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Historic and ancient tsunamis uncovered on the Jalisco-Colima Pacific coast, the Mexican subduction zone

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ABSTRACT

Research on extreme wave events such as tsunamis using the geological record in areas of infrequent and or small magnitude earthquakes can aid in extending the long-term history and recurrence intervals of large events. This information is valuable for risk management and community preparedness in coastal areas. Here we investigate tsunami deposits on the Jalisco coast of Mexico that overlies the subducting Rivera Plate under the North American plate, an area due for a large thrust earthquake and potential tsunami. Here, we apply a full battery of rock-magnetic analyses that also include a detailed AMS study and other typically applied proxies in tsunami deposits research. We present evidence to demonstrate that anomalous sand units with sharp basal contacts at La Manzanilla, Tenacatita Bay, and El Tecuán shore sites on the Jalisco coast may be the products of tsunamis generated by known historical (M_s 8.2 earthquake of 3 June 1932) and other earlier tsunamigenic earthquakes. A sandy unit with a sharp basal contact, flame structures at the base, rip-up clasts at La Manzanilla, and four sand units with sharp basal contact overlying buried soils at El Tecuán, together with other proxies, such as magnetic properties and others, suggest tsunami deposits. ^{210}Pb dating of sediments slightly above the upper sand layer indicate an age A.D. 1935 ± 11 at El Tecuán. Historical accounts of tsunami inundation at both sites provide further evidence that this is most probably the result of the 3 June 1932 tsunami. Hence this study may provide the first evidence of a tsunami triggered by this earthquake and also of three probable predecessors. Further evidence of at least three earlier tsunamis that occurred since the fifteenth century is also evident in the stratigraphy. These events may correspond to events listed in historical archives, namely the 1563, 1816, and/or the 1818 events.

1. Introduction

Reconstructing tsunami records in areas of infrequent and/or small magnitude seismic activity is important for tsunami hazard assessment, and in turn in risk management of coastal areas, and for a coastal community's preparedness. The geological signature of ancient tsunamis can aid in expanding the record of large inundation events hundreds and up to thousands of years. This is of particular importance in areas where instrumental and historical records are relatively short or unavailable. Tsunamis of the last two decades have provided valuable information on the characteristics of tsunamis and have improved our understanding of tsunamis in the geological record (e.g., Atwater et al., 2005; Moore et al., 2005; Dawson and Stewart, 2007; Hawkes et al., 2007; Jankaew et al., 2008; Matsumoto et al., 2008; Monecke et al., 2008; Horton et al., 2011; Brill et al., 2012, 2014; Goto et al., 2012, 2014, 2015; Naruse et al., 2012; Prendergast et al., 2012; Sugawara et al., 2012; Cuven et al., 2013; Dura et al., 2014; Spiske et al., 2014; Nentwig et al., 2015; and many others).

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Seismic activity and the principal source of tsunamis along the Pacific coast of Mexico are mostly related to subduction of the Rivera and Cocos plates under the North America plate (Fig. 1). Unlocking of this plate interface produced an M ~ 8.6 earthquake on 28 March 1787 (Núñez-Cornú et al., 2008; Suarez and Albini, 2009; National Geophysical Data Center-National Oceanic and Atmospheric Administration, 2012), but only Mw 7.3–8.2 earthquakes have been instrumentally recorded in the last 100 years (Singh et al., 1985). The largest earthquake of the last century resulted from the rupture of the Rivera Plate interface on 3 June 1932 (Ms 8.2). This was followed by aftershocks on 18 June (Ms 7.8) and 22 June (Ms 6.9) (Singh et al., 1981, 1985; Astiz and Kanamori, 1984). The 30 January 1973 earthquake, Mw 7.6, ruptured the Cocos-North America interface, producing a tsunami registered by tide gauges (wave amplitude 1.2 m). An Mw 8.0 earthquake occurred in this region in October 1995 (Pacheco et al., 1997), however it did not rupture the whole 3 June 1932 area (Núñez-Cornú et al., 2004). The 1995 event produced a tsunami recorded at several localities in the Jalisco and Colima coast producing up to 4- to 5-m wave heights (Borrero et al., 1997; Carrillo-Martínez, 1997; Lander et al., 2003). On 22 January 2003, an Mw 7.4 earthquake hit the coast of Colima and triggered a small local tsunami similar to a high tide (1.2 m height) that did not cause flooding. However, no great earthquakes (M > 8) have occurred at the Rivera-North America plate interface since 1932 (Fig. 1).

The 3 and 18 June 1932 ruptures triggered tsunamis that caused regional and local flooding, respectively; and the 22 June event produced a local tsunami with 11- to 12-m wave heights (Corona and Ramírez-Herrera, 2012a, b). The unusual wave height and effects of the 22 June tsunami have been explained by two different source mechanisms: (i) a tsunamigenic earthquake and a splay fault (Okal and Borrero, 2011) and (ii) by a submarine landslide (Corona and Ramírez-Herrera, 2015). On 9 October 1995, an Mw 8.0 earthquake triggered a local tsunami on the Jalisco coast that inundated the town of La Manzanilla located in the Tenacatita Bay.

Earthquakes and tsunamis on the Pacific coast of Mexico have been registered instrumentally and in a few written documents (e.g., Cumming, 1933; Abe et al., 1986; Sánchez and Farreras, 1993; García-Acosta and Suárez, 1996; Corona and Ramírez-Herrera, 2012a; National Geophysical Data Center-National Oceanic and Atmospheric Administration, 2012; Valdivia et al., 2012; Castillo-Aja and Ramírez-Herrera, in prep.); however, their geologic signatures have been reported only in a few cases (Ramírez-Herrera et al., 2005, 2007, 2009, 2012, 2014; Ramírez-Herrera, 2011). We expand the record of earthquake and tsunami events by compiling geologic evidence of past tsunamis at La Manzanilla, Tenacatita Bay, and El Tecuán lagoon backbarrier on the Jalisco segment of the Pacific coast of Mexico. Our investigation of low-lying areas along this segment of the coast revealed several sites with anomalous sand layers preserved within fine-grained, low energy depositional environments, including the 3 June 1932 tsunami and at least three earlier tsunamis that occurred since the fifteenth century. These post-fifteenth century tsunamis potentially coincide with events listed in historical archives.

1.1. Regional setting of the Jalisco-Colima coast

We selected an ~105-km-long stretch of the Jalisco-Colima to search for geologic evidence of historical and paleotsunamis. In addition to the tsunamis of the last century (1932, 1995, and 2003), historical records indicate prior near-field tsunamis affected this coast. Historical studies indicate that several near-field tsunamis occurred from 1563 to 1900 (Cumming, 1933; Sánchez and Farreras, 1993; Corona and Ramírez-Herrera, 2012a; National Geophysical Data Center-National

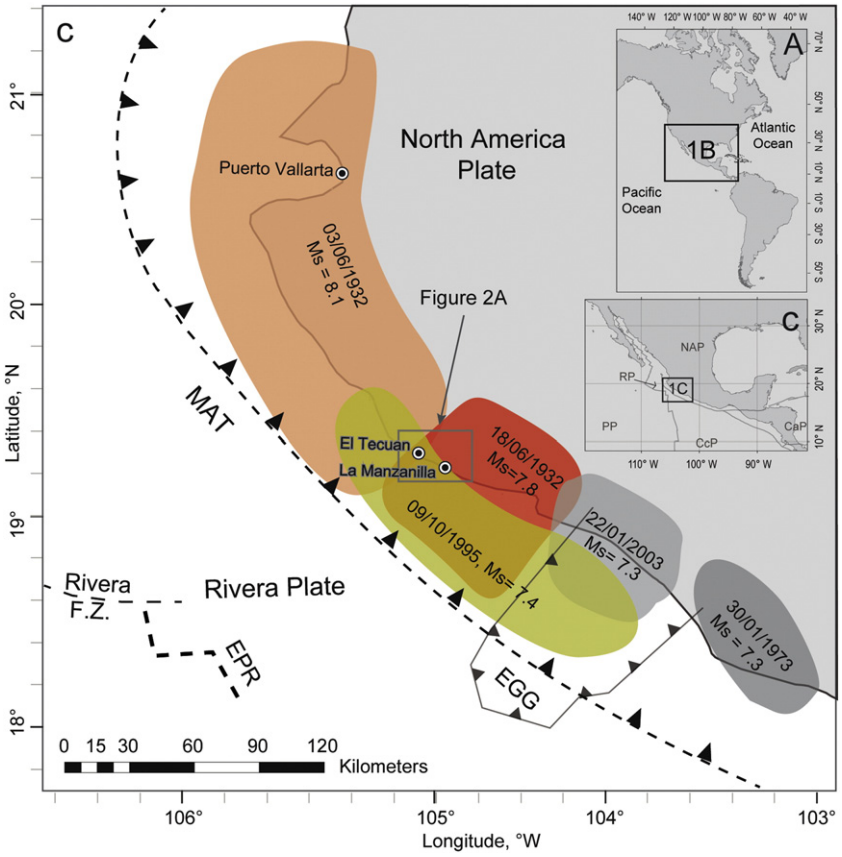

Fig. 1. Tectonic setting showing the locations of historical earthquakes. Inset A — location; inset B: square 1C shows the location of the Jalisco-Colima coast and plate tectonic setting: NAP — North America Plate; RP — Rivera Plate, CcP — Cocos Plate, PP — Pacific Plate; CaP — Caribbean Plate; (C) Map shows the location of the Jalisco-Colima coast, tectonic setting and historical earthquakes. Symbols: F.Z. — fracture zone, MAT — Middle American Trench, EGG — El Gordo graben, EPR — East Pacific Rise, shaded areas — rupture areas.