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# Reconstructed seismic and tsunami scenarios of the 1905 Calabria earthquake (SE Tyrrhenian sea) as a tool for geohazard assessment

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ABSTRACT

Italy is one of the most seismically active regions in the central Mediterranean and one of the countries with the longest record of historical earthquakes in the world. Over the last decades the scientific community has recognised the value of historical data when used to constrain modelling tools in hazard analyses. This is the case of the destructive 1905 Calabria (South Italy) earthquake, followed by a tsunami and by many secondary effects on the environment observed both inland and offshore. Recently acquired geophysical data allowed to identify an active normal fault, named Sant'Eufemia Fault, located nearshore in the Sant'Eufemia Gulf (SE Tyrrhenian sea), considered the most probable seismogenic source of the 1905 earthquake and capable to trigger future events.

In this paper we perform a scenario-based deterministic analysis for an earthquake resulting from the rupture of the Sant'Eufemia fault (SEF) and a preliminary potential risk analysis. After defining source parameters compatible with the 1905 earthquake (ca. 40 km fault length and ca. 2.3 m slip, Mw 6.9), KF-analysis and tsunami simulations are carried out and modelling results are compared against historical available data. The obtained results allow one to border areas in central Calabria that are most exposed to geohazard deriving from the analyzed fault. Some of these areas happen to be zones with intense economic/touristic and urban development, which calls for the need to integrate the ongoing development plans with adequate programs of risk mitigation and prevention.

## 1. Introduction

The Mediterranean region is characterized by active geodynamic processes, responsible for the high seismicity level affecting the active arc systems (Fig. 1, top). In the Central Mediterranean, the Calabrian Arc system exhibits the highest release of seismic moment in terms of historical (see Fig. 1b; Rovida et al., 2011) and of instrumental seismicity (see Fig. 1a; http://www.seismicportal.eu/; see also http://csi.rm.ingv.it/versione_inglese/index_eng.htm; Castello et al., 2004; Chiarabba et al., 2005; CSTI 1.0 Working Group, 2001). It follows that this region is affected by the highest hazard and risk level of the Central Mediterranean area, linked both to earthquakes and tsunamis (Tinti, 1993; Slejko et al., 1998; Lucantoni et al., 2001; Tinti and Armigliato, 2003; Gruppo di Lavoro MPS, 2004). Moreover, tsunamis were triggered by several of the largest earthquakes that struck the Central Mediterranean (Tinti and Maramai, 1996; Tinti et al., 2004; Maramai et al., 2014). Restricting the attention to Calabria and eastern Sicily (Fig. 1c), examples of these earthquake-generated tsunamis are the well-known occurrences of 1693 in eastern Sicily (e.g. Tinti et al., 2001), of 1783 in central-southern Calabria (e.g. Tinti and Gavagni, 1995), of 1905 in western Calabria (Tinti and Piatanesi, 2002) and of 1908 in the Messina Straits (Tinti and Armigliato, 2001). Several studies have been performed by the scientific community during the last decades to identify the source faults capable to generate these earthquakes. A good synthesis of the research carried out until today can be found in the freely accessible database DISS showing the active seismogenic faults of Italy (DISS: http://diss.rm.ingv.it/dissmap/), in which the recently identified (Loreto et al., 2013) fault source of the 1905 is included (Fig. 1d). Looking at the DISS faults map, one can observe that the Calabria and NE-Sicily regions are the ones with the largest, and well assessed, NE-trending seismogenic sources (Fig. 1d), such as the ones involved in the 1783 and 1908 events and the one that

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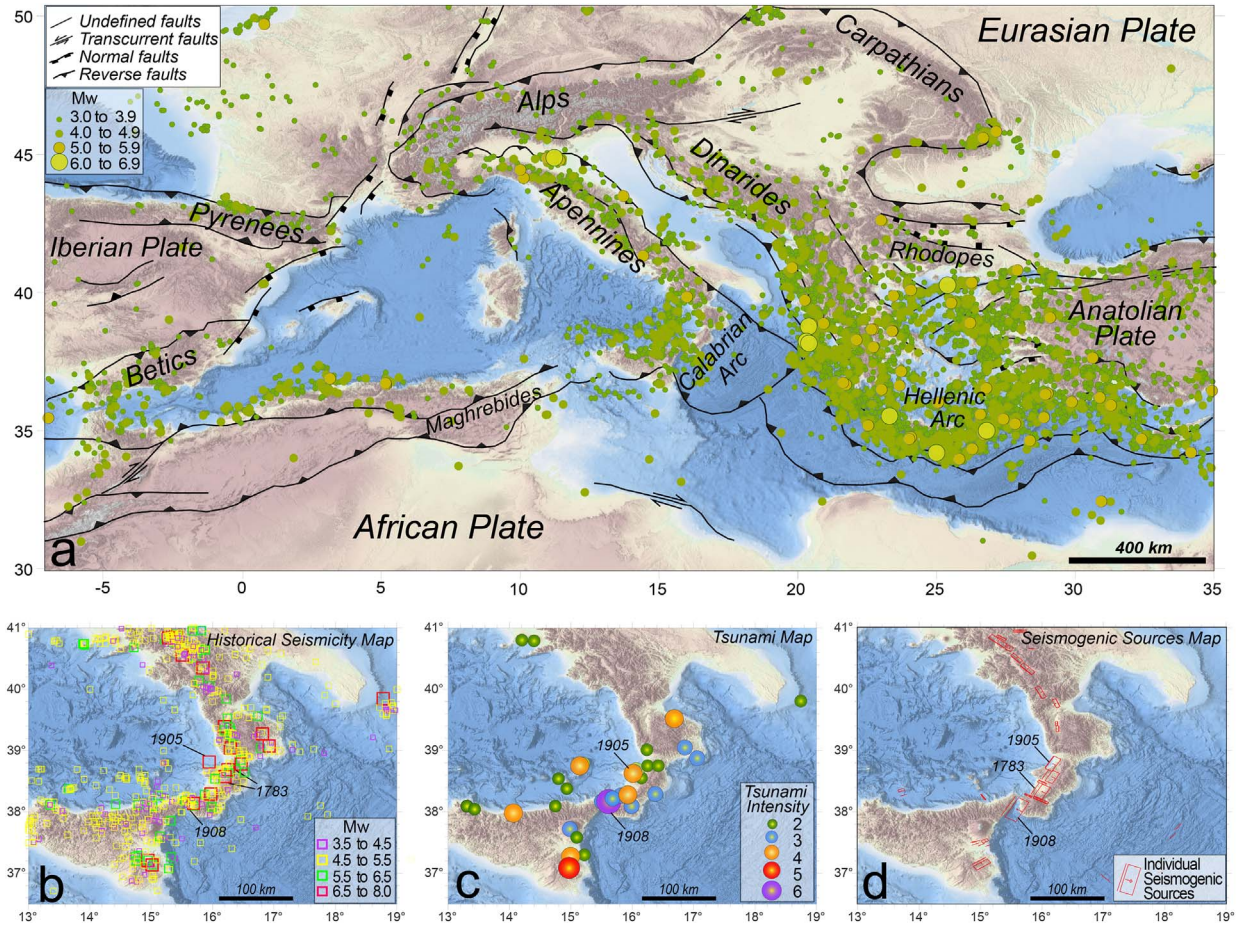


**Fig. 1.** Shaded relief from EMODnet bathymetry portal (http://portal.emodnet-bathymetry.eu/gebco-bathymetry-basemap). a) Mediterranean structural sketch modified after an online Tectonic Map (Woudloper - Own work, CC BY-SA 1.0). Instrumental seismicity (2012–2013) from EMSC (http://www.seismicportal.eu/). b) Historical Seismicity Map (1000–2006) from INGV seismic database (Rovida et al., 2011). c) Tsunami Map modified after Maramai et al. (2014): tsunami intensity is expressed in the Sieberg-Ambraseys scale. d) Seismogenic Sources Map, including only individual sources, modified after DISS (http://diss.rm.ingv.it/dissmap/dissmap.phtml). Marked are the most important historical events that struck the region.

can be associated with the 1905 event.

The aim of this work is to reconstruct the 1905 event that hit western-central Calabria by modelling an integrated scenario including the macroseismic field, the impact of tsunami on the coast and the environmental effects. The motivation of this study is that the source fault of this earthquake, which is one of the largest occurred in Calabria in the last centuries, was and is still object of a debate where many authors propose different parent faults. The scenario elaborated here takes the recently identified Sant'Eufemia fault (SEF; Loreto et al., 2013; Sandron et al., 2015) as the fault responsible for the earthquake. The good comparison between the observations and modelling results can be used as a validation of the source fault hypothesis. It is also stressed that this study provides a contribution to assessing seismic and tsunami hazard for Calabria. A relevant outcome is that the computed 1905 integrated scenario shows that several zones, currently characterized by development of infrastructure facilities and tourism activities fall within the high-impact region of the 1905 event, which outlines the need for developing appropriate, now missing or insufficient, mitigation plans.

## 2. Geo-structural setting

The Sant'Eufemia Gulf (Fig. 2) lies between the Calabrian Arc and the southeastern side of the Tyrrhenian basin, a Neogene-Quaternary back-arc basin belonging to the Apennines-Ionian crust subduction system (Patacca and Scandone, 2004). The Calabrian Arc is an independent, continental block that bridges the NW-trending southern Apennines (to north) with the approximately E-trending Sicilian Apennines (to south; Bonardi et al., 2001; Critelli et al., 2017). The rapid southeast-ward migration of the Calabrian Arc, and the abundant seismicity recorded at different depths support the hypothesis that subduction of the oceanic crust is still active beneath the Calabrian block. Laterally, the subduction is confined by two main tear faults: the well identified Tindari fault to south; and the Sangineto-Crati faults system (Van Dijk and Scheepers, 1995; Rosenbaum et al., 2008) or the Catanzaro shear zone (Guarnieri, 2006; Brutto et al., 2016) to north. The Calabrian Arc is further segmented, laterally, by NW-trending shear zones that, from middle Miocene (Van Dijk and Scheepers, 1995) to Recent (Tansi et al., 2007; Tripodi et al., 2013), have accommodated differential movements between minor blocks (Malinverno and Ryan, 1986). Further, this transversal system allowed the opening of Neogene transversal basins like that hosted in the Catanzaro paleo-strait (Ghisetti, 1979; Zecchin et al., 2015). From middle Pleistocene times, the Calabrian Arc experienced a rapid uplift up to ~1 mm/yr (Westaway, 1993; Tortorici et al., 2003), partially accommodated by the major NE-trending normal faults (Ghisetti, 1979; Monaco and Tortorici, 2000; Brutto et al., 2016) affecting the entire Calabria block. These NE-trending normal faults, all active, are arranged as graben and semi-graben systems, such as the Crati graben or the more recently defined Lamezia graben (Brutto et al., 2016). Most of these active normal faults are associated to the largest historical earthquakes that struck the region (Figs. 1b and 2).

## 3. The 1905 Calabria earthquake and tsunami

The earthquake that in the night of 8th September 1905 hit the