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Original paper

The 6 September 1997 (M_w4.5) Coatzacoalcos-Minatitlán, Veracruz, Mexico earthquake: implications for tectonics and seismic hazard of the region

Shri Krishna Singh*, José Francisco Pacheco, Xyoli Pérez-Campos, Mario Ordaz and Eduardo Reinoso

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Resumen

Analizamos el sismo del 6 de septiembre de 1997 (M_w4.5), que se produjo a unos 25 km al SE de Coatzacoalcos, Veracruz. El sismo fue registrado por la estación local TUIG de banda ancha de (tiempo S-P = 5 s). Las polaridades de la onda P a distancias regionales y telesísmicas, y el modelado de las formas de onda de desplazamiento en TUIG sugieren un mecanismo focal inverso (ϕ = 150º; δ = 70º; λ = 90º). En la misma región ocurrió un sismo destructivo el 26 de agosto de 1959 (M_w6.4), a una profundidad similar y con un mecanismo similar. El análisis del sismo de 1997 refuerza la conclusión anterior de que la corteza inferior bajo la cuenca del Coatzacoalcos-Minatitlán, está en un régimen de esfuerzos de fallamiento inverso, en contraste con la parte superficial de la corteza que se caracteriza por un fallamiento normal; esto implica una permutación con la profundidad de los esfuerzos principales máximo y mínimo. Esto está de acuerdo con las observaciones, en otros sitios, que el estado de esfuerzos en las cuencas sedimentarias pueden ser diferentes del que se tiene a mayor profundidad.

Mecanismos focales están disponibles para siete sismos en y cerca del Golfo de México. Todos estos eventos muestran en la región una corteza media y baja en un régimen de fallamiento inverso. La tendencia observada de los ejes P de estos sismos se puede explicar por una o más de las siguientes causas: acoplamiento fuerte a lo largo de la interfase de la placa en subducción fuera de la costa en Tehuantepec; el movimiento absoluto de la placa de América del Norte; y el hundimiento de la litosfera debido a la acumulación de la carga de los sedimentos.

Usamos los registros del sismo de 1997 como función de Green empírica para simular los movimientos de tierra en la región epicentral de un sismo de M_w6.4 postulado en la cuenca Comalcalco. Bajo supuestos razonables, los valores esperados de aceleración, velocidad y desplazamiento picos son 120-260 gales, 12 a 28 cm/s, y 6 a 11 cm, respectivamente. La extensa licuefacción reportada en Coatzacoalcos durante el sismo de 1959, M_w6.4, sugiere que los sedimentos de la cuenca se comportan de manera no lineal bajo tal excitación.

Palabras clave: Sismo de Jáltipan, movimientos fuertes, tectónica del Golfo de México, peligro sísmico del Golfo de México.

S.K. Singh*
X. Pérez-Campos
Instituto de Geofísica
Universidad Nacional Autónoma de México
Ciudad Universitaria
Delegación Coyoacán, 04510
México D.F., México
*Corresponding author: krishnamex@yahoo.com

J.F. Pacheco
Observatorio Vulcanológico y Sismológico
de Costa Rica
Universidad Nacional

M. Ordaz
E. Reinoso
Instituto de Ingeniería
Universidad Nacional Autónoma de México
Ciudad Universitaria
Delegación Coyoacán, 04510
México D.F., México

Abstract

We analyze the 6 September 1997 M_w4.5 earthquake, which occurred about 25 km SE of Coatzacoalcos, Veracruz. The earthquake was recorded by the local broadband station TUIG (S-P time = 5 s). P-wave polarities at regional and teleseismic distances and modeling of the displacement waveforms at TUIG yields a thrust-faulting focal mechanism (ϕ = 150º; δ = 70º; λ = 90º). In the same region a destructive M_w6.4 earthquake occurred on 26 August 1959 at a similar depth and with a similar mechanism. The analysis of the 1997 event reinforces a previous conclusion that the lower crust beneath the Comalcalco basin is in a thrust-faulting stress regime, in contrast to the shallow part of the crust, which is characterized by normal-faulting; this implies a permutation with depth of the maximum and minimum principal stresses. It agrees with observations elsewhere that the state of stress in sedimentary basins can be different from the one at greater depth.

Focal mechanisms are available for seven earthquakes in and near the Gulf of Mexico. All of these events indicate a thrust-faulting type stress regime at mid- and lower-crustal levels. The observed trend of the P axes of these earthquakes can be explained by one or more of the following causes: strong coupling along the subduction plate interface offshore Tehuantepec; absolute motion of the North American plate; and downwarping of the lithosphere due to sediment loading.

By using the recordings of the 1997 event as empirical Green's function, we simulate the ground motions in the epicentral region of a postulated M_w6.4 earthquake in the Comalcalco basin. Under reasonable assumptions, the expected peak acceletion, velocity and displacement are 120-260 gal, 12-28 cm/s, and 6-11 cm, respectively. The extensive soil liquefaction in Coatzacoalcos during the 1959, M_w6.4, earthquake suggests that the sediments of the basin behave nonlinearly under such excitation.

Key words: Jáltipan earthquake, strong motion, tectonic of the Gulf of México, seismic hazards of the Gulf of México

Introduction

A detailed analysis of the M_w4.5 earthquake of 6 September 1997, which occurred near Coatzacoalcos-Minatitlán, Veracruz, is of interest for three reasons. First, the surface and the near-surface information from volcanic alignments, borehole elongations, and unpublished PEMEX seismic sections points to active normal-faulting in the region (Suter, 1991). The focal mechanism of an earthquake which occurred nearby on 26 August 1959 (M_w6.4), however, shows thrust faulting at a depth of about 26 km (Wickens and Hodgson, 1967; Suárez, 2000; see Figure 1). It is, therefore, of interest to know whether the 1997 earthquake confirms such a change in the stress regime (permutation of the least and maximum principal stresses) with depth in the region. In most regions, the stress regime at relatively shallow depth agrees with that at mid-crustal depth. There are some exceptions (see, e.g., Zoback and Zoback, 1991) and one such exception appears to be the coastal plain of the Gulf of Mexico (Frohlich, 1982; Zoback and Zoback, 1991; Suter, 1991). Another classical example is the decoupling of the stress field across the basal detachment of the Jura fold-thrust belt; the near-surface stress field is different from that in the basement (Becker *et al*., 1987).

Second, the earthquake of 26 August 1959 caused serious damage to the towns of Jáltipan, Coatzacoalcos, and Minatitlán (Figueroa, 1964; Rosenblueth, 1964; Resén-diz, 1964). The latter two towns have beco-me important industrial centers related to the intense activity of PEMEX, the national petroleum company, and population has grown by 22% in the last 10 years to reach more than half million people (INEGI, 2010). For this reason, it is important to estimate ground motions that may be expected in these towns if an earthquake, such as that of 1959, were to recur in the region. We may use the records of the 1997 earthquakes obtained at the near-source broadband station of TUIG as empirical Green's function to simulate the corresponding motions from an M_w6.4 event. Although the station is about 25 km SE of Coatzacoalcos-Minatitlán, the geology of these sites is roughly similar; to a first approximation, the results for the TUIG site may be valid for the entire region in case of an earthquake at about the same focal distance from TUIG as the event of 1997.

Finally, a study of the 1997 earthquake (and other events in and along the Gulf of Mexico) has an important bearing on the seismic safety of the Laguna Verde nuclear power plant (Figure 1) as well as the hydrocarbon exploration and production facilities in this region.