SEISMOLOGICAL INTERPRETATION OF THE HISTORICAL DATA RELATED TO THE 1929 CUMANA EARTHQUAKE, VENEZUELA

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INTRODUCTION

The January 17, 1929 Cumana earthquake, northeastern Venezuela, was associated with the activity of the El Pilar Fault Zone, along which the dextral motion between the Caribbean and South-American plates is presently taking place. Nowadays, seismic activity concentrates towards the easternmost tip of the Fault Zone, close to its junction with the Lesser Antilles subduction zone. This seismic activity can be divided into three main types (e. g. Russo et al., 1993): shallow earthquakes displaying right-lateral strike-slip motions when located along east-west trending quasi-vertical faults, deep earthquakes (focal depth h greater than 60 km) associated with the descending slab of the Lesser Antilles subduction zone, and intermediate depth earthquakes (20 km < h < 60 km) which are representative of the complex strain release taking place at the junction between the El Pilar Fault Zone and the subduction zone, in the vicinity of Trinidad island. The area close to Cumana city contrasts with these later regions by its low level of seismic activity. Three different hypothesis can be proposed to explain this observation: (1) creep phenomena contribute mainly to the motion in this area, (2) seismic motion has already been accomodated during historical large events, (3) tectonic stresses are presently accumulating in this area. In this context, a detailed study of the 1929 event is important because it is the latest major event which occured in the area prior to 1962, when the Worl-Wide Standard Seismograph Network became operational. In particular, were the reported widespread damages due mainly to local site effects, or was this event a major one ?

INTERPETATION OF HISTORICAL DATA

Cumana city is settled on a compressional fault jog of the El Pilar Fault Zone. The total width of the fault jog reaches 5 km in a north-south direction, and Cumana city is located on the northern edge of the jog, on the western side of the so-called Cerros de Caiguïre (Figure 1). These 2 km wide hills consist of folded pliocene sediments. These folds accomodate stress changes due to the termination of the northernmost branch of the El Pilar Fault Zone. This kind of geological structure is now widely recognized as an impediment to the propagation of seismic rupture (King, 1986; Sibson, 1986). Indeed, Paige (1930) reported that during the 1929 event, two linear surface ruptures emerged south of Punta Delgada, propagated westward, and stopped their propagation soon after affecting the Cerros de Caiguïre (Figure 1). There is no strong evidence for a further westward propagation of the rupture. A 3 m high sea-wave invaded the harbour in the place named El Salado. In this area, the slope of the coast is very steep, up to 45°, and overlain with loosy water-saturated sediments. Seaward lateral spreading of the headland bar was documented during the earthquake (Beltran and Rodriguez, 1995). Therefore, slumping can explain the occurence of this wave. The presence of a shattered zone within the area where rupture ends has been documented for californian earthquakes by Scholz (1990). Such phenomenon can explain the strong ground motions reported in Cumana City. Shaking was also amplified by local site effects. Indeed, the town was built on loosy sediments. Detailed geomorphological mapping (Beltran and Rodriguez, 1995) showed that most of severe damages occured within sites where buildings were constructed either on lagunal areas or upon deserted meanders of the Manzanares river (Figure 1).

First-hand historical documents, photographs, reports, and testimonies related to damages inside and outside Cumana city have been carefully compiled by Rodriguez and Chacin (1993). These descriptions include the damages and destructions which affected public buildings and houses, ground fractures, liquefaction phenomena, water and sand blows, induced landslides, collapse spreadings, and ground noise. The most destructive effects were concentrated along a 30 km long narrow band fringing the southern coast of the Gulf of Cariaco. These macroseismic data enable us to draw the isoseismal map shown in Figure 2. The instrumental epicenter relocated by Russo et al. (1992) is also shown. The error ellipse of the relocated epicenter is rather large because instrumental data were sparse. However, this location is concordant with the MKS VIII intensity area derived form macroseismic data. The white dots in Figure 2 represent the locations where aftershocks were most strongly felt up to one week after the main shock. In our view, these data indicate that the ruptured fault length should not have been longer than 25 to 30 km.

One of the most important macroseismic data was the widespread testimony that people in Cumana city felt shaking during 5 to 15 sec (Paige, 1930). While we make the hypothesis that this duration was not overestimated by frightened people, its value must be regarded as a maximum value, because it involves the total source duration τ, the different arrivals of near-field seismic waves, and the response of soil and buildings. Since the total seismic moment M_0 of an earthquake scales with τ^3 (e. g. Furumoto and Nakanishi, 1983), these maximum values correspond to 10^{17} Nm $\leq M_{0max} \leq 10^{19}$ Nm, or equivalently, $5.3 \leq M_{W max} \leq 6.7$, where M_W is the energy magnitude defined by Kanamori (1977). Unfortunately, no scaling relations are available yet for venezuelan earthquakes. By analogy with californian earthquakes, these values correspond to maximum fault lengths comprised between 5 and 30 km. This latest value is in good agreement with the maximum fault length inferred from macroseismic data.

CONCLUSIONS

The 6.9 magnitud derived by Gutenberg and Richter (1954) from the instrumental record of Pasadena (California) should be regarded as an extreme possible value, because it would involve fault length and source duration values greater than 40 km, and 20 sec, respectively. Macroseismic data indicate that the total fault length must have been smaller than 30 km. Most destructions are explained by local site effects. This interpretation means that (1) the 1929 Cumana earthquake did not release a significant amount of tectonic stress along the southern Caribbean plate boundary, and that stresses are going on accumulating in this area, (2) local soil conditions in Cumana city and surrouding regions are very poor in the sense that they amplify greatly the destructive effects of moderately sized earthquakes.

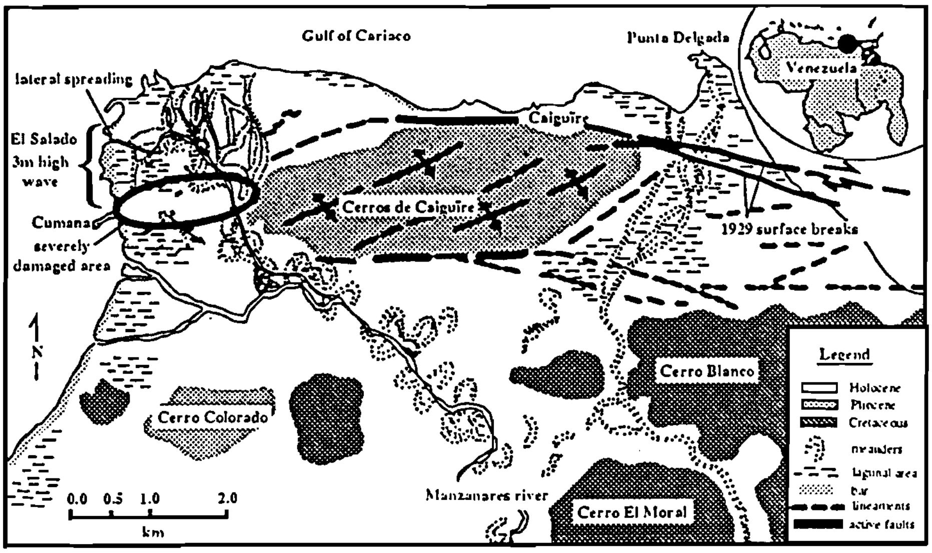

Fig. 1. Tectonic map of Cumana city and surrounding area, after Beltran and Rodriguez (1995).

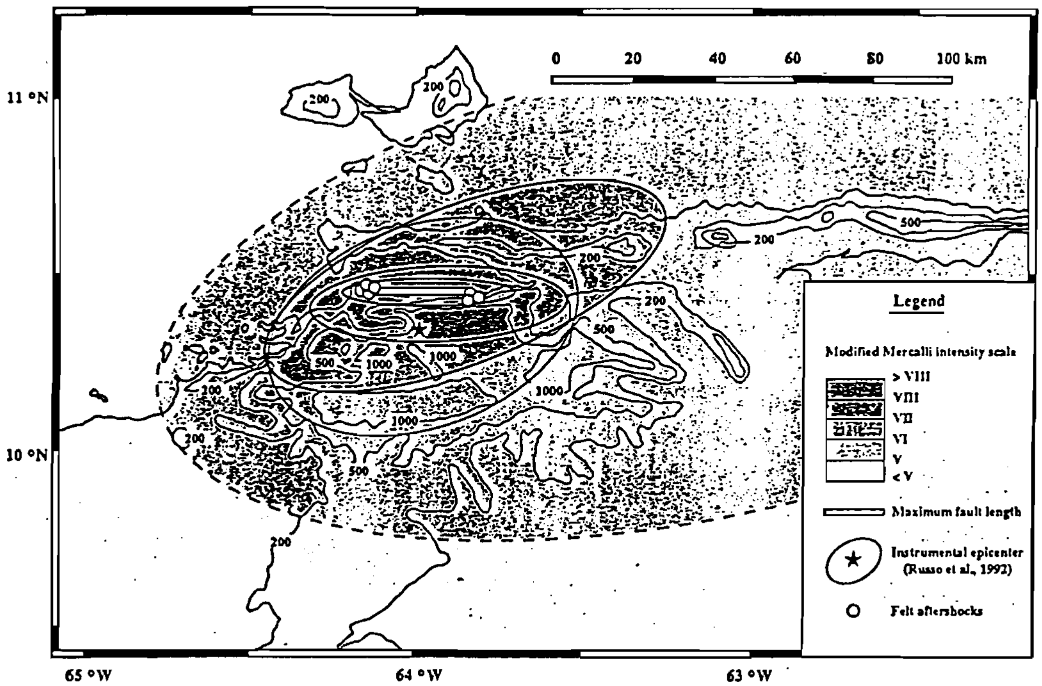

Fig. 2. Isoseismal curves of the January 17, 1929 Cumana earthquake, Venezuela. Topography is indicated in meters.

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