ON PREDICTING COASTAL UPLIFT AND SUBSIDENCE DUE TO LARGE EARTHQUAKES IN CHILE

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SUMMARY

Vertical elevation changes, observed for three large earthquakes in Chile (1960, 1985 and 1995 events), are used to determine the downdip extent of the seismogenic region. Interpolation of the axis of the observed null elevation change for these three large earthquakes, as a function of their distance to the trench, to other zones of the country allow future estimations of coast uplift or subsidence.

INTRODUCTION

In subduction zones like the Chilean convergent margin, the size of a large earthquake is determined by the length, width (updip and downdip extension) of the rupture region as well as the amount of displacement on it. The location of the downdip extension of rupture determines the position of greater subsidence -and the null elevation change axis- at the surface and concurrently, the location of greater subsidence and null coseismic change give a very good estimation of the location of the downdip end of faulting. This place is almost independent of the updip extension location. The amount of slip on the fault only acts as a scaling factor, it does not produce any change in the shape of the elevation change as a function of distance from the trench.

The most common way to estimate the downdip extension of the rupture zone is to locate the transition zone between reverse and tensional faulting along the dip of the subducted region, as revealed by earthquake focal mechanisms. In this work, we use crustal deformation observations of three large earthquakes in Chile as well as an estimation of the downward curved Wadati-Benioff zone to estimate no only the downdip extension of the seismogenetic region but the implication that its location has along the coast of Chile, i. e., expected uplift or subsidence along the coast.

DATA and ANALYSIS

Crustal deformation has been well documented for three large earthquakes in Chile: The May 22, 1960 M_W=9.5, the March 3,1985 M_W=8.0 and the July 30, 1995 M_W=8.1 events, we briefly describe the related information on each event.

The 1960 earthquake has been the largest event recorded in this century (Kanamori, 1977). Remarkable changes in land levels were observed in a region 1000 km long and 200 km wide. Extreme coseismic changes ranged from 5.7 m of uplift at Guamblin Island to 2.7 m of subsidence in Valdivia. Plafker and Savage (1970) analyzed the static deformation data and presented teleseismic surface wave evidence to support their preferred uniform slip dislocation model that involved between 20 and 40 m of slip on a rupture 1000 km long by 60 km wide. Later, Plafker (1972), Linde and Silver (1989) and Barrientos and Ward (1990) revisited the deformation field concluding that the main portion of slip took place on a roughly 900-km long fault by 120-150 km wide. Fig. 1 (C and D) shows the elevation changes on three profiles according to Plafker and Savage (1970).

The M_W=8.0, 1985, Central Chile earthquake has been the largest event in this region since 1906. Aftershock surveys, body-wave modeling, surface wave analysis, gravimetric observations and geodetic estimates revealed a rupture length of approximately 160 km in a north-south orientation with maximum slip of about 3.5 m (Christensen and Ruff, 1986, Comte et al, 1986, Barrientos, 1988; Choy and Dewey, 1988). A first-order leveling lines, repeatedly surveyed in 1981 and four months after the earthquake, evidenced 0.5 m of uplift at the coast nearby the city of San Antonio and a 10-cm subsidence about 60 km inland. The projected elevation changes on a profile perpendicular to the coast is shown in Fig. 1(B).

The deformation field produced by the 1995, M_W=8.1, Antofagasta earthquake has been the first ever detected by a GPS array in Chile. This is one of the largest events during this century in the region and took place just south of the estimated rupture region of the 1877 M_W=8.7 earthquake. GPS observations (Ruegg et al, 1996) were made in 1992 and two weeks after the great event. Comparisons between these two groups of observations indicate relative horizontal displacement, to the east-southeast, of 0.7 m of the coastal bench marks. Those points located inland subsided several centimeters and the one located in Mejillones Peninsula was uplifted more than 15 cm (Fig. 1A).

In this work, the null axis of the elevation change profiles is the input to establish the depth of the downdip extension of the coupling region. An additional ingredient to estimate this parameter is the shape of the Wadati-Benioff zone. For the Chilean convergent margin, the shape of the Wadati-Benioff region is roughly the same down to depths of the order of 60 km (Kadinsky-Cade, 1985; Pardo et al., 1996).

As a first step, we plot the observed null elevation change points as a function of distance from the trench. Fig. 1 (left) shows a plot of distance trench-coast as a function of latitude in which are superimposed the places where null coseismic observations were made: Antofagasta, Central Chile and two for the 1960 event, labeled A, B, C and D. Those regions in which the distance coast-trench is less than the expected null elevation change (dashed line) the coast is expected to be uplifted with each large event. This is the case for the region between 26¤S and 35¤S, and the Mejillones and Arauco Peninsulas. Conversely, those regions in which the distance trench-coast is greater than the expected null elevation change will subside. This is expected for northern Chile (north of Mejillones Peninsula, 23S) and the Valdivia region.

To establish the relation between depth extent of the seismogenic zone and elevation changes, instead of using rectangular fault planes embedded in an elastic halfspace, we describe the surface changes as a product of the superposition of line sources, infinite along strike located along the seismogenic zone as described by Pardo et al. (1996). We will be presenting these results.

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REFERENCES

Barrientos, S. and S. Ward, The 1960 Chile earthquake: coseismic slip from surface deformation, *Geophys. J. Int.*, *103*, 589-598, 1990.

Barrientos, S., Slip distribution of the 1985 Central Chile earthquake, *Tectonophysics*, *145*, 225-241, 1988.

Kadinsky-Cade, K., Seismotectonics of the Chile margin, Ph. D. Thesis, 153 pp, Cornell University, Ithaca, New York, 1985.

Kanamori, H., The energy release in great earthquakes, *J. Geophys. Res. 82*, 2981-2987, 1977.

Choy, G. and J. Dewey, Rupture process of an extended sequence: Teleseismic analysis of the Chilean earthquake of March 3, 1985, J. Geophys. Res., 93, 1103-1118, 1988.

Christensen, D. G. and L. J. Ruff, Rupture process of the March 3, 1985 Chilean earthquake, *Geophys. Res. Lett., 13*, 721-724, 1986.

Comte, D., A. Eisenberg, E. Lorca, M. Pardo, L. Ponce, R. Saragoni, S. K. Sing and G. Suárez, The great 1985 Central Chile earthquake: A repeat of previous great earthquakes in the region?, *Science, 233*, 449-453, 1986.

Linde, A. T. and P. Silver, Elevation changes and the great 1960 earthquake: support for aseismic slip, *Geophys. Res. Lett, 16*, 1305-1308, 1989.

Plafker, G. and J. Savage, Mechanism of the Chilean earthquake of May 21 and 22, 1960, *Geol. Soc. Am. Bull., 81*, 1001-1030, 1970.

Pardo, M., D. Comte, T. Monfret, E. Vera and N. González, Central Chile seismotectonics and stress distribution along the subducted Nazca plate (25-40S), ISAG, 1996, this issue.

Plafker, G., Alaskan earthquake of 1964 and Chilean earthquake of 1960: Implications for arc tectonics, *J. Geophys. Res., 77*, 901-925, 1972.

Ruegg, J. C. J. Campos, R. Armijo, S. Barrientos, P. Briole, R. Thiele, M. Arancibia, J. Cañuta, T. Duquesnoy, M. Chang, D. Lazo, H. Lyon-Caen, L. Ortlieb, J. C. Rossignol and L. Serrurier, The Mw=8.1 Antofagasta (Northern Chile) Earthquake of July 30, 1995: First results from teleseismic and geodetic data, *Geophys. Res. Lett.*, in press.

Tichelaar, B. and L. Ruff, Variability in depth of seismic coupling along the Chilean subduction zone, J. *Geophys. Res., 96*, 11997-12022, 1991.