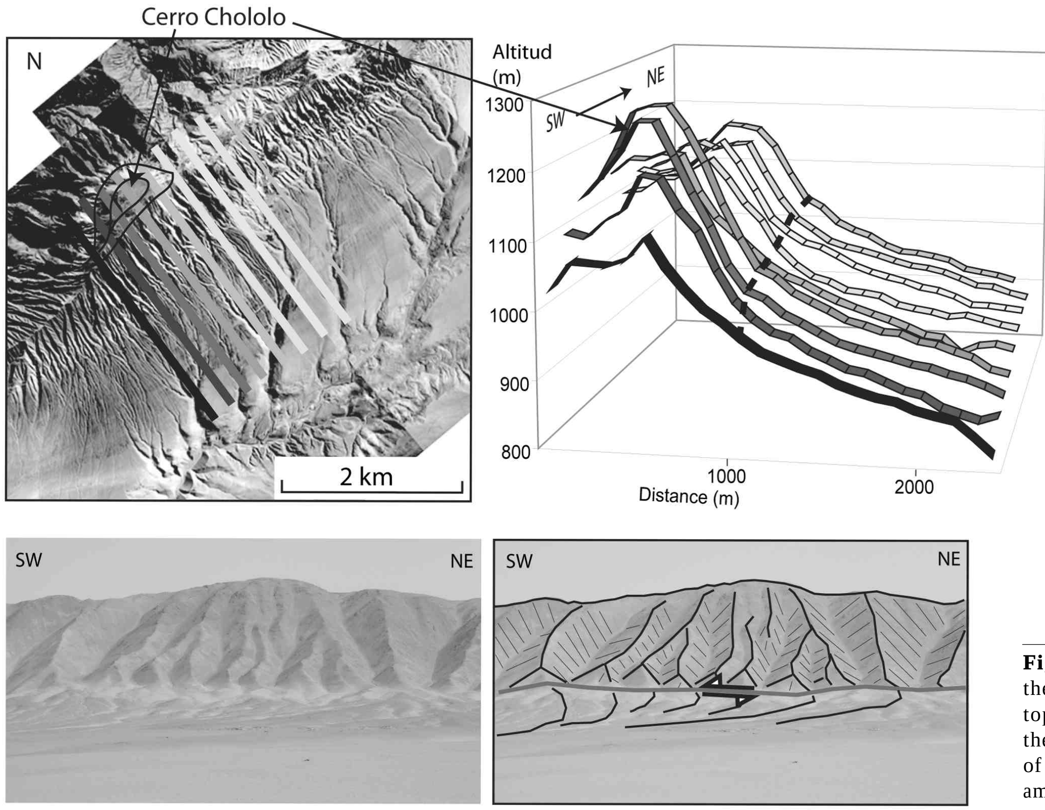

Figura 10: Aerial photography of the central segment of the fault and topographic profiles issued from the SRTM DEM. Field photography of some left lateral offset of a stream and hill set.

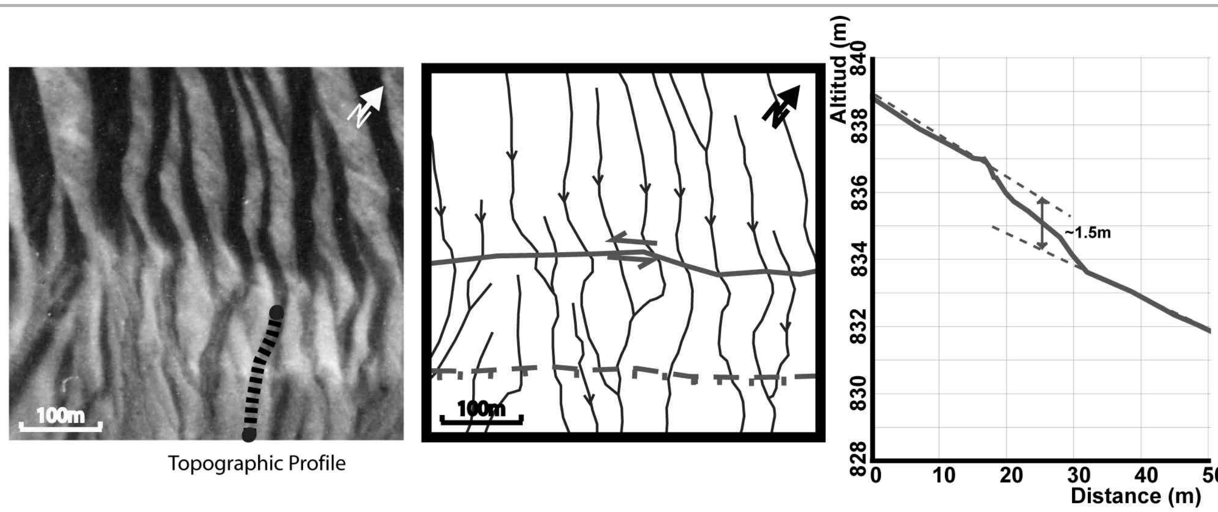

Figura 11: Aerial photography of one site illustrating the left lateral and normal components. The systematic left lateral offset of the temporary network underlines the strike slip component. The topographic profile (in red on aerial photography) issued of GPS kinematic field survey, shows a recent vertical displacement affecting the active channel of a small rio, it probably indicates 2 cumulated events. Superimposed topographic profile across secondary normal fault, projected to a line perpendicular to strike of the fault

red by active tectonics (Fig. 1). Indeed the extremely dry climate does not participate to erosion processes due to those erosion processes.

In conclusion, the Quaternary tectonic deformation of the forearc in southern Peru, between 17-18º30'S, varies significantly along-strike from Moquegua to Tacna (Fig. 1). It is characterized by the reactivation of major older structures that formed during the previous tectonic episodes, probably during the Eocene. This region does not accommodate high tectonic displacements nor extension, despite documentation that the Neogene period corresponds to the mean surrection episode of the Andean range. The western cordillera piedmont is affected by either normal faults with lateral components or emergent thrust that belongs to the Incapuquio fault system. The coastal range is affected by a system a normal faults trending perpendicularly to the coast, which is comparable to northern Chile reverse or normal ones that are trending obliquely to the coast (Gonzalez *et al.* 2003, Allmendiger *et al.* 2005, Fig.1). These normal faults are especially frequent on the eastern border of the Central Valley and affecting the Coastal Cordillera crystalline formations. This fault set can be interpreted as progressive step faults, triggered by gravitational effects due to major subduction earthquakes (Fig. 1).

Sébrier *et al.* 1985 stated that the Pacific Lowlands were suffering NS extension since the Late Quaternary time; but we would precise this to be rather the case along the Coastal Cordillera. Indeed, either the seismic data or the geomorphic evidences of Quaternary tectonic activity indicate NS extension along the Coastal Cordillera (Fig. 1, Audin *et al.* in press).

Our morphological data suggest an interpretation that differs from the GPS measurements and models which report that no active deformation is observed in the forearc of southern Peru (Khazaradze and Klotz 2003). Although there is only one permanent GPS station; segmentation of the faults, small displacements and long recurrence times could be the origin of such observations. Paleomagnetic studies in the modern Chilean forearc have shown widespread rotations in Mesozoic-Paleogene rocks and no rotation in Neogene formations (Roperch *et al.* 2002). On the other hand, recent paleomagnetic results seem to favor an Oligocene age for the rotations in the southern Peruvian forearc, whereas rotations in northern Chile seem to be mainly Eocene or older as no rotation is recorded in Quaternary For-mations (Roperch *et al.* 2002, 2006, Von Rotz *et al.* 2005). This suggests that the timing of tectonic rotations also changes along-strike in the forearc. This may be also true for Neogene tectonic activity. We suggest that the southern Peruvian forearc presents more active tectonic structures than the northern Chilean forearc in general, but may be no difference in the deformation magnitude recorded along the reactivated structures. Another key factor of the along-strike change in tectonic morphology and activity may be the original shape of the South American margin along the Bolivian Orocline and respective obliquity to the subduction of the Nazca plate.

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