Magnetic properties – testing an innovative proxy in tsunami deposit identification

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Abstract

Magnetic properties in estuarine sediments were analyzed to aid in identifying tsunami deposits. A study of large historic and prehistoric earthquakes and their tsunamis using a multi-disciplinary approach (geomorphic features, sediment deposits, microfossils, sediment geochemistry and more recently the use of magnetic properties) has provided valuable information in the assessment of earthquake and tsunami record. The Pacific coast of Mexico is located over the active subduction zone (~1000 km) that has experienced numerous large magnitude earthquakes in historical time (Mw>7.5), and more than 50 documented tsunamis since 1732. We present here results from a study using magnetic susceptibility to distinguish tsunami deposits in the Ixtapa-Zihuatanejo area.

Resumen

Se analizaron las propiedades magnéticas de sedimentos estuarinos del área de Ixtapa Zihuatanejo con la finalidad de identificar depósitos de tsunamis. Mediante el uso de una metodología multiproxy (características geomorfológicas, depósitos de sedimentos, microfósiles, geoquímica de sedimentos y más recientemente, el uso de las propiedades magnéticas), se ha obtenido información valiosa para la evaluación de terremotos y el registro de tsunamis. La costa del Pacífico en México se encuentra en una zona de subducción activa (~1000 km), que ha sufrido numerosos terremotos de gran magnitud (Mw>7.5), en tiempos históricos; se han documentado más de 50 tsunamis desde 1732. Se presentan aquí los resultados de susceptibilidad magnética de baja frecuencia que han permitido identificar depósitos de tsunamis en el área de Ixtapa- Zihuatanejo.

Introduction

Research on the geological evidence and records of past tsunamis are an important tool in determining the recurrence interval of such events in a region. These studies are also the only way of determining the prehistoric occurrence and tsunami hazard in areas of infrequent seismic activity for large events. Since the 2004 Indian Ocean Tsunami, the ability to identify tsunami events in the past using geological evidence has greatly improved. Detailed studies on the deposits related to that event have been numerous (e.g. Moore et al., 2005; Liu et al., 2005; Hawkes et al., 2007). Recently, more opportunities due to the frequency of great events such as the south Java in 2006; Solomon and Chile in 2007, Samoa/American Samoa/Tonga in 2009; Haiti, Chile (e.g. Horton et al., 2011) and Mentawai (Indonesia) in 2010; and now the 2011 Tohoku tsunami in Japan also allow us to improve our understanding of the deposits left by a tsunami and on those coastal morphologies where they can be preserved. However, it is still difficult to distinguish between tsunami deposits and those laid down by other high-energy events, such as storm surge or hurricane. Prior studies show that no one but a series of diagnostic criteria must be use to highlight the differences between tsunami and other storm deposits (Goff et al., 2001; Morton et al., 2007; Kortekaas and Dawson 2007).

Typically, tsunami deposits have been identified base on proxies such as sediment characteristics, such as grain size, structure, thickness, and microfossils. Because storm- and tsunami-deposits are generated by similar depositional mechanisms making their discrimination hard to establish using classic sedimentologic methods, here we test on the Ixtapa estuary, with a history of tsunami inundation, an alternative approach to identify tsunami-induced deposits using rock magnetism method. This method, first tested for the Lisbon 1755 event (Font et al., 2010), seems to be a very promising tool to identify, together with other proxies, tsunami-induced deposits.

The focus of this study is the application of magnetic properties in identifying tsunami deposits. Other proxies have been used and discussed by Ramirez-Herrera et al. (submitted, 2011) that support the effectiveness of rock magnetism in identifying tsunami deposits.

Because the Ixtapa-Zihuatanejo area was affected in historical times by large earthquakes followed by tsunamis (Sanchez and Farreras, 1993; National Geophysical Data Center NOAA, 2010), we selected this region to develop a multi-disciplinary study designed to search for geological evidence of historical tsunami deposits (Figure 1).

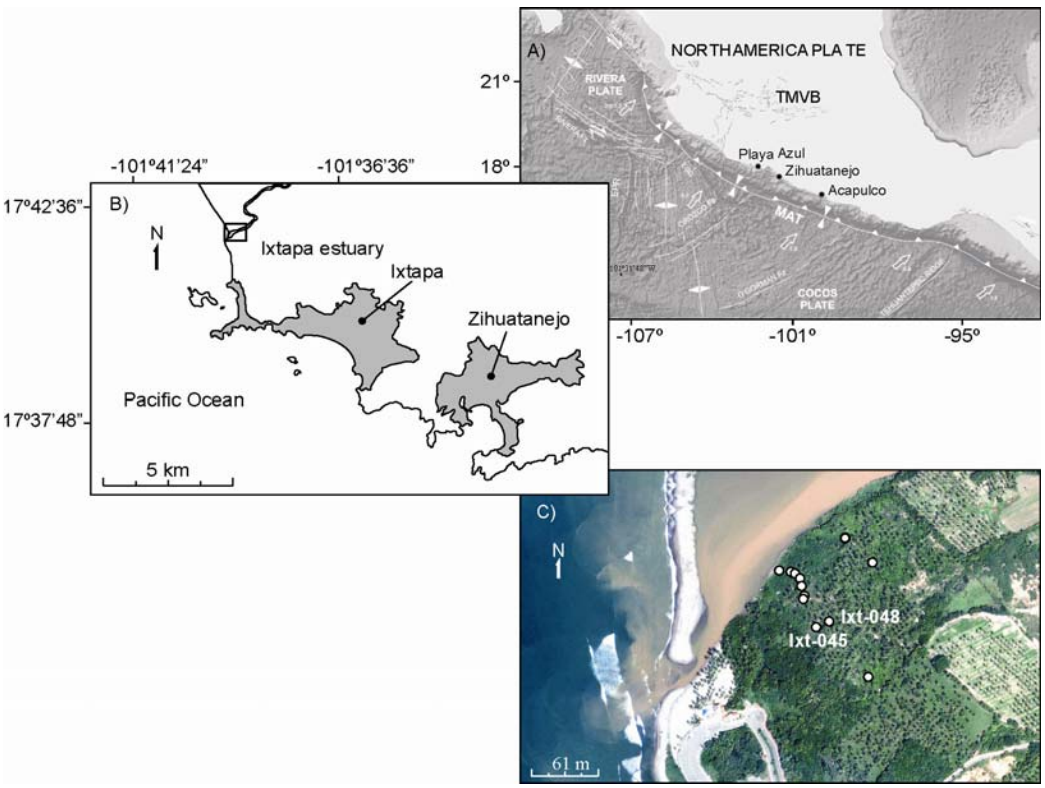

Figure 1. Study site location. a) Mexico's tectonic setting and location in the Eastern Pacific with major plate boundaries and morphotectonic features. Symbols: MAT-Middle American Trench, EPR-East Pacific Rise, EGG-El Gordo Graben, Fz- fault zone, J-Jalisco block, C-Colima graben, M-Michoacan, TMVB-Trans-Mexican Volcanic Belt, bc-Balsas submarine canyon, oc-Ometepec submarine canyon. Numbers indicate convergence rate in cm/yr. b) Ixtapa-Zihuatanejo coast, Guerrero, Mexico showing regional coastal morphology of Ixtapa estuary and Zihuatanejo Bay. c) Detail of Ixtapa estuary and core, pit and trench sites.

Methodology

A series of test pits and a trench were dug and cores recovered (1 m in length) using a hand-driven corer to determine wetland and estuary stratigraphy in Ixtapa-Zihuatanejo. We focused on the Ixtapa estuary record.

Here we introduce the use of sediment magnetic techniques (Evans, 2003, Font et al., 2010). We applied magnetic susceptibility (MS) techniques to identify variations in the magnetic properties of the Ixtapa stratigraphic sequence. Variations in magnetic properties in continuous stratigraphic sequences reflect changes in detrital component mineralogy, that in the case of a tsunami or a storm, the sudden change of detrital input into the sedimentary column is easily depicted by an abrupt shift of MS values (Font et al., 2010).

The low-frequency susceptibility measurements were performed by using the AGICO Kappabridge MFK1-B equipment. To obtain the susceptibility (k) measurements at high and low-frequency ($k\ hf$ at 4700 Hz, $k\ lf$ at 470 Hz) we used the Bartington MS2B apparatus. From these k values, mass specific susceptibility (χ) was calculated. Frequency-dependent susceptibility $k_{FD}\ [\%] = (k lf - k hf) * 100/k lf$ is used to determine the possible presence of superparamagnetic (SP) grains in the magnetic fraction (Evans and Heller, 2003). At higher frequencies of applied magnetic field, a portion of the small SP grains is unable to follow the field changes and will no longer contribute to the susceptibility.

Results and Analysis

The stratigraphic and sediment data collected at the Ixtapa estuary sites provide evidence for the first geologic record of two marine inundations (tsunamis or storms) that occurred during the past century. Two anomalous sand units: at 25-33 cm and at 39-41 cm depth in trench Ixt-048. Magnetic susceptibility techniques show variations in the magnetic properties of the Ixtapa stratigraphic sequence. The increase of MS between 25-30 cm and at around 40 cm, indicates a magnetic enhancement due to an extraordinary contribution of ferromagnetic minerals. Below 40 cm, the lower values of MS detected may be attributed to changes in magnetic mineralogy – i.e. minor contribution of ferromagnetic minerals and higher proportion of antiferrimagnetic and diamagnetic grains (Figure 2).

Figure 2. Detail of Ixt-048 trench showing stratigraphy and magnetic susceptibility data. Dash lines bound events 1 and 2.

Proxies such as grain size, organic content (LOI), geochemistry, foraminifera and diatoms (Ramirez-Herrera et al. submitted) also point to the presence of two sand units that reflect a high-energy environment, together with a marine precedence (geochemistry signature) and a land-level change indicated by microfossils, all characteristics of tsunami deposits. No one, but all proxies together indicate two marine inundations produced by tsunamis in recent time.

Conclusions

Two tsunami deposits found at the Ixtapa site. The application of the magnetic susceptibility proxy reinforced the presence of these two anomalous layers. We should mention that the research of tsunami deposits in Mexico is a new line of research only recently undertaken (Ramirez-Herrera et al., 2007 and 2009) and thus the multi-proxy approach used for identification of tsunami deposits has been tested and systematized. Although, as in other areas of the world, difficulties remain with dating and preservation of tsunami deposits, this approach can be applied to other tropical coastal environments.

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