Geofísica Internacional (1998), Vol. 37, Num. 1, pp. 49-52

SHORT NOTE

The earthquake of 16 November, 1925 (Ms=7.0) and the reported tsunami in Zihuatanejo, Mexico

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Received: October 10, 1997; accepted: January 13, 1998.

RESUMEN

Actualmente se está estudiando un proyecto para la instalación de un sistema de alerta de tsunami en México, utilizando los datos de las estaciones de banda ancha del Servicio Sismológico Nacional. Un primer paso en esta dirección es la revisión del catálogo de maremotos de México. En estos catálogos, uno de los maremotos más grandes reportados se localiza en el Puerto de Zihuatanejo y se relaciona con un temblor que ocurrió el 16 de noviembre de 1925. Este temblor se localiza a una distancia cercana a 600 km del Puerto de Zihuatanejo y tiene una magnitud de ondas superficiales, Ms, de 7.0. Para desarrollar un sistema de alerta para maremotos es importante conocer si este maremoto estuvo o no asociado al temblor de 1925. En esta nota examinamos la evidencia y encontramos que el maremoto no estuvo relacionado con el temblor. No hay evidencia de un sismo cercano a Zihuatanejo que pueda haber generado un maremoto. Por lo que concluimos que el maremoto se produjo a causa de un deslizamiento submarino cerca de Zihuatanejo o a causa de un fenómeno meteorológico en la región.

PALABRAS CLAVE: Tsunami de 1925, tsunami en Zihuatanejo.

ABSTRACT

A feasibility study to develop a tsunami alert system for Mexican earthquakes, using broadband seismograms from the National Seismological Service, is currently under way. A first step in this direction is a revision of the Mexican tsunami catalogs. In these catalogs, one of the largest tsunamis of this century is reported in the Port of Zihuatanejo and has been related to an earthquake which occurred on November 16, 1925. This earthquake was located at a distance of about 600 km from Zihuatanejo and had a surface-wave magnitude, Ms, of 7.0. In developing a tsunami alert system, it is important to know if the tsunami was indeed related to the earthquake of 1925. In this note we examine available evidence and find that the tsunami was not related to the earthquake. There is no evidence of a local earthquake near Zihuatanejo which may have resulted in the tsunami. We conclude that the tsunami was either caused by slumping of the sea floor near Zihuatanejo or by a meteorological phenomenon in the region.

KEY WORDS: Tsunami of 1925, tsunami in Zihuatanejo.

TSUNAMIS IN MEXICO FROM LOCAL AND REGIONAL EARTHQUAKES

Major and great earthquakes along the Mexican subduction give rise to tsunamis along the Pacific coast of Mexico whose maximum height rarely exceeds 5 m in and near the epicentral region (Sánchez and Farreras, 1993; Farreras, 1997). Two recent examples are the great earthquakes of 19 September, 1985, Michoacán (Mw=8.0) and 9 October, 1995, Colima-Jalisco (Mw=8.0). Maximum tsunami heights were 3 m or less in the epicentral area of the Michoacán earthquake (Farreras, 1997). Following the Colima-Jalisco earthquake, the tsunami height was measured by Borrero *et al.* (1997) at 25 sites. It was found to be less than or equal to about 5 m at 24 sites but reached a height of 10.9 m at one site. Borrero *et al.* (1997) suggest that the run-up height of 10.9 m, which was measured on a cliff, was probably caused by the site being located behind a narrow steep-sided indentation in the coast line.

Two of the largest tsunami heights reported along the Pacific coast of Mexico during this century are associated with relatively small earthquakes (Sánchez and Farreras, 1993; Farreras, 1997).

1. Tsunami in Cuyutlán, Colima in 1932

An earthquake on June 22, 1932, Ms=6.9, caused a tsunami of 9 to 10 m on the coast of Cuyutlán, Colima, resulting in the death of 75 persons and injuries to 100 persons. This is the most destructive tsunami in Mexico during this century. The description of the damage is well documented in Mexico City newspapers of June 23, 1932 and the following days. The origin time of the earthquake and the time of the tsunami coincide (~7 a.m. local time). Furthermore, the location f the earthquake (18.74°N, 104.68°W; Singh *et al.*, 1985) was close to Cuyutlán (see Figure 1). For these reasons, there is no doubt that the tsunami was related to the earthquake of June 22, 1932.

This earthquake was an aftershock of the two great earthquakes of Jalisco which occurred on 3 June (Ms=8.2) and 18 June, 1932 (Ms=7.8) (Singh *et al.*, 1985). The mechanism of the tsunami generation from the 22 June earthquake remains uncertain. It has been suggested that the slumping of the sediments deposited in the sea by the Armería river, which flows to the south of Cuyutlán, may have been the cause of the anomalously high tsunami (M. Ortiz, personal communication, 1997).

2. Tsunami in Zihuatanejo, Guerrero in 1925

A 6 to 9 m high tsunami is reported in the Port of Zihuatanejo and attributed to an earthquake of magnitude 7 which occurred on 16 November, 1925 (Heck, 1947; Iida *et al.*, 1967; Sánchez and Farreras, 1993; Farreras, 1997). The location of the earthquake given by Figueroa (1970) and Gutenberg and Richter (1954) is 20.367°N, 106.383°W and 18$^{1/2}$°N, 107°W, respectively. The corresponding origin times (GMT) are 11:56:49 and 11:54:54. With respect to these locations, Zihuatanejo is about 600 km away (Figure 1). It seems unlikely that an earthquake of magnitude 7 could have produced a tsunami of 6 to 9 m at a distance of 600 km. There are three plausible explanations for this discrepancy: (1) The reported magnitude is in error or it was a particularly slow earthquake. (2) The epicenter is in gross error; its true location was close to Zihuatanejo. (3) The reported sea wave was not related to the earthquake 600 km away but was caused by (a) another local earthquake, (b) slumping of the sea floor off the coast of Zihuatanejo, or (c) a meteorological phenomenon. Below we consider each of these possibilities.

(1) Gutenberg and Richter (1954) report magnitude M of the earthquake as 7.0 and Abe (1981) assigns it Ms=7.0. The magnitude Ms of historical Mexican earthquakes can also be roughly estimated from Wiechert seismograms of Uppsala, Sweden (Singh *et al.*, 1984). The relation is Ms = log A+5.28, where A= $(A_N^2 + A_E^2)^{1/2}$, and A_N, and A_E are the maximum amplitudes in microns on the horizontal components during surface waves of about 20 sec period. For the 1925 earthquake, the Uppsala bulletin lists A_N=25 microns, A_E=39 microns, which gives Ms=6.95. Since the three determinations of the magnitude are consistent, we conclude that Ms=7 for this earthquake is not in error. Another possibility is that the 1925 earthquake was a slow earthquake, i.e., its moment magnitude, Mw, was much larger than Ms=7.0. Such discrepancy is characteristic of tsunami earthquakes (Kanamori, 1972; Abe, 1979; Kanamori and Kikuchi, 1992). This possibility, however, does not explain why there was no report of tsunami from the Port of Manzanillo, which was much closer to the epicenter than Zihuatanejo (Figure 1), or from Acapulco Δ~800 km).

(2) We relocated the earthquake of 1925 using the (S-P) times recorded on Wiechert seismographs of Manzanillo (MNZ), Guadalajara (GUM), and Mazatlán (MZX) (Figure 1). In order to facilitate the identification of the S phase and to convert (S-P) time to epicentral distance, we used broadband seismograms of an earthquake which occurred on the Rivera fracture zone on 1 May, 1997 (Mw= 6.9), and was recorded at Colima (COIG) and Chamela (CJIG) (Figure 1). From these broadband records we synthesized Wiechert seismograms. The knowledge of the epicentral distance of the 1997 earthquake to COIG and CJIG helped us in the identification of the S phase. The conversion factor to obtain epicentral distance from (S-P) time was found to be 10 km/sec. For a Poisson solid, this conversion factor implies an average P-wave speed of 7.3 km/sec, which is reasonable since the wavepath is mostly oceanic. For the 1925 earthquake, the (S-P) times at MNZ, GUM, and MZX are 31, 45, and 52 sec, respectively. The intersection of the corresponding epicentral distances gives the approximate location of the 1925 earthquake as 18.4°N, 106.5°W, close to that given by Gutenberg and Richter (1954) and but still 540 km from Zihuatanejo. Thus we can not attribute an error in the location of the epicenter of the 1925 earthquake as an explanation for the large tsunami in Zihuatanejo.

(3) The reports of the tsunami in Zihuatanejo appeared in Mexico City newspapers on 20 November, 1925 (e.g., Excelsior and El Universal of 20 November, 1925). The newspaper accounts were based on a telegram received by the Ministry of Communication and Public Works in Mexico City from the town of Petatlán (~40 km SE of Zihuatanejo) mentioning that a sea wave, 6-7 m in height, had devastated the Port of Zihuatanejo. According to the telegram a disagreeable wind started blowing.... a fearful noise came from the sea and the sea went up suddenly. Excelsior mentions that the sea wave invaded the port around 6 p.m. but it is not clear on the date. However, the English section of Excelsior of the same day clearly stated that a 35 feet-high sea wave struck the Port of Zihuatanejo on the evening of Tuesday. Tuesday was 17 November. This means that the reported tsunami occurred on 18 November around 00:00 hour (GMT). We recall that the origin time of the earthquake was 16 November, ~11:55 hour (GMT). Thus, there is a difference of about 36 hours between the occurrence of the earthquake and the reported tsunami. Since the expected time for tsunami to travel 600 km is less that an hour, we conclude that the reported tsunami in Zihuatanejo was not related to the 16 November earthquake.

(3a) Since the bulletins and seismograms from the Mexican Seismological Network do not show any earthquake near Zihuatanejo between 15 to 20 November, 1925, a local shock as the cause of the tsunami can be ruled out.

(3b) It is possible, however, that the tsunami resulted from slumping of the sea floor close to Zihuatanejo. The

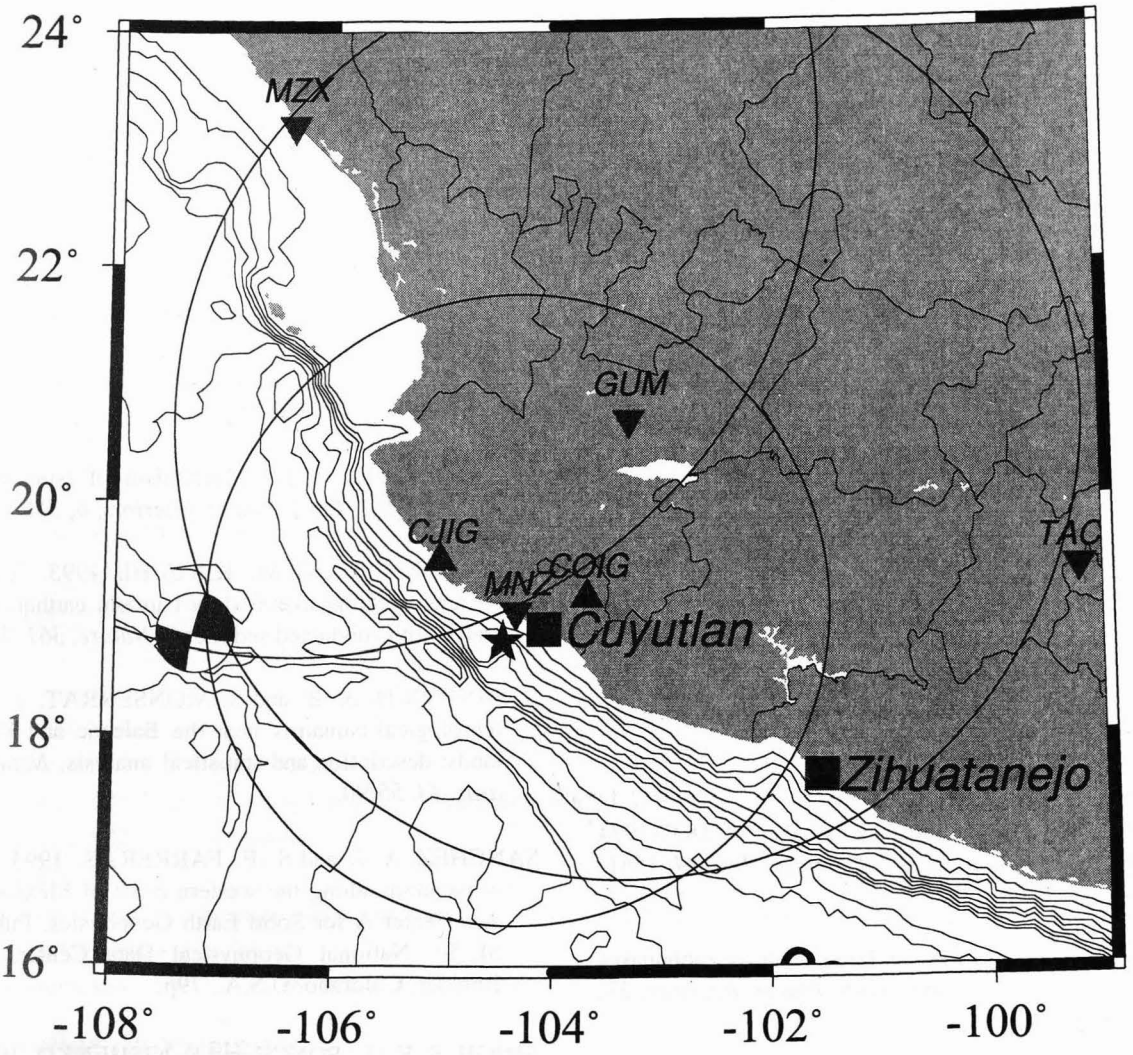

Fig. 1.. A location map of Mexico. Star shows the epicenter of the 22 June, 1932 earthquake (Ms=6.9), which caused death and destruction in Cuyutlán. The intersection of circles at about 18.4° N, 106.5° W, based upon (S-P) times at stations MNZ, GUM, and MZX (inverted triangles), gives approximate epicenter of the 16 November, 1925 (Ms= 7.0) earthquake. This earthquake is supposed to have resulted in large tsunami in Zihuatanejo. The strike-slip focal mechanism corresponds to the earthquake of 1 May, 1997 (Mw=6.9) which was recorded by the broadband stations of COIG and CJIG (triangles).

source process of such a phenomenon may have been sufficiently slow so that it was not recorded by Wiechert seismograms of the National Seismological Service.

(3c) A catalog of tropical Mexican cyclones (*Arroyo et al.*, 1975) lists one between 6 and 15 November, 1925. It started on 6 November near the coast of Costa Rica, went along the Pacific coast, and turned and entered the continent near Zihuatanejo on 11 November. It crossed the continent and died in the Gulf of Mexico on 15 November. Since the tsunami invaded Zihuatanejo after 15 November, it may not be attributed to this cyclone. Excelsior of 20 November, 1925, in a separate section, mentions bad weather since 17 November along the Pacific coast, from Salina Cruz to Manzanillo. It is possible that the sea wave in Zihuatanejo was, in the nomenclature of Defant (1961), a meteorological tsunami.

Heck (1947) cites seismological dispatches of Georgetown University as the source of the tsunami data. The catalog of tsunamis of Iida *et al.* (1967), citing Heck (1947), lists a "possible" tsunami in Zihuatanejo related to the 16 November, 1925 earthquake and adds "town said swept by wave 35 ft high. No confirmation from any other source. Report is doubtful and at the very least must be exaggerated". Sánchez and Farreras (1993) reproduce part of the text from Excelsior of 20 November, 1925 which mentions that the sea wave at Zihuatanejo struck at 6 p.m. As mentioned above, it does not mention the date. Since the earthquake occurred at 5:55 hour (local time) (11:55 hour,

GMT) and the sea wave invaded Zihuatanejo at 6 p.m., there is at least a 12 hour difference between the two events. It seems that Sánchez and Farreras (1993) overlooked this time difference.

CONCLUSION

The reported tsunami in Zihuatanejo, which was apparently one of the highest of this century to hit the Pacific coast of Mexico, was not related to the earthquake of 16 November, 1925 (Ms=7.0). A local earthquake near Zihuatanejo must also be ruled out as the cause of the tsunami. It is possible that slumping of the sea floor near Zihuatanejo was responsible for the tsunami. Alternately, the sea wave may have been caused by meteorological forces, which are sometimes difficult to distinguish from tsunamis (see, e.g., Rabinovich and Monserrat, 1996 for a extensive discussion). Such waves have been called meteorological tsunamis by Defant (1961), among others.

ACKNOWLEDGMENTS

Fruitful discussions with M. Ortiz are acknowledged. We wish to thank C. Lomnitz and S. Farreras for their comments and review of the manuscript.

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