Subject offered for a contract starting october 2015

SUBJECT TITLE: **Study of mechanical properties and transient deformation at subduction zones from analysis and modeling of seismic activity, the case of Northern Chile.**

Advisor: **Pascal Bernard, Physicien, bernard@ipgp.fr**
Second Advisor/ Supervisor:
Claudio Satriano, Physicien Adjoint, satriano@ipgp.fr
Host lab/ Team :
IPGP – Sismologie – UMR7154

Financing: Doctoral contract with or without assignment

For more information go to http://ed560.ipgp.fr, section: Offres de these (PhD offer), You must apply on the Doctoral School website

Active deformation at subduction zones is accommodated by transient seismic or aseismic slip events on the frictionally coupled plate-interface and within the brittle lithosphere. These events encompass several scales of energy and duration, ranging from the low-magnitude background seismicity to megathrust ruptures, and may include slow earthquakes, tremor and aseismic slow slip (e.g., *Ide et al.*, 2007).
Seismic and slow-slip activity at subduction zones is controlled by many parameters: deformation rate; fault zone coupling at different scales; geometrical complexity; heterogeneous distribution of non-stationary stress and strength along the fault interface; temperature, fluid pore pressure and rock composition variations along the fault interface.
Seismic and geodetic observations thus provide a key tool for understanding and modeling the mechanical properties of fault zones and the dynamic mechanisms controlling transient deformation.

The overall objective of this thesis is to advance our understanding of the relation between forcing processes (tectonic loading, slow-slip, fluid pore pressure), mechanical properties and seismic activity at subduction zones. This objective will be pursued by the development of improved methods for detection and characterization of the seismicity and by the interpretation of the observed activity through mechanical models of earthquake nucleation rupturing and interaction.

The main study area will be the northern Chilean subduction, a 500-km-long seismic gap, which last fully broke in 1877 (Mw ~8.8) and that recently produced two large earthquakes on its southern (Mw 7.7, 2007 Tocopilla) and northern termination (Mw 8.1, 2014 Iquique). The Mw 8.1 2014 Iquique earthquake was prepared by an acceleration of seismic activity, with an increasing number of M > 3.5 events in the period of August 2013 – April 2014, with respect to the period of January - July 2013 (*Hayes et al.*, 2013). This activity culminated into a large foreshock on March 16, 2014 (Mw 6.7), followed by four other strong foreshocks

(Mw 6.2-6.3) between March 17 and March 23. This gradual destabilization of the interplate may have been accompanied by one or more slow-slip events, as revealed by long-base tiltmeter data analysis (*Boudin et al.*, 2014) and GPS data (*Meneses et al.*, 2015).

Seismic activity in Northern Chile is monitored by two dense networks, managed by CNRS-INSU (France), GFZ (Germany) and Universidad de Chile: the regional broadband IPOC network, covering the whole northern Chilean seismic gap, and the Iquique Local Network (ILN), comprising 20 stations around the city of Iquique, close to the 2014 rupture. Geodetic measures are provided by a permanent GPS network and by two long-base tiltmeters (*Boudin et al.*, 2014).
The presence of such dense station coverage provides an incredible opportunity to study the seismic and slow-slip activity preparing and following the Iquique earthquake.

A first objective of this thesis is to create an improved seismic activity map for Northern Chile by lowering the detection threshold and increasing the location resolution. At this scope, the candidate will employ and further develop new methods for detection and characterization of seismic sources exploiting the frequency selective coherence of the wave field at dense seismic arrays (*Poiata et al.*, 2014). The statistical properties of space-time seismic activity (e.g. space-time clustering, repeating earthquakes) will be analyzed in relation with: the known structure of the subduction zone; the asperities ruptured during the Iquique mainshock and the larger fore- and aftershocks; the coupling map of the subduction interface (*Métois et al.*, 2013); the slow-slip activity.

A second objective of this thesis is to develop and test mechanical models of earthquake nucleation, rupturing and interaction in relation with the frictional and geometrical properties of the subduction zone and the forcing processes (tectonic loading, slow-slip events, fluid pore pressure).

This work will be conducted in close collaboration with researchers at GFZ (Potsdam, Germany) and at the Universidad de Chile (Santiago, Chile).

References

Boudin, F., Bernard, P., Esnoult, M.-F., Olcay, M., Tassara, C., El Aissaoui, M., Nercessian, A., Vilotte, J.P. (2014). Evidence for slow slip events preceeding the M8, April 1st, 2014 Pisagua Earthquake (Chile), from an underground, long base hydrostatic tiltmeter. AGU Fall Meeting, San Francisco, USA, 15-19 December 2014.

Hayes, G. P., Herman, M. W., Barnhart, W. D., Furlong, K. P., Riquelme, S., Benz, H. M., et al. (2014). Continuing megathrust earthquake potential in Chile after the 2014 Iquique earthquake. *Nature*, 1–9. doi:10.1038/nature13677

Ide, S., Beroza, G. C., Shelly, D. R., & Uchide, T. (2007). A scaling law for slow earthquakes. *Nature*, *447*(7140), 76–79. doi:10.1038/nature05780

Meneses, G. and Vigny, C. (2015) Monitoring of the Northern Chile subduction interface. PhD Thesis (ongoing).

Métois, M., Socquet, A., Vigny, C., Carrizo, D., Peyrat, S., Delorme, A., et al. (2013). Revisiting the North Chile seismic gap segmentation using GPS-derived interseismic coupling. doi:10.1093/gji/ggt183

Poiata N., C. Satriano, P. Bernard, T. Matsuzawa, J.-P. Vilotte and K. Obara (2014). Applying array methods to multiscale imaging of slow earthquakes in Nankai subduction zone. AGU Fall Meeting, San Francisco, USA, 15-19 December 2014