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The Al-Borani submarine landslide and associated tsunami. A modelling approach☆

J. Macías [a,*], J.T. Vázquez [b], L.M. Fernández-Salas [c], J.M. González-Vida [d], P. Bárcenas [a], M.J. Castro [a], V. Díaz-del-Río [b], B. Alonso [e]

[a] Departamento de Análisis Matemático, Facultad de Ciencias, Universidad de Málaga, Campus de Teatinos s/n, 29080 Málaga, Spain
[b] Instituto Español de Oceanografía, Centro Oceanográfico de Málaga, Puerto Pesquero s/n, 29640 Fuengirola, Spain
[c] Instituto Español de Oceanografía, Centro Oceanográfico de Cádiz, Puerto Pesquero, Muelle de Levante s/n, 11006 Cádiz, Spain
[d] Departamento de Matemática Aplicada, Escuela Politécnica Superior, Universidad de Málaga, Campus de Teatinos s/n, 29071 Málaga, Spain
[e] Instituto de Ciencias del Mar, CSIC, Passeig Maritim, 37–49, 08003, Barcelona, Spain

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ABSTRACT

The key goals to studying submarine landslides and associated tsunamis are to better assess the magnitude information of palaeo-tsunamis and to contribute to assessing future tsunami risks. The numerical modelling of submarine landslides and the tsunamis thus generated comprises important interdisciplinary research that requires knowledge of both geology and numerical modelling. Models are capable of delineating the time evolution of tsunami hydrodynamics, sediment transport, and the resulting morphological changes associated with deposition. To advance towards the ultimate goal of improved tsunami risk assessment, modellers and geologists need to develop an in-depth mutual understanding of the advantages, limitations, and uncertainties in both numerical modelling and geological records. In this work, seafloor features related to former submarine landslides in the Alboran Sea basin have been identified through multibeam bathymetry data and high- to very high-resolution seismic profiles. The mathematical modelling and hindcasting have been performed through numerical simulation of a hypothetical submarine landslide and the associated tsunami that could have originated one of the submarine landslides identified. This system, on the southern Alboran Ridge slope, is currently reworked by turbidite processes, forming a submarine canyon-sedimentary fan system known as the Al-Borani System. The HySEA numerical model simulates the submarine landslide triggering the tsunami and the water mass evolution, wave propagation, and the final penetration of the tsunami waves onto the coast, reproducing initial and subsequent tsunami wave impacts by means of a single coupled numerical model. This numerical model allows an analysis of the influence of basin morphology on the tsunami propagation features, such as shape and propagation patterns, speed or wave amplitude and, finally, its impact on the coast (in this case South Iberia and North Africa). This model can also be used as a prediction tool for the simulation of potential landslides, many of which generate tsunamis. Monitoring of critical areas, where landslides are more probable, and modelling their consequences will allow a choice of the appropriate mitigation strategies. Therefore, monitoring and modelling are areas of key scientific and socio-economic interests.

1. Introduction

Tsunami wave generation is a geological hazard that can have a severe impact on society. Coastal areas are not only the most populated regions of the planet, but also where economic activity clusters. Tourism is a significant activity on the South Iberian coastline and an emergent one on the North African coastline (growing continuously over the last decade) (Fig. 1).

To evaluate the tsunami risk in a region, it is necessary first to consider the most probable tsunamigenic sources. The two major geological mechanisms generating tsunamis that have to be considered are seismic–tectonic activity and sedimentary instability processes that generate submarine landslides, in particular, subaerial or submarine landslides affecting the seafloor surface. In the Alboran basin, the study of tsunamis triggered by seismic–tectonic activity has been considered by several authors in recent years (González et al., 2010; Álvarez-Gómez et al., 2011a,b). As an example, Álvarez-Gómez et al. (2011a and b) deal with tsunami generation from both the tectonics and potential seismic sources in this marine region. They consider 12

☆ A five-step educational sketch summarizing the hypothesis, methodological process and results of this study can be found at: edanya.uma.es/menulandslides/109.

* Corresponding author. Tel.: +34 952132016.
E-mail addresses: jmacias@uma.es (J. Macías), juantomas.vazquez@ma.ieo.es (J.T. Vázquez), luismi.fernandez@cd.ieo.es (L.M. Fernández-Salas), jgv@uma.es (J.M. González-Vida), pbarcenas@uma.es (P. Bárcenas), mjcastro@uma.es (M.J. Castro), diazdelrio@ma.ieo.es (V. Díaz-del-Río), belen@icm.csic.es (B. Alonso).

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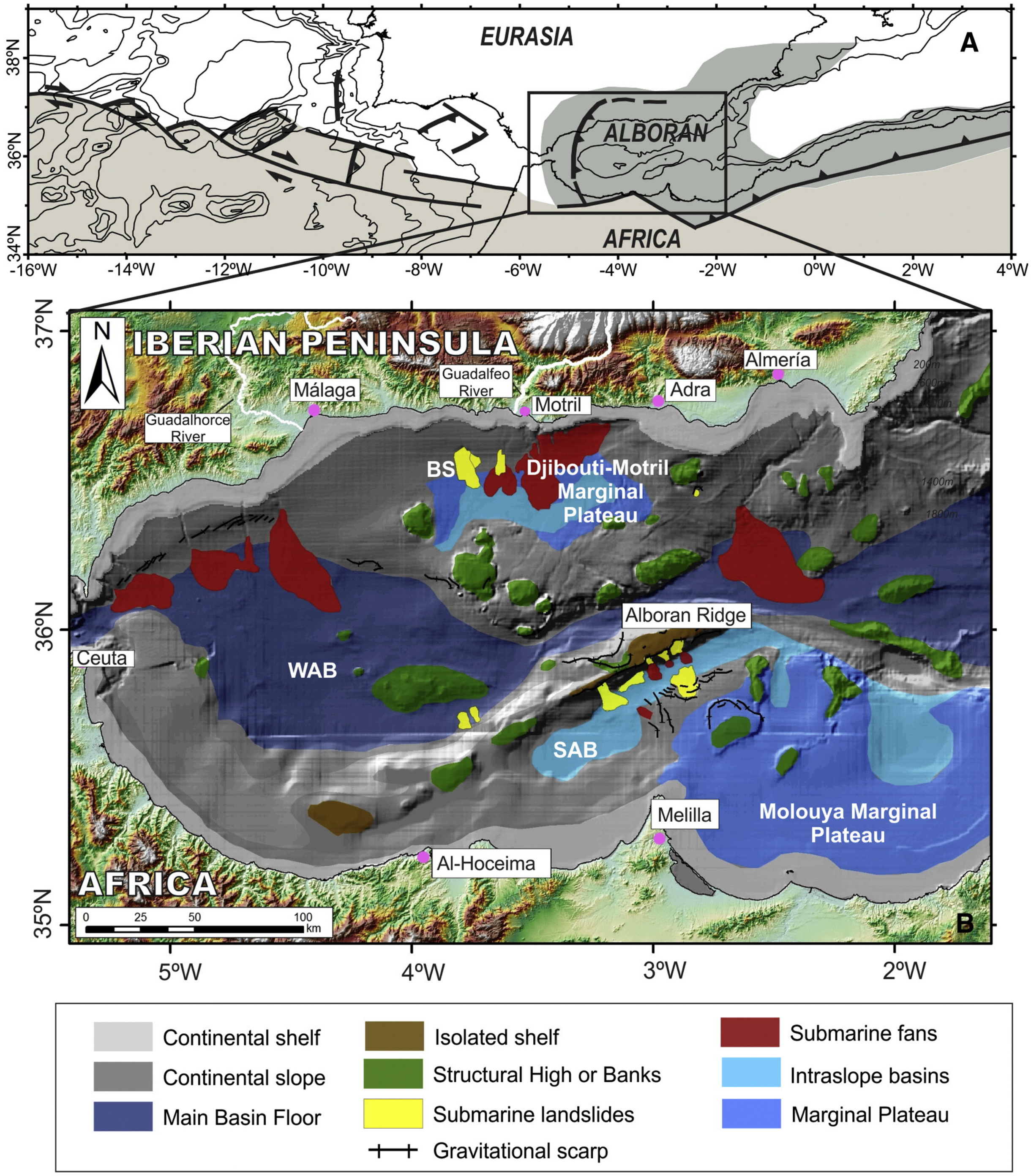

Fig. 1. (A) Plate-tectonic scheme of the Ibero–Maghrebian region (modified from Vázquez and Vegas, 2000). WAS: Western Alboran Subduction Zone. (B) Physiographic Map of the Alboran Sea basin plotted on a hillshade model. A compilation of multibeam bathymetry (40 × 40 m) has been used for the construction of this model and has been plotted on a general hillshade model based on ETOPO bathymetry (1000 × 1000 m). On land, a DTM model has been used based on the 1° × 1° files available from the 2000 Shuttle Radar Topography Mission, the resolution is about 90 m. BS: Baraza slide. SAB: South Alboran Basin, WAB: West Alboran basin.

probable tsunamigenic seismic sources from geological studies of the seafloor. Their research concludes that earthquakes located on the Alboran Ridge show the maximum potential to generate damaging tsunamis, with a maximum wave elevation on the coast exceeding 1.5 m.

The study of tsunamis triggered by submarine landslides has increased considerably in the last 20 years. Our expanded knowledge of the seafloor due to the development of exploration techniques has revealed numerous submarine landslides on the seafloor surface. The observation of these features has spurred the evaluation of the role that submarine landslides play as potential tsunami sources in order to assess the hazard and risk to which a given coastal region is exposed (Harbitz, 1992; Haugen et al., 2005; Løvholt et al., 2005; Harbitz et al., 2006; Masson et al., 2006; Tappin, 2010; Harbitz et al., 2014). The triggering of submarine landslides usually includes several factors such as high-amplitude sea-level changes, sediment overburden, storms, the presence of bubble gas within the sediments and