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Original paper

Study of Seismic Clusters at Bahía de Banderas Region, Mexico

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Resumen

La costa de Jalisco y el sur de Nayarit es una región con un fuerte desarrollo turístico donde el incremento en la población es grande y se encuentran en una zona de alto potencial sísmico. Esto motivó a las autoridades de Protección Civil de Jalisco y la Universidad de Guadalajara a iniciar en el año 2000 estudios para evaluar el riesgo sísmico en la región. Este trabajo se enfocó en el estudio de la sismicidad en el área de Bahía de Banderas y la costa norte de Jalisco, área considerada un Gap Sísmico. Se realizó un análisis de los sismogramas disponibles para identificar estructuras corticales activas, su relación con la morfología superficial y la posible prolongación de estas estructuras a la parte somera de la bahía. Los datos utilizados en el presente trabajo son los registrados en el año 2003 cuando se desplegó una red sísmica en la región. El método está basado en la identificación de acumulaciones sísmicas o familias usando correlación-cruzada de los sismogramas, relocalización de sismos y modelado de planos de falla. A partir de un conjunto inicial de 404 sismos localizados, se seleccionaron 96 sismos con $M_L < 3.6$ que están relacionados con 17 estructuras continentales potencialmente activas. Se obtuvo un modelo del plano de falla para 11 estructuras. Un subgrupo de 7 estructuras se encuentra alineado paralelamente a la trinchera mesoamericana, lo cual puede ser una consecuencia de un proceso de subducción oblicuo. Los focos de los sismos se agruparon en acumulaciones sísmicas que se pueden correlacionar con fallas con dimensiones de cientos de metros, éstas pueden ser consideradas como asperezas o barreras en estructuras tectónicas con longitudes entre 10 y 30 km. Estas estructuras pueden generar terremotos someros con magnitudes entre 5.0 y 6.0, y representan una amenaza sísmica adicional en la región.

Palabras clave: Gap sísmico, placa de Rivera, bloque de Jalisco, Bahía de Banderas, familias sísmicas, correlación-cruzada.

Abstract

The coast in the state of Jalisco and south of Nayarit is located within a region of high seismic potential, increasing population, and tourism development. This motivated Civil Defense authorities of Jalisco and the Universidad de Guadalajara to launch in the year 2000 the assessment of the seismic risk of the region. This work focuses in the seismicity study of the area of Bahía de Banderas and northern coast of Jalisco, which is actually a seismic gap. We perform an analysis of available seismograms to characterize active crustal structures, their relationship to surface morphology, and possible extent of these structures into the bay shallow parts. The data consist of waveforms recorded during 2003 when the seismograph network spanned the region. Our method is based on the identification of seismic clusters or families using cross-correlation of waveforms, earthquake relocation and modeling of fault planes. From an initial data set of 404 located earthquakes, 96 earthquakes with $M_L < 3.6$ are related to 17 potentially active continental structures. We present fault plane model for 11 structures. A subgroup of 7 structures is aligned parallel to the Middle America Trench, as a possible consequence of oblique subduction. The foci of the earthquakes were grouped into clusters corresponding to fault dimensions of hundred of meters, may be considered as asperities or barriers in tectonic structures with lengths between 10 and 30 km. These structures could generate shallow earthquakes with magnitudes between 5.0 and 6.0 and represent an additional seismic threat to the region.

Key words: seismic gap, Rivera plate, Jalisco block, Bahía de Banderas, seismic clusters, cross-correlation.

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Introduction

Bahía de Banderas is located in the Jalisco Block (JB) (Figure 1). This region undergoes different deformation stages from the Mezosoic to the present, producing several active linear structures due to its proximity to a triple junction. The seismic activity recorded by temporary and permanent seismic networks, as well as the structures observed in the continental crust are manifestations of the tectonic deformation that accommodates the JB.

The 1932 (M=8.2) earthquake, the largest event in Mexico during the twentieth century occurred in the JB was followed 15 days later by another large event (M=7.8). Singh *et al.* (1985) studied these events and concluded that the surface expression of the composite rupture area extends across the entire coast of the states of Jalisco and Colima. They suggested a recurrence time of 77 years for the occurrence of a major earthquakes in this region. In 1995 a Mw=8.0 earthquake near Manzanillo involved the central part of the 1932 rupture area, leaving undisturbed patches to the north and south, which are now termed the Vallarta and Colima gaps, respectively (Figure 2).

In addition to the large subduction earthquakes (M>7.6), the complexity of the region of the coast in the state of Jalisco and south of Nayarit is reflected in the existence of poorly known tectonic structures where earthquakes of moderate magnitude occur (7.0<M<7.6); for example the December 3, 1948 event occurred near the Marías Islands (Figure 2). More recently, on 14 September 2010 a thrust fault earthquake (M=6.0) followed by 25 aftershocks in 24 hours with M_L>4.0, recorded by a local seismic network, took place to the south of Marías Islands. Of particular interest is the Mw=7.4 earthquake of 22 January 2003; a shallow earthquake off the state of Colima, México, near the town of Armería. Both, the damage pattern and the surface effects of this earthquake in the neighboring states of Colima and Jalisco were stronger than those caused by recent large earthquakes in these regions and affected different areas; especially in Colima City and Zapotitlan de Vadillo, Jalisco, on the western flank of Colima volcano. An analysis of its aftershocks (Núñez-Cornú *et al*. 2004, 2010) indicates that the earthquake was caused by a continental intraplate reverse fault. These earthquakes may be related to the possible oblique subduction of the Rivera Plate.

The microseismicity at the north of Jalisco and south of Nayarit coasts was studied during the CORTES96 project (Dañobeitia *et al.*, 1997); a joint project between the Universidad de Guadalajara (UG) and the Centro de Investigación Científica y Educación Superior de Ensenada (CICESE) was carried out during 1996-1998 aimed to study the microseismicity occurring north of the JB. Based on the analysis of these results and historical data the spatial distribution of earthquakes, Núñez-Cornú *et al.*, 2002 suggested the existence of various seismogenic zones. Thus, the purpose of this work was to

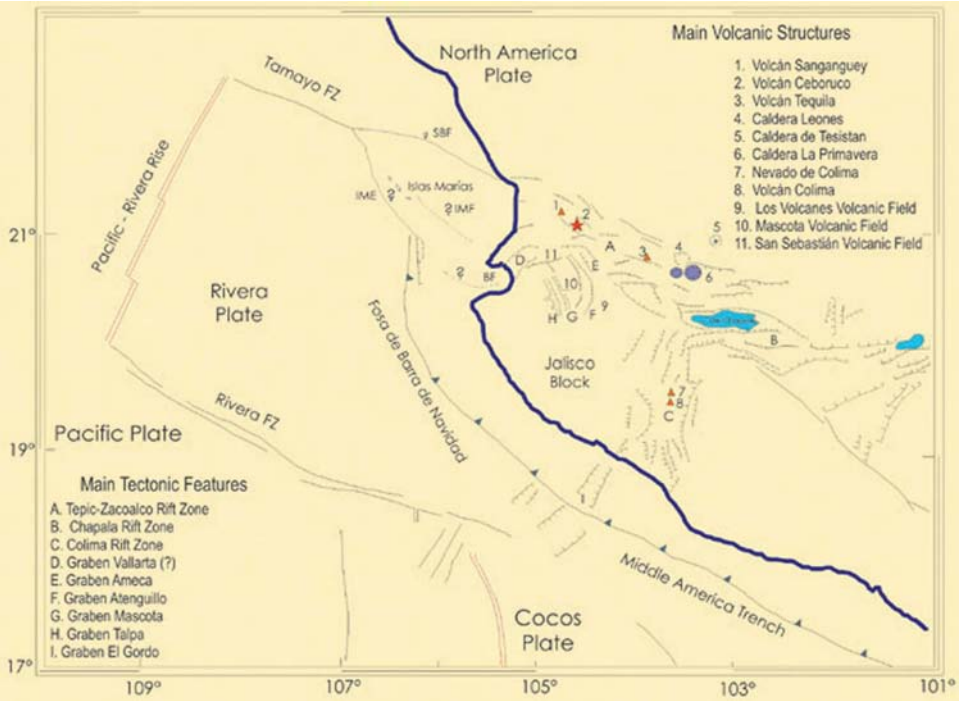

Figure 1. Tectonic frame of Jalisco Block region: SBF, San Blas Fault; IME, Islas Marias Escarpment; IMF, Islas Marías Fault; BF, Banderas Fault (Bahía de Banderas). (Modified from Núñez-Cornú *et al.* (2002).