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Crustal seismicity and active tectonics in the Arica bend forearc

Claire David [1], Laurence Audin [2], Diana Comte [1], Hernando Tavera [3], & Gérard Hérail [2]

[1] DGF, U. de Chile, Blanco Encalada 2002, Santiago, Chile; d.claire@dgf.uchile.cl, dcomte@dgf.uchile.cl
[2] IRD-LMTG, 14 avenue Edouard Belin 31400 Toulouse, France; Laurence.Audin@ird.fr, gherail@paris.ird.fr
[3] I.G.P. Calle Calatrava N° 216, Urb. Camino Real, La Molina, Lima 100, Peru; jtavera@geo.igp.gob.pe

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INTRODUCTION

The forearc of the Central Andes is characterized by a monoclinal shaped piedmont (Isacks, 1988) with very few evidences of shortening (folds, faults ..). The origin of this forearc morphology remains enigmatic and how it is deforming currently is a subject of investigation. However, this continental subduction margin of fast convergence seems to deform slowly. Indeed, it presents a very moderate but continuous crustal seismicity and the markers of the activity of the structures exist but are discrete. The impressive superficial expression of the ancient faults and its correlation with shallow microseismicity suggests that these main structures are active.

CRUSTAL SEISMICITY

In this work, we make a compilation of all the seismological data existing in the study area (Figure 1).

a-Teleseismic data : Relocalizations and Focal Mechanisms :

In this work, we use the earthquakes recorded by the WGSN, localized by ISC y NEIC and relocalized by Engdahl et al., 1998 (1964-2004) and his compilation before the global seismological network operation (1900-1964). We also use the focal mechanisms determined by Harvard Centroid Moment Tensor Database (http://www.seismology.harvard.edu/). Teleseismic data recorded by the WGSN (World Global Seismographic Network) permit to select the earthquakes with magnitude > 3, occurred in the study region and to obtain the focal mechanisms of the greatest ones (magnitude > 5.5).

From Engdahl et al., 1998 data base (black dots in the Figure 1), we suggest that in the forearc crust of the Arica Bend, there is no great crustal earthquakes generated between 1900 and 2004, their magnitude Mw varying from 3.4 to 6.3. The largest earthquakes occurred in the region present a moderate magnitude Mw 6.3 in 2001 and $M_{G\&R}$ 6.9 in 1934 (Gutenberg & Richter, 1954). The earthquakes which occurred under the Coastal Cordillera and the Central Depression are deep and may be associated to the seismicity of the interplate contact of the subduction, (considering the horizontal and vertical errors). The shallow earthquakes are distributed along the Western Cordillera border from 7 to 36 km depth with an average of 22 km depth. It is interesting to note that the crustal seismic activity showed a strong increase after the crisis of 2001 (Tavera et al., 2005).

The study area is described by four well constrained focal mechanisms, a reverse one (dip=44°) in southern Perú (Tavera & Audin, 2004) and various strike-slips in northern Chile (http://www.harvard.edu.com).

The P and T axes associated with the focal mechanisms change their orientation from NW-SE in Southern Peru, NNE-SSW in the Arica Bend and NE-SW in Northern Chile. The P, T axes correspond to earthquakes of different depth and the apparent rotation could be related to the depth change of stresses.

b-Local data :

We present the microseismicity of 0-30 km depth recorded by permanent and temporary local short period networks (see inverted triangles in figure 1). Very shallow micro-earthquakes (0-15 km depth) are distributed in the Western Cordillera border –ie- the limit of the Altiplano plateau that extends to the east and support the Late Neogene volcanoes. In the Pacific Piedmont the seismicity is deeper and less frequent. Finally, the teleseismic and the local data show that :

- the seismicity in the Arica Bend is moderate, with low magnitude and low temporal frequency.
- the brittle deformation is then continuous but discrete, and is mainly localized in the Western Arc border.
- the kinematics vary within the Arica Bend.

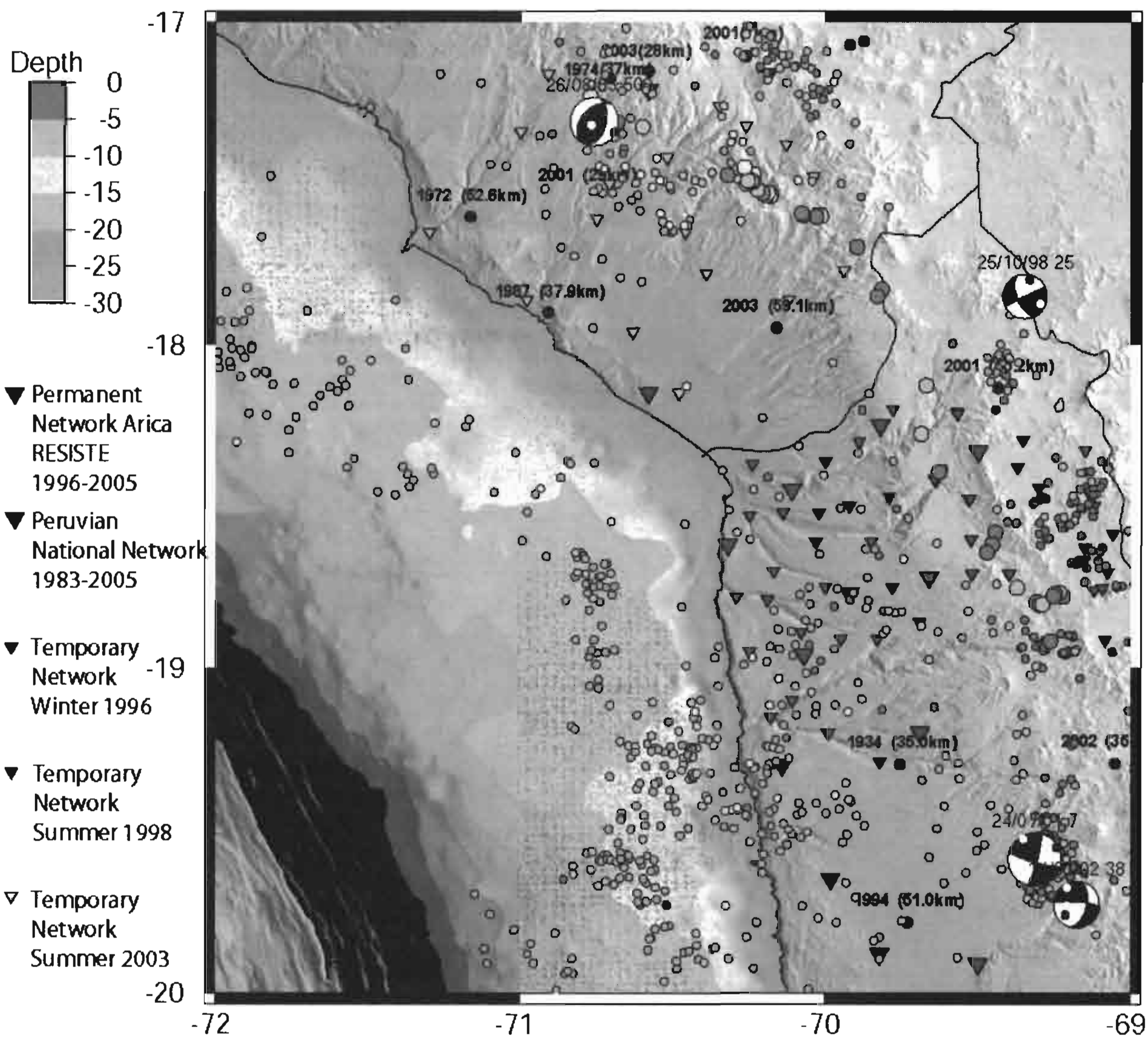

Figure 1 : Crustal Seismicity 0-30 km depth in the Arica Bend from different sources : Harvard (1976-2004), Engdhal (1900-2004), local short period networks (1996-2004).

The focal mechanisms are from Harvard except the reverse one in Peru that was modelised by Tavera & Audin, 2004. The black dots are "crustal" earthquakes from Engdahl et al., 1998 database. The small colour dots are 0-30 km depth crustal seismicity recorded from local data. The bigger colour dots are the 0-30 km depth seismicity in the Western Cordillera border studied in this work.

We focus this work in two ancient fault systems, the Incapuquio Fault System in southern Peru and the Copaquilla-Tignamar Thrust Fault Belt in Northern Chile. Those are the two active systems which limit the Pacific Piedmont from the Western Cordillera.

FAULTS and ACTIVITY

a-Northern Chile : The Copaquilla-Tignamar Fault :

In Northern Chile, the western vergent thrust system described and studied by Muñoz and Charrier, (1996), García, (2001) corresponds to a complex system of thrust faults and fault propagation folds which permitted creating the wide Belén Ridge. It propagated towards the West from 18 Myr to 2.7 Myr (Figure 2):

- The Chapiquiña-Belén thrust uplifts the Paleozoic CMB (core metamorphic Belén) on the Volcanic Formation Lupica of 24-17 My. It strikes N-S to NW-SE and dips 40°-60°.
- The Belén-Tígnamar fault thrusts the Volcanic Formation Lupica 24-17 Ma on the Conglomeratic Copaquilla Formation 12 – 5 Myr. It strikes N10°E-N40°W and dips 30°-60°
- The Socoroma fault thrusts Volcanic Formation Lupica 24-17 My on the Volcanic Zapahuira Formation 16-12 My. It strikes N-S and dips 30°.
- The Copaquilla–Tignamar thrust uplifts the conglomeratic Copaquilla Formation and Ignimbrite Lauca (2.7 My) on themselves. It strikes N25°W and dips 25°-35°.

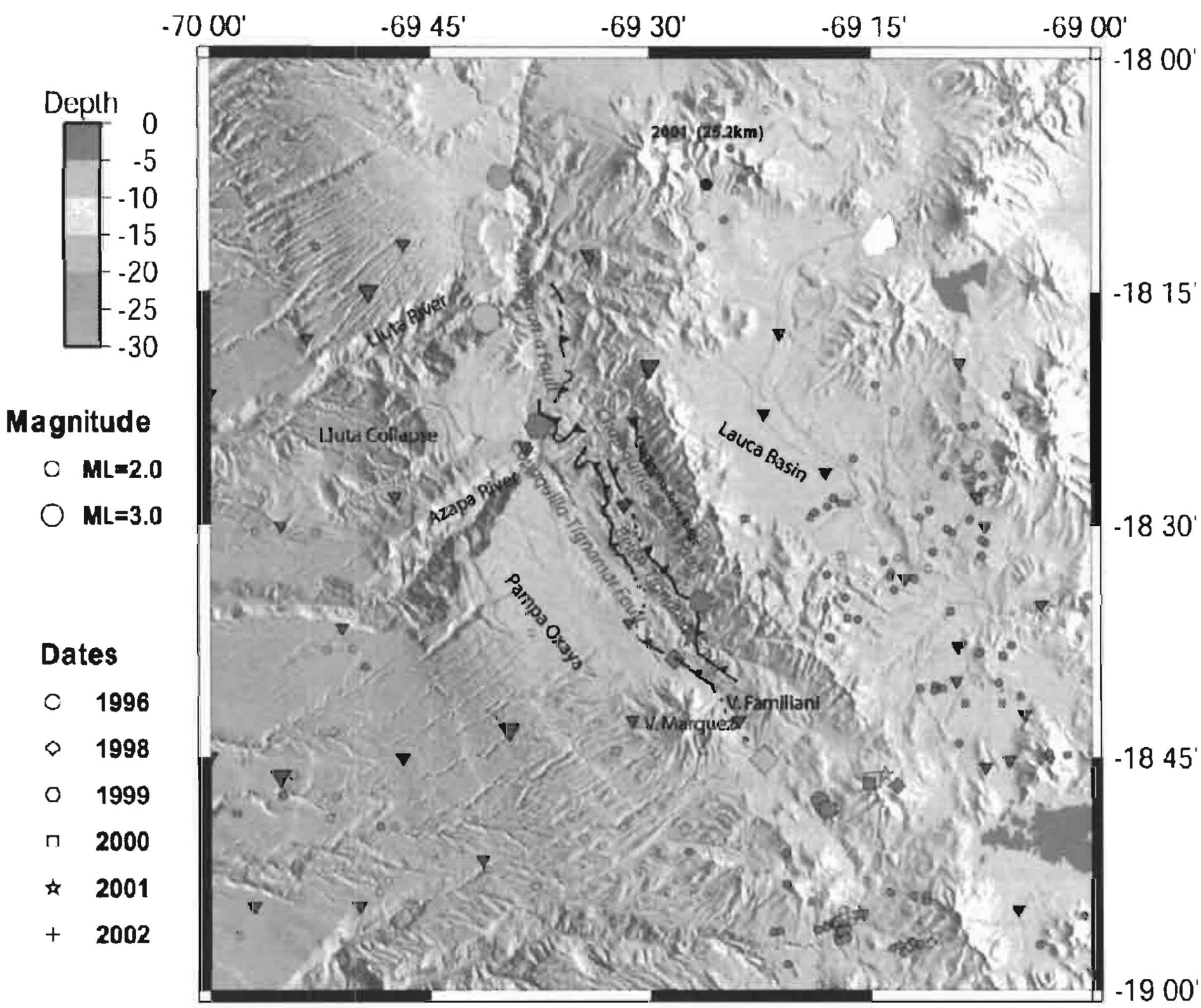

Figure 2 : Crustal Seismicity 0-30 km depth on the fold and thrust belt of the Chapiquiña-Belén Ridge : See legend of Figure 1.
The crustal seismicity represented by small dots were registered by local short period networks (1996-2004). The crustal earthquakes represented by symbols are the superficial earthquakes on the the Copaquilla-Tígnamar fault of the fold and thrust belt of Chapiquiña-Belén.

Geological evidences show that the Pliocene activity of the system is localized on the Copaquilla-Tignamar fault and reaches at least 2.7 My : the Lauca ignimbrite (2.7 My) is systematically 100m higher at the East of the fault than at the West. The activity post 2.7 Myr has not been observed but continuous and moderate superficial seismicity occurs on the fold and thrust belt of the Chapiquiña-Belén Ridge (Figure 2). The low superficial seismicity, with local magnitude between 2 and 3, between 0 and 10 km depth, is localized along the Copaquilla-Tìgnamar thrust. Registered from local reds, these earthquakes are horizontally well constrained but their depth depends strongly on the velocity structure in depth. However, they indicate that the thrust is active and that the Chapiquiña-Belén ridge is a zone of brittle deformation.

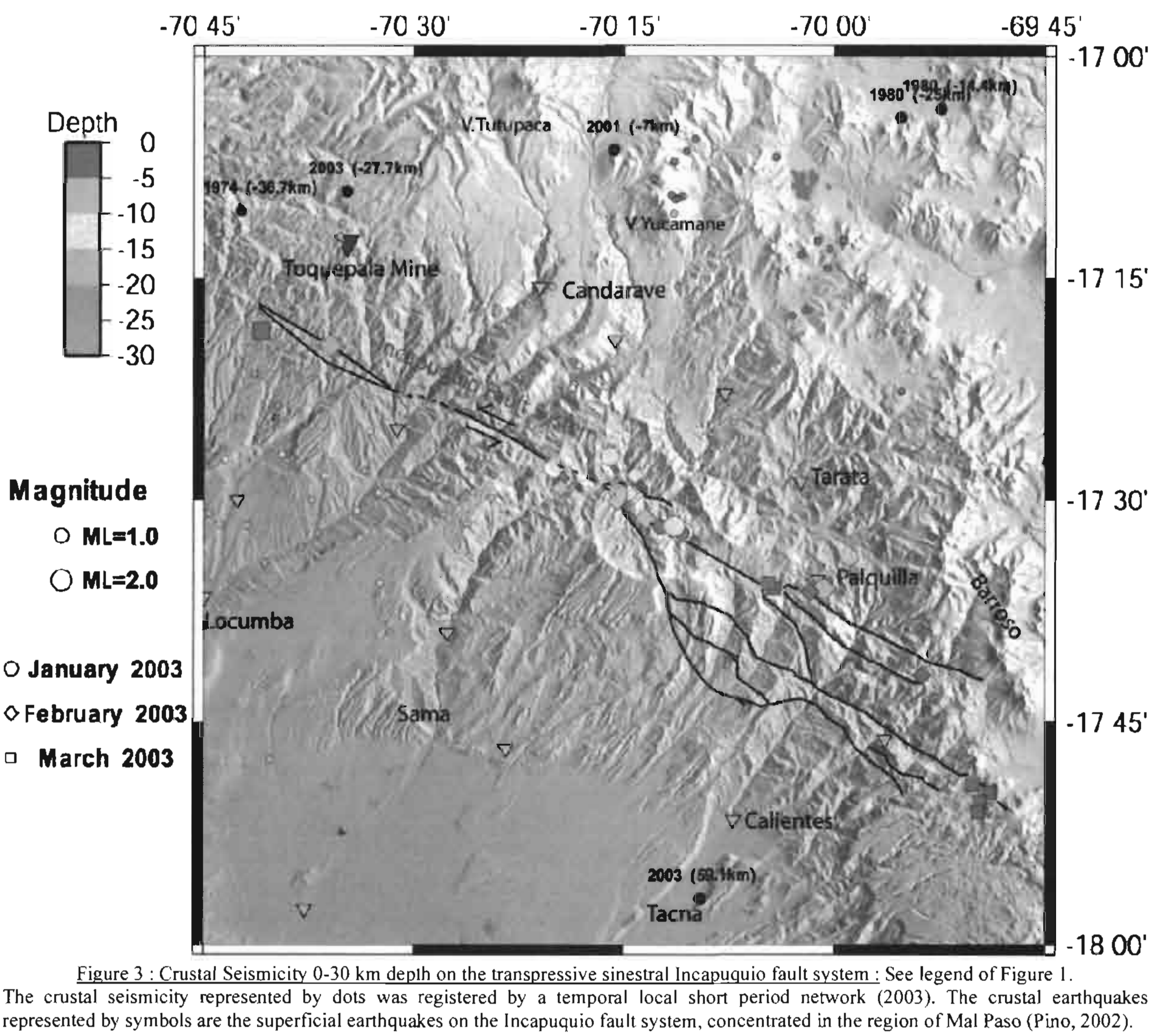

Figure 3 : Crustal Seismicity 0-30 km depth on the transpressive sinestral Incapuquio fault system : See legend of Figure 1.
The crustal seismicity represented by dots was registered by a temporal local short period network (2003). The crustal earthquakes represented by symbols are the superficial earthquakes on the Incapuquio fault system, concentrated in the region of Mal Paso (Pino, 2002).

b-Southern Perú : Incapuquio Fault System :

In Southern Perú the fault system Incapuquio – Challaviento – Micalaco – Capillune is a huge structure which strikes SSE-NNW and dips subvertically. Its structural characteristics indicate a sinestral strike-slip system that has actuated mainly in a transpressive way from Cretaceous Superior, Palaeocene, Palaeogene, (Jacay et al., 2002, Sempéré et al., 2002) until the Oligocene and Miocene (Rehrig and Hardy, 2004). This fault system affects very ancient rocks : Precambrian, Palaeozoic, Mesozoic ones and is strongly associated with igneous rocks derived from the mantle (Pino et al., 2002), it shows that it is subvertical and lithospheric scale. The Incapuquio Fault in the region of Mal Paso is characterised by a rhombus positive asymmetric flower structure, accompanied by mylonites and cataclasites (Jacay et al., 2002, Pino et al., 2002). This segment of the fault presents a concentration of superficial seismicity (0-15 km depth) localized in the branches junctions of the fault system. This very ancient structure whose current morphology suggests recent activity is therefore seismically active and stresses seem to focus in the Mal-Paso region where faults converge.

CONCLUSIONS

Northern Chile fold and thrust belt strongly differs from Southern Peru transpressive lithospheric scale system. The change of the strike of the trench of the inner forearc and the orogen structures in the same convergent environment could be responsible for the different stress regimes.

However the compression governs both systems and the current superficial seismic activity affects the main systems of the Western Cordillera border.

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