COSEISMIC AND ASEISMIC SLIP OBSERVED
from continuous gps measurements
FOR THE 2001 SOUTHERN PERU EARTHQUAKE (Mw = 8.4)

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KEY WORDS: co-seismic slip, aseismic slip, slow earthquake, gps

INTRODUCTION

On June 23, 2001 at 20:33, UTC, a major earthquake occurred near the coast of southern Peru, about 190 km west of Arequipa (16.15°S, 73.40°W) .A magnitude of 8.4 was computed for this earthquake by the USGS (NEIC). The earthquake occurred along the west coast of Peru (Figure 1) at the boundary between the Nazca and South American plates and resulted from thrust faulting along this boundary as the Nazca plate subducts beneath the South American plate. The two plates are converging towards each other at a rate of 78mm/yr (DeMets et al., 1990). This earthquake took place at a zone of the plate boundary where no major rupture occurred since the 1868 earthquake of magnitude approximately 8.5 – 9 (Dorbath et al., 1990, Comte and Pardo, 1991). The June 23 shock filled partially the South Peru seismic gap (Nishenko, 1985).

DATA

GPS data of the IGS station of AREQ (Arequipa, Peru) are used to determine the quasi-static displacement associated with the Mw = 8.4 Southern Peru earthquake on June 23, 2001. Daily processing of the AREQ data together with those from other IGS stations in South America and one close station in Chile (UAPF, Iquique) gives the position of the AREQ station with respect to other GPS permanent stations in the far field. It results a time history of the source relaxation seen from AREQ station (figure2).

INTERPRETATION

At the time of the main shock (day 174/2001) a co-seismic displacement is evidenced of about 50 cm WSW in the opposite direction to the known interseismic velocity. The observed co-seismic AREQ vector is consistent with the modelled displacement (0.52 m) associated with a reverse fault on the subduction interface (dimension 240x110 km2, 4.50 m slip, rake 76°, Mw = 8.35) fitting approximately the aftershock zone. The computed magnitude and mechanism are consistent with those given by the USGS (NEIC).

The time serie of the observed displacement (Figure 2) shows that the main shock is followed by a significant post seismic signal occuring in the same direction as the co-seismic movement: (1) a first period lasting two week shows a rate of about 4 mm/day (about 8 cm of after-slip); during this period the strong aftershock (Mw=

7.6) of July 7, is seen as a step of about 2-3 cm on the time series, (2) a lower rate period is following (0.3 mm/day) during at least 9 month after the main shock and seems to continue for the beginning of the year 2002. Altogether the post-seismic signal reaches 12-15 cm, that is 30 % of the co-seismic size. This afterslip signal is consitent with a progressive relaxation of accumulated strains (slow earthquake) in the deeper part of the subduction plane.

A slight preseismic displacement (20-30 mm) is detectable during the 6 months before the main shock. It is particularly evidenced as a change in the slope of the time series during the 30 days preceeding the June 23, 2001 event (rate of about 0.7 mm/day). This pre-seismic signal seems also consistent with slow strain events in the deeper part of the rupture zone.

CONCLUSIONS

The daily analysis of GPS data from Arequipa (Peru) and other continuous GPS stations in South America, during the year 2000-2001 reveals four stages of the seismic cycle associated with the subduction of the Nazca plate beneath the South American continent. During the year before the earthquake the end of the interseismic loading is seen as the almost stability of the baseline UAPF-AREQ. A weak pre-seismic signal is emerging from the background noise during the month preceeding the mainshock and is evidenced by a change in the slope of the time series. The mainshock is characterized by an abrupt change of the baseline (day 174) corresponding with the rupture of the locked zone. A significant afterslip movement is seen for the month following the co-seismic rupture. It is continuing at the end of our investigation (March 2002), reaching 30% of the co-seismic displacement.

The June 23, 2001 South Peru earthquake (Mw=8.4) is very similar in size and in seismotectonic context to the 1995 Mw=8.1 Antofagasta earthquake (Ruegg et al., 1996). Each one occurred at the northern and southern extremity of the 1877 Northern Chile seismic gap which has now a strong probability to undergo a similar event.

REFERENCES

Bevis, M., E.C. Kendrick, , R. Smalley, T. Herring, J. Godoy and F. Galban, Crustal motion North and South of the Arica deflection : comparing recent geodetic results from Central Andes, *Geochem., Geophys., Geosyst.*, **1**, 1999.

Comte, D. and M. Pardo, Reappraisal of great historical earthquakes in the Northern Chile and southern Peru seismic gaps, *Natural Hazards,* **4**, 23-44, 1991.

DeMets, C., R.G. Gordon, D.F. Argus and S. Stein, Current plate motions, *Geophys. J. Int.*, **101**, 425-478, 1990.

Dorbath L., A. Cisternas and C. Dorbath, Quantitative assessment of great earthquakes in Peru, *Bull. Seism. Assoc. Amer.*, **80**, 551-576, 1990.

Nishenko, S.P., Seismic potential for large and great intraplate earthquakes along the Chilean and southern Peruvian margins of South America: A quantitative reappraisal, *J. Geophys. Res.*, **90**, 3589-3615, 1985.

Okada Y, Surface deformation to shear and tensile faults in a half space, *Bull. Seism. Assoc. Amer.*, **75**, 1135-1154, 1985.

Ruegg J.C., J. Campos, R. Armijo, S. Barrientos, P. Briole, R. Thiele, M. Arancibia, J. Canuta, T. Duquesnoy, M. Chang, D. Lazo, H. Lyon-Caen, L. Ortlieb, J.C. Rossignol and L. Serrurier, The Mw=8.1 Antofagasta earthquake of July 30, 1995 : First results from teleseismic and geodetic data, *Geophys. Res. Lett.*, **23**, 9, 917-920, 1996.

J.C. Ruegg , M. Olcay and D. Lazo , Co, post and pre(?) -seismic displacements associated with the Mw = 8.4 Southern Peru earthquake of June 23, 2001 from continuous GPS measurements, Seismological Research Letters, vol.72, number 6, pp. 680-685, Nov.-Dec. 2001.

Figure Caption:

Figure 1 – Map of the Southern Peru aera, showing the main shock Mw=8.4 earthquake (red star inside a white circle), the focal mechanism, the main aftershock Mw = 7.6, and the aftershocks (red dots) as determined by the USGS. The observed co-seismic displacement vectors associated with the main shock is shown by an heavy blue arrow and the modelled vector by a thin pink arrow. The total displacement vector (co-seismic + post-seismic) reached after 9 months following the mainshock is shown in green (65 cm). The interseismic velocity vectors for AREQ and other regional GPS sites are shown by thin colored arrows [yellow from Norabuena et al. (1998), green from Bevis et al.(1999), blue from Angerman et al. (1999), and red from Ruegg et al. (preprint, 2001)]. The Nuvel 1A plate convergence vector is show in brown. The modeled rupture zone contour is shown in yellow.

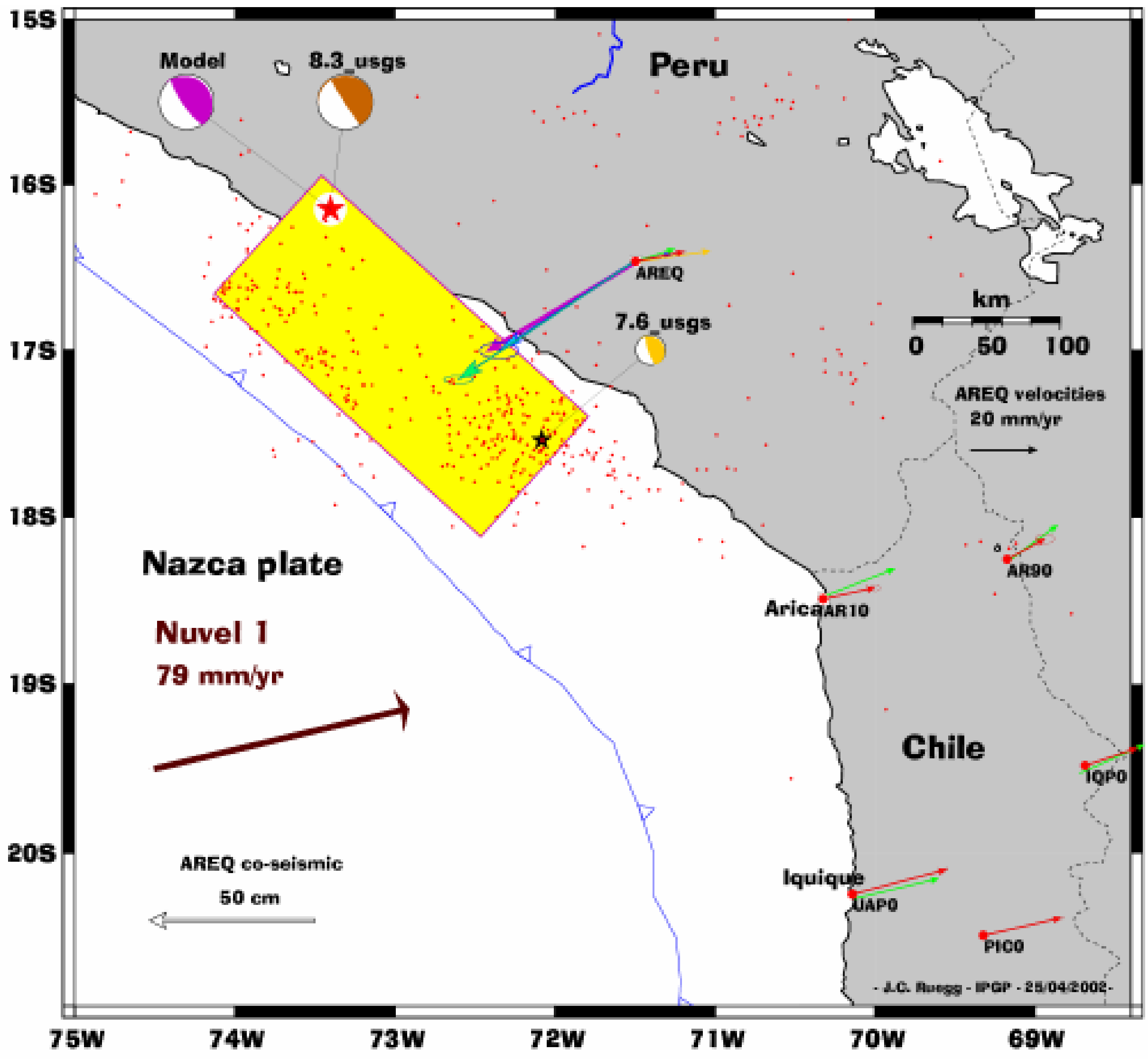

Fig_1

Figure 2 – Variations of the displacement vector of the GPS station AREQ (Arequipa) deduced from the baseline AREQ_UAPF between January 2000 and April 2002. The main shock (Mw=8.4) occured on day 174/2001. During the 6 months preceeding the main shock a signal of about 2-3 cm is seen on the time serie. During the two week following the main shock an after-slip with a mean rate of about 4 mm/days is partly associated with the strongest aftershocks. This afterslip is continuing a a lower rate (0.3 mm/day) during the 9 following months