CODA WAVE ATTENUATION BEFORE AND AFTER THE ANTOFAGASTA MAJOR EVENT OF JULY 30, 1995

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KEY WORDS: intrinsic attenuation, scattering attenuation, precursor.

INTRODUCTION

Most of the methods used to find a precursor signal to big earthquakes in seismic gaps have generally failed, mainly because they are not reproducible in space and time. From a seismological point of view, the usual parameters which are looking for as a medium or short term event precursors, are the local seismicity pattern versus time, temporal variations of seismic velocities and coda wave attenuation [1].

At the beginning, coda wave was mainly focused on a simple way to study the seismic source and later the attenuation between the source and the receiver. Complex processes as interferences of S-waves with heterogeneities into the propagation medium is considered to be one of the cause of coda wave generation. Furthermore, coda wave is also involved in defining site effect, magnitude and seismic moment.

Single scattering theories were developed in order to explain, for an isotropic medium, the observed coda wave decay with time as a function of the attenuation, where it is not necessary to take out the instrumental response from the signal and to know precisely the source mechanism, but only the absolute S-arrival time [2,3]. In a first approximation, coda wave attenuation Q^{-1} is the sum of the intrinsic attenuation Q_i^{-1} or absorption, which dissipates seismic energy into heat and the scattering attenuation Q_s^{-1} as the result of heterogeneities into the propagation medium which redistributes seismic energy into a certain volume. However, these theories assume that only one body can scatter the seismic ray between the hypocenter and the sensor.

Our study is involved mainly with the behavior of coda wave attenuation prior and after the Antofagasta July 30, 1995 earthquake, the biggest one which occured in the Antofagasta region, by using a multiple scattering attenuation method to analyze the time evolution of the intrinsic and scattering attenuation at different seimic stations of the Antofagasta local seismic network, whose the closest station (CEN) to the epicenter of the main event was at distance of about 20 km [4].

METHOD AND DATA PROCESSING

Nowadays, several isotropic multiple scattering methods are available and consider a more realistic travel path between the source and the station to better fit the coda amplitude decay. Therefore, for our purpose, we used the isotropic multiple scattering algorithm developed by Zeng [5] for the acoustic approximation, to calculate Q_i^{-1} and Q_s^{-1} and applied it to a set of local earthquakes recorded at the Antofagasta seismic network between January 1993 and the first months of 1996. As we are interested in following the variations of attenuation versus time, we consider every attenuation measurement as the result of an independent physical process and do not make any average to smooth the results. Otherwise, we chose the mean free frequency ∂ ($\partial=\omega Q^{-1}$) as a better parameter to represent the attenuation process and which can be determined without filter the coda at different frequencies. We focused mainly our observations on the attenuation behavior prior and after the Antofagasta seismic event of July 30, 1995 of magnitude M_w 8.1.

During June, 1990, The Institut de Physique du Globe of Strasbourg (France), ORSTOM (France) and the University of Chile (Chile) installed a telemetric seismic network of nine short period (1s) stations around the city of Antofagasta, in order to monitor the local microseismicity of magnitude more than 2. This network is situated on the southern edge of the rupture zone of the 1877's Northern Chile earthquake of magnitude M_W 8.8. In spite of some lacks of data because of some power cuts and acquisition failures, the dataset of more than five years of local seismicity is almost complete previous, during and after the Antofagasta big earthquake of last July 30, 1995. With the threshold used in the Antofagasta telemetric local network, between five to ten earthquakes were commonly daily recorded prior to the Antofagasta earthquake. The majority of this microseismicity is localized along the Benioff zone from depths of about 25 km till depths of about 250-300 km.

In this study, we were mainly interested in earthquakes with an arbitrary epicentral distance of less than 30 km from the seismic stations considered, because the higher the epicentral distance, the bigger the volume involves in generating coda wave and the more difficult to interpret one attenuation measurement from another. Obviously, if the distance between the station and the epicenter is to short , the number of data will not be enough to follow the attenuation behavior versus time. Keeping in mind these conditions, we select from the nine stations of the Antofagasta seismic network, only 5 (MEJ,CEN, GOR, PAS and APB) where the attenuation time sequence is almost continuos from 1993 to march 1996. The station CEN is localized upon the modeled fault plane of the Antofagasta earthquake, at 20 km away from the epicenter, and MEJ at about 45 km far of the northern edge of the rupture zone [6]. Once a seismogram is chosen at a station, it must be not saturated (in general, the magnitude M_L of the seismic event must be less than 3.5), the coda wave must reach the noise level (in fact, twice the amplitude of the noise prior to the first P-arrival) and no glitches have to be included into the coda portion. The number of events selected varies from one station to another mainly because the seismicity in that region is not uniform in both space and time.

DISCUSSION AND CONCLUSIONS

The mean free frequencies ∂_i and ∂_s for the time period 1993 to 1996 are still in process at CEN, APB, GOR and PAS and could not be part of the following discussion, but will be incorporate later. They were, however, performed at MEJ but with a dataset not complete in time as it was expected. Thus, although our discussions and conclusions will be partial and concerned only the region around MEJ, we can nevertheless make some remarks.

The propagation medium between the interface of the Nazca subducting plate and the South American plate around MEJ is mainly homogeneous in space and time because intrinsic attenuation always exceeds scattering attenuation and thus control the attenuation process (figure 1). Furthermore, the intrinsic attenuation in this study is in fact the total attenuation calculated by the single scattering attenuation theory of Sato [3] as it was already observed for intrinsic scattering as a function of frequency [7].

Although each local attenuation measurement in time can be very different to the others (day 1096 on figure 1), probably because they are generated by different scattering volumes, the general temporal behavior of intrinsic attenuation is uniform and does not show any evidences of variation prior and after the Antofagasta earthquake of July 30, 1995 (figure 1). On the other hand, the scattering attenuation is in general higher in 1995 prior to the big event than in 1993 and the beginning of 1996 (figure 1). However, more attenuation measurements should be performed at MEJ, specially for the year 1994, to improve the temporal coverage of scattering attenuation, in order to localize in time, with a better precision, this variation.

We used our program to calculate intrinsic and scattering attenuation from synthetic coda waves which had crossed different propagation mediums. Each medium has a different number of scatters, randomly distributed in an equal volume. Though, they were generated for the single isotropic scattering case [8], we found that when the number of scatters increases of a factor of 2 for a same volume, the intrinsic and total attenuation decrease of a factor of about 2, whereas scattering attenuation increases of a factor closed to 4.5. So, if the scattering attenuation increases before and decreases after a major earthquake as it seems to be the case for the Antofagasta earthquake, therefore, the number of scatters increased prior to the main event and diminished after. These observations could be explained by a dynamical system of earthquake occurrence where shear stress an pore pressure control both the spatial and temporal pattern of the distribution of heterogeneities or scatters [9].

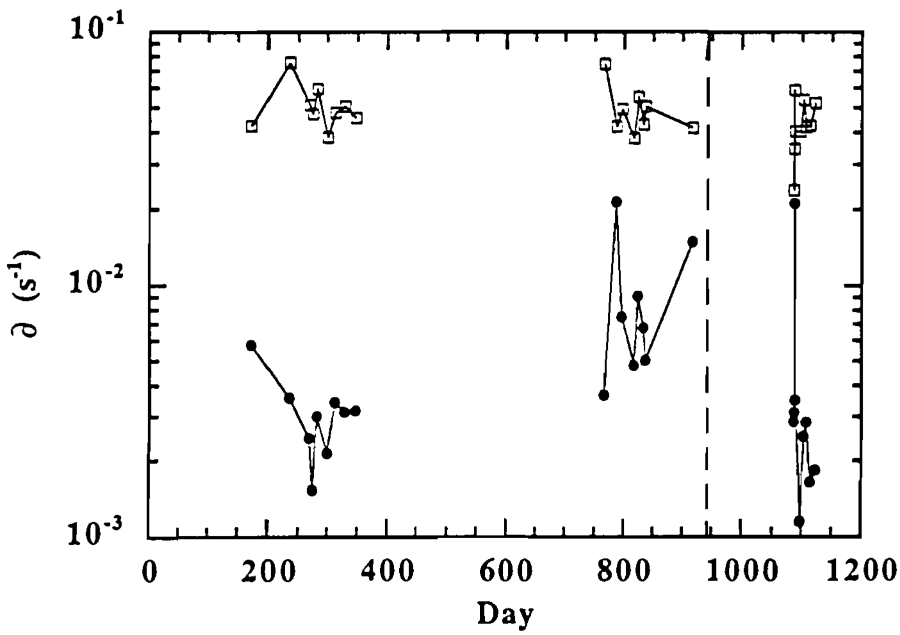

Figure 1: Intrinsic (open squares) and scattering (black dots) mean free frequency versus time calculated at MEJ. Each symbol is an independent measure. Segments link the different symbols according to their time occurrence. The day 0 is January 1st, 1993. The vertical dashed line represents July 30, 1995 when occurred the big Antofagasta earthquake of magnitude $M_W = 8.1$.

ACKNOWLEDGMENTS

I am grateful to Juan Thomas, Jean-Philippe Caminade and Helmut schatte for having localized the seismicity recorded at the Antofagasta network from 1993 to 1996.

REFERENCES

[1] Sato H, 1988. Temporal change in scattering and attenuation associated with the earthquake occurrence - A review of recent studies on coda waves, Pure Appl. Geophys., 126, 465-497.

[2] Aki K. and B. Chouet, 1975. Origin of coda waves: source, attenuation and scattering effects, *J. Geophys. Res.*, 80, 3322-3342.

[3] Sato H., 1977. Energy propagation including scattering effects, single isotropic scattering approximation, *J. Phys. Earth*, 25, 27-41.

[4] Monfret T., L. Dorbath, J.P. Caminade, M. Pardo, D. Comte, L. Ponce, A. Cisternas, B. Delouis and L. Rivera, 1995. The July 30, 1995 Antofagasta earthquake: an "hypocritical" seismic event, *EOS Trans. AGU*, 76, 46, S51-25.

[5] Zeng Y., 1991. Compact solutions for multiple scatterd wave energy in time domain, *Bull. Seism. Soc. Am.*, 81, 1022-1029.

[6] 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, 1996. The M_W=8.1 Antofagasta (North Chile) earthquake of July 30, 1995: first results from teleseismic and geodetic data, *Geophys. Res. Lett.*, in press.

[7] Monfret T., 1994. Coda S-wave attenuation calculated by single, double and multiple isotropic scattering theories, *EOS Trans. AGU*, 75, 44, S31C-04.

[8] Korneev V. A. and L. R. Johnson, 1993. Scattering of elastic waves by a spherical inclusion - 1. Theory and numerical results, *Geophys. Journ. Int.*, 115, 230-250.

[9] Miller S. A., A. Nur and D. L. Olgaard, 1996. Earthquake as a coupled shear stress - high pore pressure dynamical system, *Geophys. Res. Lett.*, 23, 197-200.