SEISMICITY ACTIVATED IN ANDEAN TROUGH BY STATIC STRESS INCREASE FROM THE M_W=8.8, FEBRUARY 27, 2010, MAULE EARTHQUAKE

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INTRODUCTION

Seismicity increase of about eight times is observed in a narrow area, oriented NNW-SSE between 35°S and 36°S and close to the Andes axis, comparing periods of 80 days before and after the great Maule earthquake (Figure 1). Although earthquake localizations are obtained using only two seismic stations, we are able to acceptably define the activated area assuming an average value depth. The area coincides with the northern part of a line of Pleistocene Calderas within Las Loicas trough (Ramos y Folguera 2005; Folguera et al. 2006). Magnitude Mc varies from 0.7 to 2.5, except for two earthquakes of M=4.1 and M=4.4.

GEOLOGICAL SETTING

The Neuquén basin is formed by the extension in the Upper Triassic and Lower Jurassic in the western Gondwana margin. The basin, during the Triassic-Jurassic experienced extensive cycles and faults were generated with N, ENE and NW directions, which controlled the geometry of the subsequent evolution (Vergani et al. 1995). A compressive regime was installed between the middle Cretaceous to upper Miocene (Vergani et al. 1995; Ramos and Kay 2006). Ramos and Folguera (2005) and Ramos and Kay (2006) proposed the existence of different stages of compression and extension during the Cenozoic.

Between the middle Miocene (~ 17 Ma) to late Miocene a compressive regime was installed (Ramos and Folguera, 2005). It has been attributed to a subducted Nazca plate flattening process (Ramos and Kay 2006) and become responsible for: a) the fold and thrust belt of Malargüe (FPCM) main structure, and b) the crystalline San Rafael block exhumation. FPCM has both a thin and thick-skin tectonic, in the first the deformation is controlled by low-angle thrust new structures oriented N-S to NNE, and in the later by high-angle reverse faults oriented NNW to NW (Giambiagi et al., 2009) corresponding to the reactivation of structures formed during the rifting episodes in the Mesozoic and inverted during Cenozoic. (Giambiagi et al, 2005; Giambiagi et al., 2009; Yagupsky et al., 2008).

During the Pleistocene, due to a slab deepening process, the asthenosphere were able to ascent and reach the sector of the Cordillera Principal and as a consequence Las Loicas trough was formed with NNW-SSE orientation between latitudes 35°S and 38°S (Folguera et al., 2005a,b; Ramos and Folguera, 2005; Folguera et al., 2006). The thick pre-existing crust causes the formation of large calderas and rhyolite domes (Ramos and Folguera, 2005).

DATA AND METHODOLOGY

Data are from two digital stations in the Andean back arc, Mendoza Province, Argentina (Instituto Geofisico-Sismologico Ing. F. S. Volponi, Universidad Nacional de San Juan, set the seismic stations at the fluorescent stations of Pierre Auger Observatory, Malargüe): COIH (35.11ºS. 60ºW, 1715m) with Guralp CMG-EDU intermediate band triaxial sensor and PUMA (35,50ºS, 69,45ºW, 1423m) with three S13 Geotech-Teledyne short period sensors (vertical and two horizontals).

Readings of P and S wave arrival times (“picking”) were made via SEISAN system (Ottemoller et al., 2011).

Localization and P-wave focal mechanisms of the two earthquakes with M>4.0 occurred on 2010/4/3 and 2010/5/29 were obtained with data from regional stations: a) Argentina: COIH, PUMA, ZON (Instituto Geofisico-Sismológico Ing. F.S. Volponi, Universidad Nacional de San Juan), 12 from INPRES (Instituto Nacional de Prevención Sísmica); PLCA (Paso Flores, Argentina, Global Telemetered Seismograph Network, USAF/USGS-IRIS), and 40 station from Maule Earthquake (Chile) (see TABLE 1)

For the earthquake M_w=3.5, 01/3/15, data are from CHARGE experiment (Chile Argentina Geophysical Experiment, PI Susan Beck, Arizona University). The localization of those three earthquakes were made using HYPOCENTER (Lienert et al., 1995). We solved the focal mechanism with the first movements of P waves using FOCMEC (Snoke et al., 1984) FPFIT (Reasenberg and Oppenheimer, 1985) and HASH (Hardebeck and Shearer, 2002). Both earthquakes with M>4.0 occurred in the northern part of the activated area and their mechanisms are normal and strike slip respectively.

To examine causal plausibility between the great earthquake and the activated seismicity we calculate static stress change with Coulomb's criterion (Toda et al., 1998, 2005) and Coulomb 3.3 software (http://usgsprojects.org/coulomb). The “source” is the fault plane displacement field of the Maule earthquake. We assume types of receiving faults selected from what geologically is known in the region, and friction coeficient μ´=0.6. Graven or hemigraven type normal faults are possible, and also faults with the same geometry as these faults but with strike slip displacement predominance over the normal one.

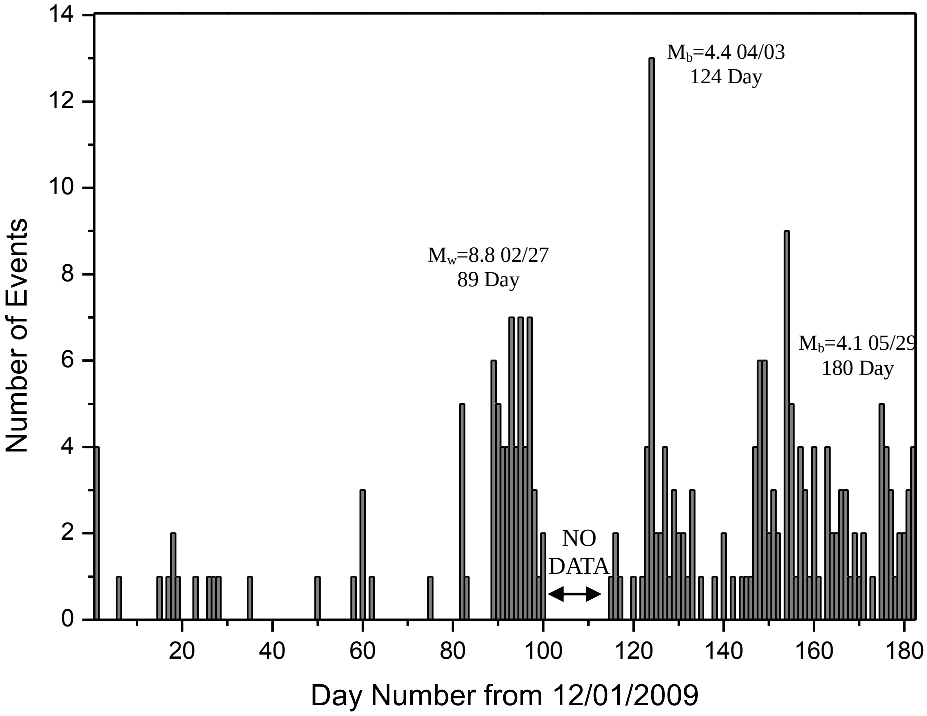

Figure 1: Events number day by day

RESULTS AND CONCLUSIONS

Focal mechanisms of earthquakes from 35.3°S to the north are in agreement with a northern termination of Las Loicas trough at about that latitude.

Static stress variation in the area of activated seismicity varies from about 5 bars in the north to about 4 bars in the south (Figure 2). This make plausible that the increased seismicity between ~35.3°S and 36°S in Las Loicas trough are caused by the great M_w=8.8, 2/27/2010, Maule earthquake.

Models of static stress variation in a near central point of the activated area show that the contribution of the normal stress is much larger than the shear stress, not only for normal slip but also for cases with strike slip predominance. Faults with the same geometry but having reverse slip do not become activated.

The extension direction, perpendicular to the though, coincides with the direction of extension determined by the Maule earthquake coseismic displacements observed with GPS (eg, Delouis et al., 2010, Vigny et al., 2011). Thus the activation of seismicity is produced but the "unclumping" of the receiver faults in Las Loicas trough.

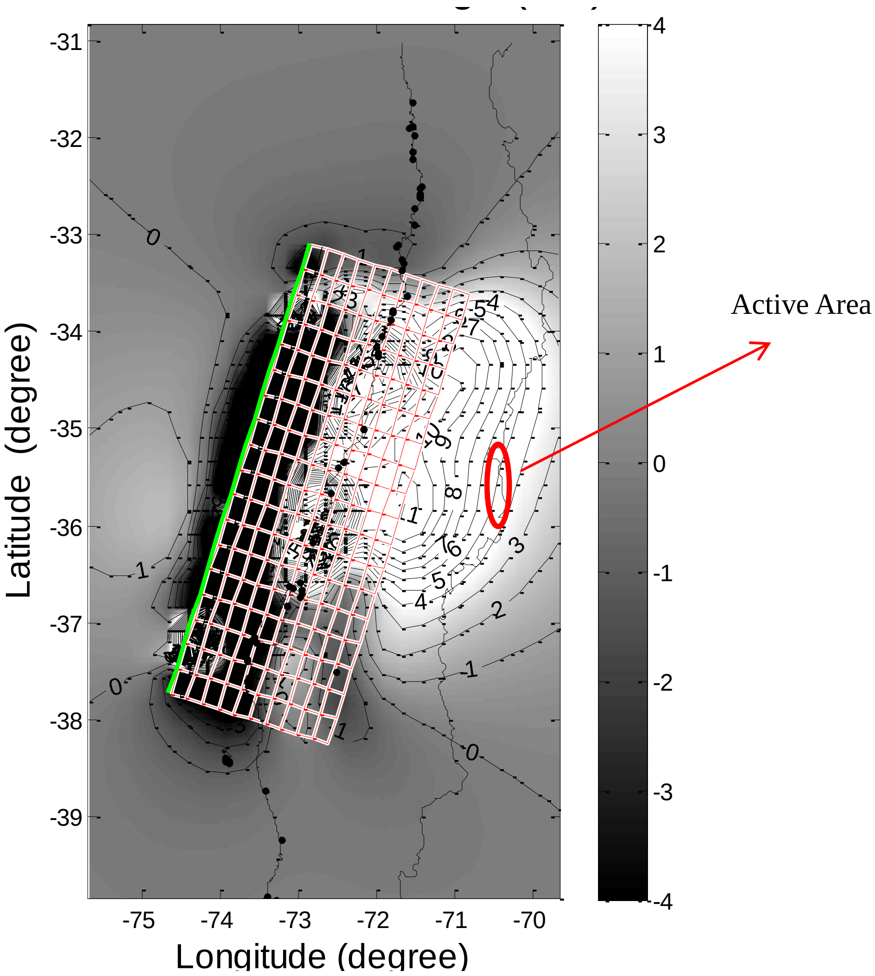

Figure 2: Coulomb stress change by the M_w=8.8, February 27, 2010, Maule Earthquake

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Network	Station name
INPRES	AGREL ARCO SALAG RTUM RTLS RTCT CFAA RTLL GUAND CCRUZ SUCO MOGNA
MAULE EARTHQUAKE AFTERSHOCK EXPERIMENT, CHILE	QC07 AANI U46B U56B U54B U51B U64B U62B U69B U65B U43B U67B U71B U61B QC12 U57B U63B U32B U66B U34B QC09 U70B U73B QC06 U68B U59B U29B U28B U60B U26B U74B U35B U36B U11B U02B U03B U12B U16B U15B U07B
CHARGE	SJAV PENA CONS NIEB RAFA PENA AREN BARD

TABLE 1: Used stations

REFERENCES IN ORDER OF APPEARANCE

Ramos, V.A. y Folguera, A. 2005. Los Andes Australes: una evolución tectónica excepcional entre el sur de Mendoza y el norte de Neuquén. 6º Congreso de Exploración y Desarrollo de Hidrocarburos, Archivos Electrónicos, Mar del Plata.

Folguera, A., Zapata, T. and Ramos, V.A. Late Cenozoic extension and the evolution of the Neuquén Andes. Evolution of the Andean margin: A tectonic and magmatic view from the Andes to the Neuquén Basin (35°-39°S latitude): Geological Society of America Special Paper 407: 267-285. 2006.

Vergani, G. D., Tankard, A. J., Belotti, H. J. y Welsink, H. J. Tectonic evolution and paleogeography of the Neuquén Basin, Argentina. En: Tankard, A. J., Suárez, R. Y Welsink, H. J. (eds): Petroleum Basins of South America. American Association of Petroleum Geologists, Memoir 62: 383-402, Tulsa. 1995.

Ramos, V. y Kay, S. 2006. Overview of the tectonic evolution of the southern Central Andes of Mendoza and Neuquén (35º-39ºS latitude). Evolution of the Andean margin: A tectonic and magmatic view from the Andes to the Neuquén Basin (35º-39ºS latitude): Geological Society of America, Special Paper 407, 1-17.

Giambiagi, L., Bechis, F., García, V., and Clark, A., Temporal and spatial relationship between thick- and thin-skinned deformation in the thrust front of the Malargüe fold and thrust belt, southern Central Andes, VI International Symposium on Andean Geodynamics: Barcelona, IRD, p. 315-318. 2005.

Giambiagi, L., Ghiglione, M., Cristallini, E., and Bottesi, G., Kinematic models of basement/cover interaction: Insights from the Malargue fold and thrust belt, Mendoza, Argentina: Journal of Structural Geology, v. 31, p. 1443-1457. 2009.

Yagupsky, D.L., Cristallini, E.O., Fantin, J., Valcarce, G.Z., Bottesi, G., and Varade, R., Oblique half-graben inversion of the Mesozoic Neuquen Rift in the Malargue Fold and Thrust Belt, Mendoza, Argentina: New insights from analogue models: Journal of Structural Geology, v. 30, p. 839-853. 2008.

Folguera, A., Ramos, V., Zapata, T., Spagnuolo, M., Miranda, F. 2005a. Pliocene to Quaternary retro-arc extensión in the Andes at 35°-37°30´ S. 6° International Symposium on Andean Geodynamics, Extended Abstracts: 277-280.

Folguera, A., Espinach, S., Utge, S., Rojas Vera, E. y Ramos, V. A. 2005b. Evolución Tectónica de los Andes entre 36° y 38° S. 16° Congreso geológico Argentino, Actas, Tomo 2: 19-22. La Plata.

Ottemöller, L., Voss, P.H and Havskov, J. Seisan: Earthquake Analysis Software for Windows, Solaris, Linux and Macosx , 2011.

Lienert, B. R. E. and Havskov, J. 1995. A computer program for locating earthquakes both locally and globally. Seis. Res. Lett., 66:26–36.

Snoke, J. A., Munsey, J. W., Teague, A. G., and Bollinger, G. A. 1984. A program for focal mechanism determination by combined use of polarity and SV-P amplitude ratio data. Earthquake notes, 55.

Reasenberg, P. and Oppenheimer, D. Fpfit, fpplot, and fppage: Fortran computer programs for calculating and displaying earthquake fault plane solutions. Technical report, U.S. Geol. Survey. 1985.

Hardebeck J. and P. Shearer, A new method for determining first-motion focal mechanisms, Bull. Seism. Soc. Am. 92, 2264-2276, 2002.

Toda, S., and Stein, R. S. Response of the San Andreas fault to the 1983 Coalinga-Nu-ez Earthquakes: An application of interaction-based probabilities for Parkfield, J. Geophys. Res., 107, 10.1029/2001JB000172, 2002.

Toda, S., Stein, R.S., Reasenberg, P.A. and Dieterich, J.H. Stress transferred by the Mw=6.5 Kobe, Japan, shock: Effect on aftershocks and future earthquake probabilities, J. Geophys. Res., 103, 24,543-24,565, 1998.

Delouis, B., Nocquet, J. M. and Vallée M. Slip distribution of the February 27, 2010 Mw = 8.8 Maule Earthquake, central Chile, from static and high rate GPS, InSAR, and broadband teleseismic data, Geophys. Res. Lett., 37, L17305, doi:10.1029/2010GL043899. 2010.

Vigny, C. Socquet, A. Peyrat, S., Ruegg, J.C., Métois, M., Madariaga, R., Morvan, S., Lancieri, M., Lacassin, R., Campos, J., Carrizo, D. Bejar-Pizarro, M., Barrientos, S., Armijo, R., Aranda, C., Valderas-Bermejo M. C., Ortega, I., Bondoux, F., Baize, S., Lyon-Caen, H., Pavez, A., Vilotte, J. P., Bevis, M., Brooks, B., Smalley, R., Parra, H., Baez, J. C., Blanco, M., Cimbaro, S. and Kendrick, E. The 2010 Mw 8.8 Maule mega thrust earthquake of central Chile, monitored by GPS, Science, 332(6036), 1417–1421, doi:10.1126/science.1204132. 2011.