EARTHQUAKE HAZARD MITIGATION IN CENTRAL AMERICA BY STUDIES OF SEISMIC SOURCE AND GROUND ACCELERATION

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SUMMARY

Central America is a region that has been prone to numerous destructive earthquakes, like the 1972 Managua earthquake, the 1976 Guatemala earthquake and the 1986 San Salvador earthquake among others. Thus, observations of complex faulting of Central American earthquakes have inspired us to investigate rupture processes of earthquakes in that region. E.g., the earthquakes, September 02, 1992, Mw=7. 6, Nicaragua, and the October 18, 1992, Mw=7.1, Colombia, events are notable examples. Thus we are studying source processess of major Central American earthquakes that have occurred during the time of the digital worldwide networks. In order to obtain rupture information we use data from both teleseismic as well as local/regional distances. The techniques we use at telsesimic distances include modelling of the source-time function by inversion of body waves as well as using a empiricial Green's function approach. From the obtained source time function of the 1992 Colombia earthquake we find that on one third of the fault the slip is 70% larger than the average.

INTRODUCTION

Focal depth, duration of the earthquake rupture as well as space-time distribution of the displacement on the earthquake fault are important parameters affecting the ground motion and earthquake hazard assessment. The duration of shaking and amount of slip of a given part of the fault may give significantly different values of the maximum ground acceleration at different sites along the fault. These differences are thus not only related to near surface structures, like loose sediments, but then also to the physics of the earthquake rupture. Therefore, as shown in a study by Takeo and Kanamori [6] the scaling of ground motion from smaller earthquakes is not always a good measure for estimating the ground motions incited by larger earthquakes with complex rupture processes. The reasons for the discrepancy were explained by directivity of the rupture and differences in earthquake focal depths between a large event and smaller events used for predicting ground motion.

In the current research study we study source processes of larger Central American earthquakes to obtain information about the complexity of the rutpuring process. We then intend to utilize this complexity for estimating maximum ground motions. In this specific paper we focus on the Mw=7.1, October 18, 1992, Colombia earthquake. This earthquake was preceeded by foreshocks from October 15 with the largest on October, 17, having the respectable size Mw=6.6 [3].

TECTONICS

Seismicity in the Atrato region is influenced by movements of the Caribbean plate, and the microplates of Panama, North Andes and North Nazca. The North Nazca is subducting in the southwest and the Caribbean plate in the north. Atrato, is located on the border between the eastern boundary of the Panama block and the western terminus of the North Andes microplate. In general the tectonic processes are still not well understood due to the

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complex interaction between the four tectonic blocks and lack of high quality data [4]. The local area around the earthquake is bordered between several geologic boundaries which are separated by NS trending faults.

EARTHQUAKE FAULTING

The rupture process for this earthquake has by several studies been indicated as complex. The Harvard CMT solution indicated a strong non-double-couple component which may have reflected that the earthquake was released by several subevents with different mechanisms. Later deconvolution of the source time function by means of empirical Green's functions indicated that the rupture may have occurred two subevents and a major aftershock about 100s after the onset of the main shock [1],[6].. Therefore the shaking produced by this earthquake may have affected a larger area with a larger intensity than expected from a Mw=7.1 earthquake. In a previous work we determined The aftershock area was determined in a previous study to be greater than what was expected from a Mw=7.1 earthquake [2].

We performed teleseismic body-wave inversion for the seismic source using direct P waves recorded at stations at epicentral distances of 30 to 90 degrees. We utilized the methodology of McCaffrey, Abers and Zwick [5]. The results were that the main energy release of the main shock occurred within a time window of 17 seconds, close to the 20 seconds given in the empirical Green's function studies. Since there may be a tradeoff of the length of the source time function with earthquake depth we went through several starting depths and we acheived the best solution at a depth of about 17 km (Figure 1). Our results agree with the empricial Green's function studies [1],[6], which indicated a small energy release initially and a second stronger pulse, totally about 20 seconds of duration.

The source time function showed to have 50% of the energy release within a five second period. Using this portion of the rupture we want to compare the displacement on this part of the rupture with the average displacement of the whole fault. First we calculate the displacement of the five second segment containing 50% of the energy realease by using the equation M=uAD where M is moment, u is rigidity of about 3.3e10 N/(m*m) and A is fault area, D is average displacement. Now we have a total moment of M=7e19 Nm. Assuming a rupture velocity of 3 km/s and the five seconds of the 50% energy realese we get a rupture length of 15 km. We also have a certain constraint on the width of the fault from the depth of energy release, we assume this width to be 20 km. Then we have the area A=20*15*1e06 m*m. The total moment of the earthquake is 7e19 Nm and using only 50% this gives 3.5e19 NM for this portion of the rupture.

Thus, the displacement for the 5 second segment is D = 3.5 m.

Doing the same calculation for the average displacement of the whole rupture, using the rupture time 17 seconds for deriving fault length, gives us an average displacement of 2 m.. However, the current estimates are based on the idea of a unilateral propagating source. If the source would be bilateral, then the estimates of slip would decrease by a factor of two. In fact, the bilateral rupture is assumed to be symmetric which in reality it most likely is not. In the asymmetric case for the bilateral rupture the difference may increase with a factor of two.

In the current project we intend to extend the study to all larger earthquakes during the past 20 years. In the cases of severe destruction we compare the observed destruction to the derived fault parameters. The source will be studied by a number of different algorithms including also local distance studies as well as empirical Green's functions studies.

CONCLUSIONS

In conclusion the maximum movement on the fault for the 1992 Colombia earthquake is about 60% larger than the average movement. This implies that close to the rupture, not only local soil conditions, but also the amount of slip on the fault due to heteregenous movements play an important role in the destruction. Likewise, using the average slip for a certain size when determining seismic hazard may give wrong results at sites close to the fault.

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REFERENCES

1. Ammon, C. J., Lay, T., Velasco, A. A.., and Vidale, J. E., (1994), "Routine Estimation of Earthquake Source Complexity: The 18 October 1992 Colombia Earthquake", *Bull. Seism. Soc. Am.*, **84**, 1266-1271.

2. Arvidsson, R., Toral Boutet, J. and Kulhanek, O. (1999), "Tectonics derived from the aftershocks of the Mw=7.1, 1992, earthquake in the Atrato region, Colombia", Manuscript.

3. Dziewonski, A.M., Ekström., G. and Salganik, M. P. (1993), "Centroid -Moment Tensor solutions for October-December 1992", *Phys. Earth Planet. Inter.*, **80**, 89-103.

4. Kellogg, J.N. and Vega V. (1995), "Tectonic development of Panama, Costa Rica, and the Colombian Andes: Constrains from Global Positioning System Geodetic Studies and Gravity", *Geol. Soc. Am., Special Paper* **295,** 75-90.

5. McCaffrey, R., Abers, G. and Zwick, P., "Inversion of teleseismic body waves", IASPEI Software library, 1991.

6. Li, Y. and Toksöz, M. N. 1993, Study of the Source Process of the 1992 Ms=7.3 Earthquake with the Empirical Green's Function Method, *Geophys. Res. Lett.*, **20**, 1087-1090.

7. Takeo, M. and Kanamori, H. (1996), "Simulation of long-period ground motion near a large earthquake", *Bull, Seismol. Soc. Am.*, **87**, 140-156.

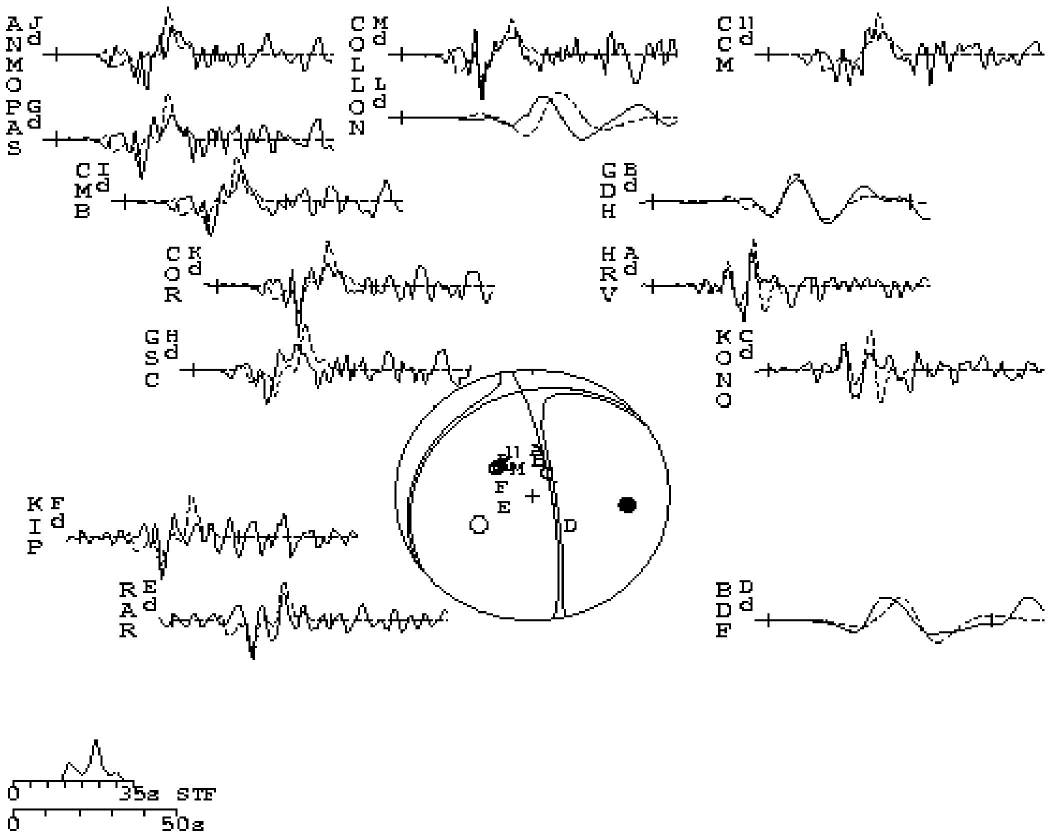

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FIGURE 1