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High-resolution analysis of a tsunami deposit: Case-study from the 1755 Lisbon tsunami in southwestern Spain

Stéphanie Cuven [a,c], Raphaël Paris [b,d,e,*], Simon Falvard [a,c], Elisabeth Miot-Noirault [f], Mhammed Benbakkar [b,d,e], Jean-Luc Schneider [g], Isabelle Billy [g]

[a] Clermont Université, Université Blaise Pascal, GEOLAB, BP 10448, F-63000 Clermont-Ferrand, France
[b] Clermont Université, Université Blaise Pascal, Laboratoire Magmas et Volcans, BP 10448, F-63000 Clermont-Ferrand, France
[c] CNRS, UMR 6042, GEOLAB, F-63057 Clermont-Ferrand, France
[d] CNRS, UMR 6524, LMV, F-63038 Clermont-Ferrand, France
[e] IRD, R 163, LMV, F-63038 Clermont-Ferrand, France
[f] Clermont Université, Université d'Auvergne, INSERM UMR 990, F-63005 Clermont-Ferrand, France
[g] Université Bordeaux 1, CNRS-UMR 5805 EPOC, Avenue des Facultés, BP 184, F-33405 Talence, France

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ABSTRACT

A multi-proxy approach using trench sediment analysis on the southwestern coast of Spain (Los Lances Bay, Andalusia) provides a high-resolution record of the 1755 Lisbon tsunami and offers new means to interpret tsunami deposits. A combination of sedimentological (grain size, sorting, AMS), micromorphological (X-ray tomography and radiography, thin sections) and geochemical analyses (X-ray microfluorescence, ICP-AES) combines to provide a comprehensive reconstruction of the different phases of tsunami deposition and flow dynamics. Vertical variations in sediment texture, fabric and composition of the 1755 tsunami deposits in Los Lances are then discussed with reference to existing literature on diagnostic criteria commonly used for identifying and interpreting tsunami deposits. Finally possible leads for future investigation are proposed.

1. Introduction

Seven years after the 2004 Indian Ocean tsunami, the sedimentary record of palaeotsunamis is becoming increasingly well documented worldwide, and scientists now have access to a more varied proxy toolkit, including sedimentological, micropalaeontological, geochronological and geochemical methods (Dawson and Stewart, 2007; Bourgeois, 2009; Chagué-Goff, 2010; Keating et al., 2011; Goff et al., 2012). Kilfeather et al. (2007) tested the feasibility of using micromorphology (on thin sections) as a diagnostic tool to identify and improve interpretation of tsunami deposits. This multidisciplinary approach also allows the palaeoenvironments before, during and after the tsunami to be investigated, even if one or more proxies cannot be applied due to local conditions. Despite considerable progress in palaeotsunami research, distinguishing tsunami from storm deposits is still complex, and reconstructing a past tsunami event from its deposits remains difficult (e.g. Jaffe and Gelfenbaum, 2007; Pritchard and Dickinson, 2008; Jaffe et al., 2012; Paris et al., 2012). Information from grain size distribution, palaeontological and geochemical analyses of bulk samples from onshore tsunami deposits can be limited by (1) the subjectivity and low resolution of manual sampling in the field, and (2) the poor preservation potential of sedimentary structures in these unconsolidated sediments. Indeed, the structure and vertical grain size trends of tsunami deposits are rapidly modified by bioturbation, as demonstrated by Szczuciński (2012).

In this study, we couple sedimentological and geochemical proxies, using both destructive and non-destructive methods, to carry out high resolution characterisation of the 1 November, 1755 Lisbon tsunami deposits in southwestern Spain (Fig. 1). The results include two- and three-dimensional X-ray imagery and X-ray microfluorescence analysis (μXRF) of previously studied tsunami deposits. We surveyed several sites where the tsunami deposits were well preserved and already studied (Luque et al., 2001, 2004; Gracia et al., 2006; Reicherter et al., 2010; Lario et al., 2011). Deposits of the 1755 tsunami are particularly well preserved at the coastal plain of Los Lances, located 25 km SW of Algeciras, near the city of Tarifa (Gibraltar Strait). Four washover fans breaching all Holocene ridges, including the Late Medieval ridge, were interpreted as evidence of the 1755 tsunami (Gracia et al., 2006).

* Corresponding author at: Clermont Université, Université Blaise Pascal, GEOLAB, BP 10448, F-63000 Clermont-Ferrand, France. Tel.: +33 473346717.
E-mail address: R.Paris@opgc.univ-bpclermont.fr (R. Paris).

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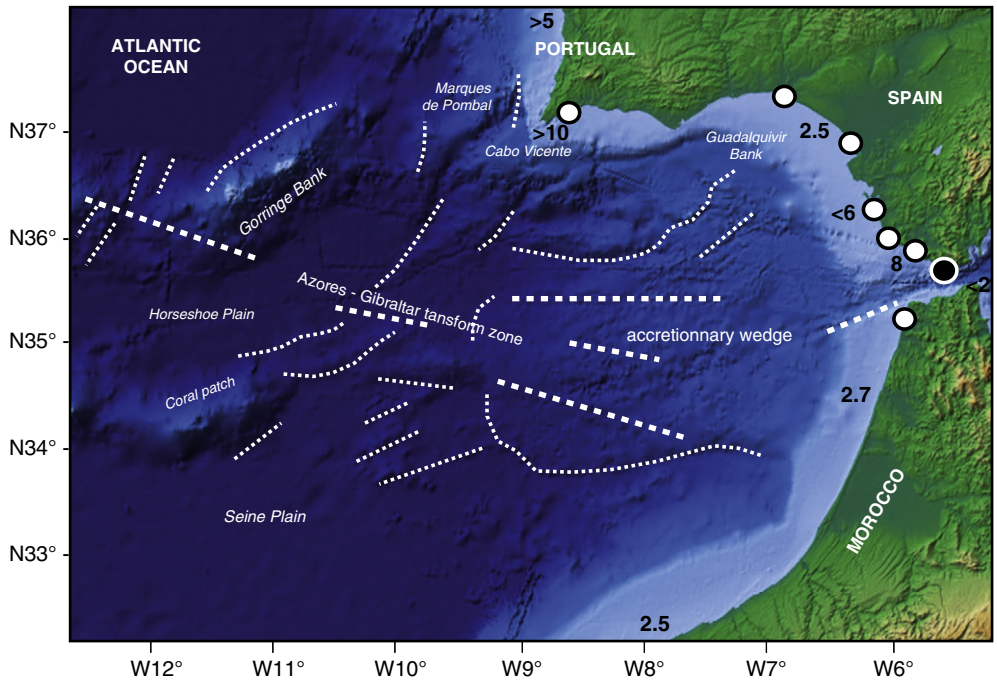

Fig. 1. General tectonic setting of the Eurasia (Iberia)–Africa (Nubia) plate boundary. White bold dotted lines: faults; White dotted lines: tectonic lineaments; white dots: observed wave height; black dot: location of the Los Lances Bay.

Based on historical reports, a bridge which was built at the beginning of the eighteenth century was partly destroyed by the 1755 tsunami (Fig. 2). Numerous bricks from the bridge can be found in the washover fan deposits. Reicherter et al. (2010) found tsunami deposits up to 700 m inland (~4 m a.s.l.). According to historical sources (Campos, 1991), the 1755 tsunami waves were 11 m high in Los Lances and the

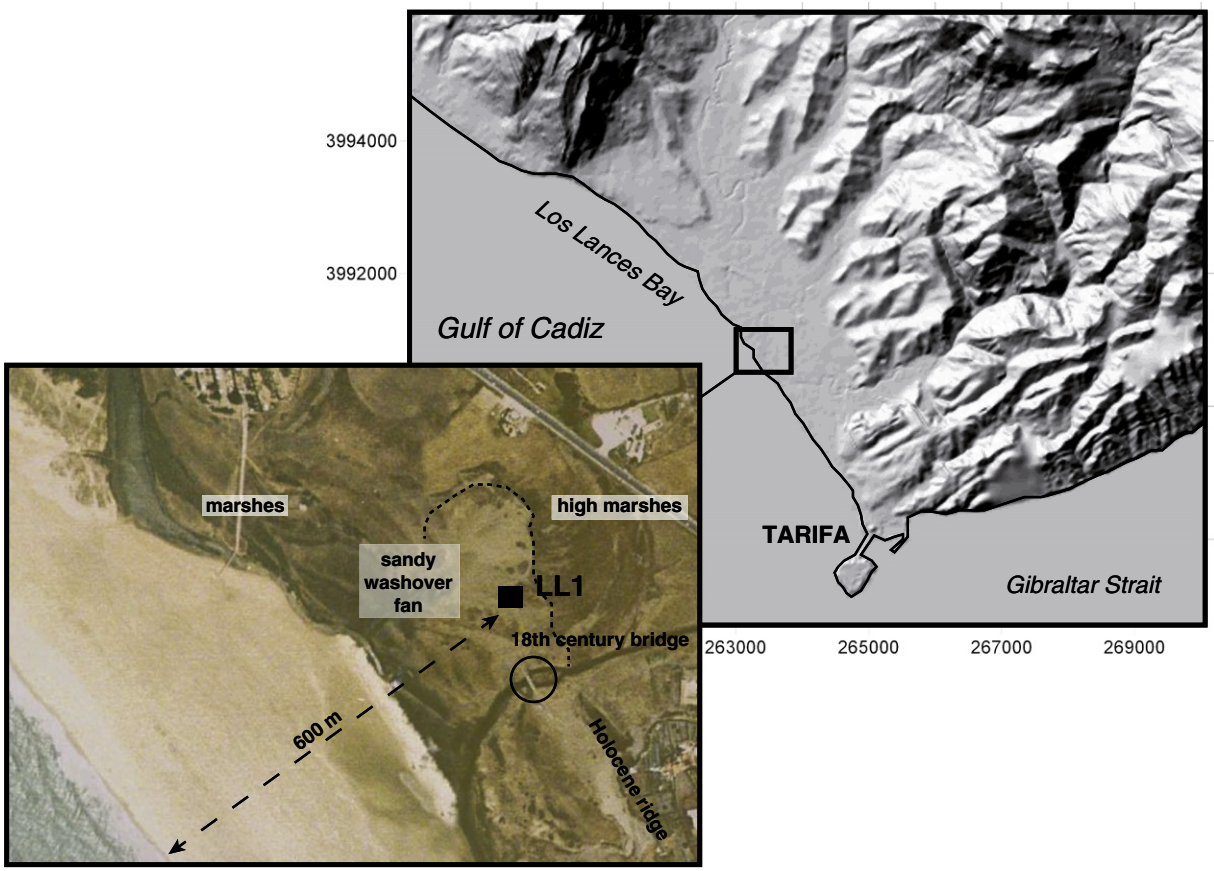

Fig. 2. Location map and satellite view of the study area. Cores LL1 and LL1bis were retrieved from the 1755 sandy washover fan (Gracia et al., 2006; Reicherter et al., 2010). The bridge was constructed at the beginning of the eighteenth century and partially destroyed by the 1755 tsunami.