Historical, archaeological and geological records of strong earthquakes at Capo Peloro (southern Italy)

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The recurrence interval for large magnitude earthquakes in Italy is generally longer than 1000 years (e.g Valensise and Pantosti, 1992; Pantosti et al., 1993; Galadini and Galli, 2004), and largest earthquakes usually have repeat times of the same order as the length of the available historical records. Although the Italian catalogues report earthquakes which occurred in a long time span (461 BC – 2002 AD) (Boschi et al., 2000; Working group CPTI, 2004), the historical data on the earthquake effects are generally sparse at least until the 13-14th century events.

During the 4th century AD southern Calabria and eastern Sicily were hit by an earthquake documented by archaeoseismic analyses, which was interpreted by Guidoboni et al. (2000) as the predecessor of the well-know 1908 earthquake, located in Messina Strait, whereas Galli and Bosi (2002) interpreted this event as the precedessor of the 1783 earthquake.

The purpose of this paper is to find further evidence of these earthquakes in Messina area by a multi-disciplinary study aimed to recognize and date historical and paleo-earthquakes. For this goal we have analyzed historical, archaeological and geological information of excavations performed at Capo Peloro near the Torre del Faro village (Fig. 1) in the Torre degli Inglesi (English Tower), built on an abandoned Roman tower.

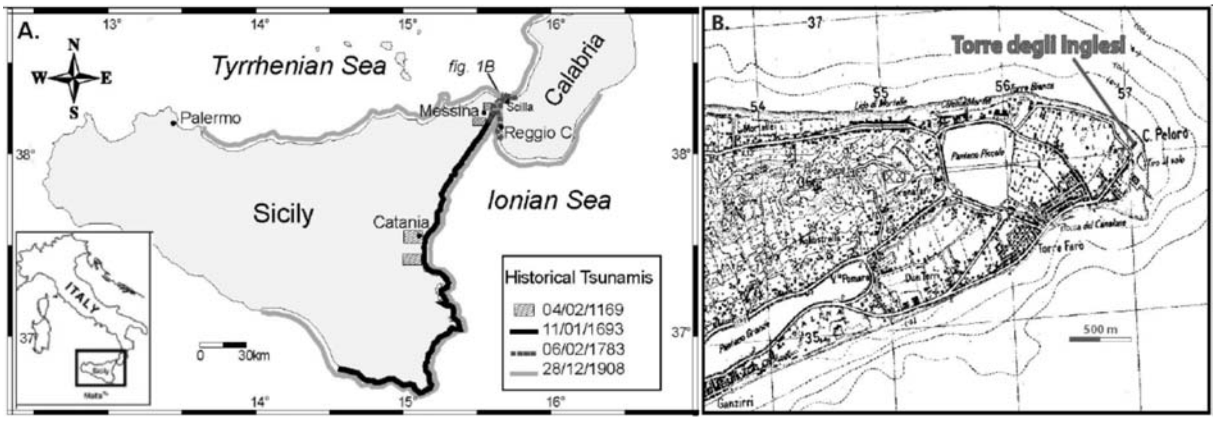

Fig. 1. (A) Tsunami inundation in Eastern Sicily: lines with different grey tones and patterns and small striped rectangles indicate the inundated coastal areas. (B) Topographic map of the Ganzirri peninsula with the location of Torre degli Inglesi (arrow) near Capo Peloro, and the village of Torre Faro on the southern coast (from IGMI 1:25000 scale topographic maps) (after Pantosti et al., 2007).

Historical earthquakes and tsunamis. There is a little evidence of earthquakes during the first millennium in the area surrounding the Straits of Messina; for the events in 91 BC, 17 AD, around the middle of the 4th century AD (Guidoboni et al., 1994, 2000), and 853 AD (Guidoboni et al., 1994; Boschi et al., 2000) no reliable information of damage is available. Between the end of the fifteenth and the end of sixteen centuries four events damaged some localities near the Messina Straits and the first observation for Torre del Faro refers to the 1509 earthquakes (Boschi et al., 2000). At Torre del Faro the two shocks of 5 and 6 Feb 1783 caused strong damage and the upper part of the Torre degli Inglesi collapsed (Vivenzio, 1783). The earthquake of 28 December 1908 caused four cracks in the new lighthouse of Capo Peloro; cracks E-W and N-S, and a large fracture E-W which caused disjunction and relative lowering of the northern wall of the Torre degli Inglesi (Baratta, 1910), also opened.

In the area of Messina Straits tsunamis were observed after the 1169 and 1693 south-eastern Sicily earthquakes, after the two shocks of 5 Feb and 6 Feb 1783, and after the 1908 earthquake. In the Ganzirri Peninsula, where Torre degli Inglesi is located, there is description for only the two most recent tsunamis with reference to the village of Torre Faro; no direct mention of Torre degli Inglesi is found. At Torre Faro the 6 Feb 1783 tsunami flooded the shore for about 400 steps (~ 400m) inland depositing a large amount of silt and dead fishes (Sarconi, 1784). Conversely, the 1908 tsunami inundation decreased substantially to the north of the town of Messina and produced a wave that, according to Baratta (1910), flooded inland at Torre Faro only 5m.

Archeological data. The Torre degli Inglesi is a rectangular base defence tower located about 40 m from the present shoreline, at an elevation of about 6 m a.s.l. (Fig. 1B). According to archaeological evidence studied by the Superintendence of the Archaeological heritage of Messina, the main building phases (Fig. 2) of the Torre degli Inglesi, can be summarized as follows: (i) between the 1st century BC and 1st century AD construction of the Roman Tower; (ii) between 3rd-16th century destruction (by an earthquake?, a fire?), abandonment and rebuilt of a new undefined structure; (iii) 16th century construction of the Torre degli Inglesi; (iv) end of 19th century construction of a paved garden. Finally, the tower was restored after the 1908 earthquake.

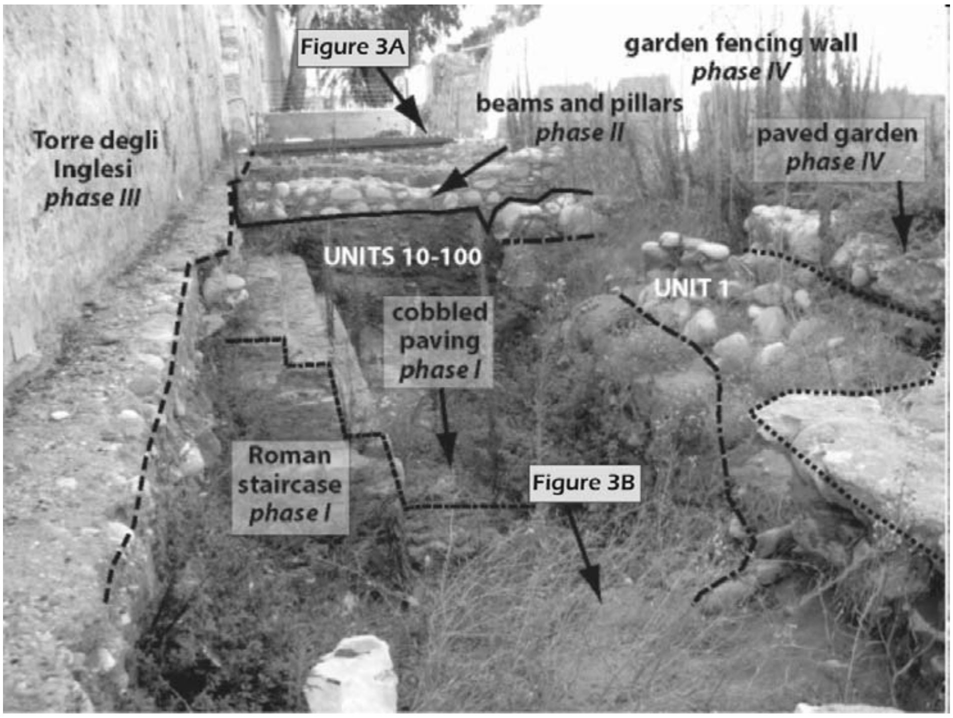

Fig. 2. View of the archaeological excavation on the NW side of Torre degli Inglesi. The main building phases (i to iv) are visible with the relative chronology. Different patterns highlight the major relationships between features of different age. Labels figure 3a and 3b indicate the view of photographs shown in the relative figure (after Pantosti et al., 2007).

Geological evidence. On the basis of the detailed survey of the deposits exposed in the archaeological excavation (Fig. 3 a and b), we found two layers (units 90/80 and 1) completely different from the deposits exposed at the site and nearby. In fact, these are composed by clean, gray, silicoclastic sands, rounded cobbles and pebbles, substantially contrasting the dark organic colluvia rich in wastes, related to human activity. Micropaleontological analyses confirmed the different origin of the deposits composing units 90 and 1 that are likely marine. The nature of these deposits, coupled to their sharp erosional contacts and their relative infrequency (i.e., if these were storm deposits these should be more frequent), allow us to interpret these layers as paleotsunami deposits (Pantosti et al., 2007).
Radiocarbon dating was performed on 6 charcoals (Fig. 3 a), sampled in the lower bioclastic sandy layer (Unit 90) and in the sandy layers just below and above the same layer, constrain the age of the lowermost tsunami sand (Pantosti et al., 2007); while the samples (Fig. 3 b) collected in the artificial

levelling deposits into two levels to the left and to the right of the fracture, well predate the younger tsunami deposit, that underlies the paved garden of the 19th century (Fig. 2).
Combining archeological, historical and radiocarbon data we may associate the oldest tsunami layer (unit 90/80) to the 17 AD earthquake, for which no knowledge and information reported by historical sources existed about tsunamis till now. Conversely, the youngest layer (unit 1) is likely related to the 1783 Feb. 6 earthquake that is well known of the triggered tsunami (Pantosti et al., 2007). No evidence for the famous 1908 Messina tsunami was found.
The deposits and the building also exhibit earthquake-related damage. Extension fractures striking N45° cross the deposits (Fig. 3b). The fractures are up to 2 cm wide and extend through the cisterns (Fig. 4) upward into 1800 walls.

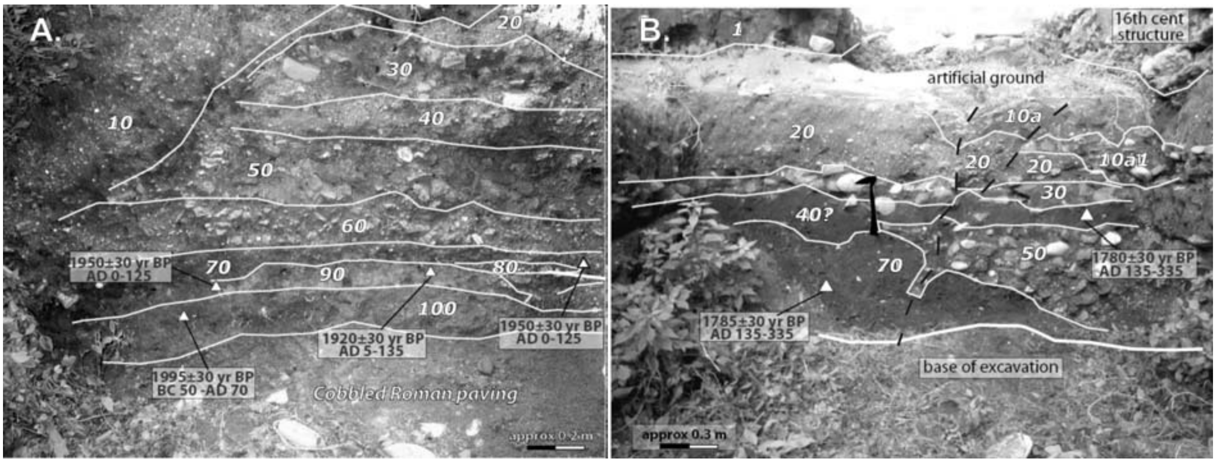

Fig. 3. View of the walls of the studied excavation at Torre degli Inglesi (see Figure 2 for location). Numbers refer to stratigraphic units described in the text, white triangles are location of dated charcoals. Measured and dendrochronologically corrected ages of samples (Stuiver et al., 2006) are reported as yr BP and 2σ intervals, respectively. a) NW wall; b) NE wall; dashed black line highlights a fracture probably related to the 1908 earthquake (modified from Pantosti et al., 2007).

Fig. 4. Fracture crossing all the manufactures at Torre degli Inglesi

Discussion. The sedimentological and archaeological stratigraphy and dating at the site of Torre degli Inglesi contain evidence of the effects of three possibly four earthquakes, two of which produced also large tsunami inundation. These are:

- The sandy layer (unit 90/80) deposited by a tsunami between 0 and 125 AD that may be associated to the 17 AD earthquake.
- The pillar and beams of a new construction intervening on the Roman structure but cut by the 16th century tower indicating the abandonment of the Roman tower and re-built of a new structure. The age of the fill around the tower containing wastes, pottery and charcoal (destruction layer?) is found consistently at AD 135-335 suggesting that the event of destruction occurred in this period of time. This event may be correlated to the 4th cent. event (Guidoboni et al., 2000).
- The sandy layer (unit 1), just below the end of 19th cent. pavement and wall that was probably deposited by the Feb 6, 1783 tsunami.
- The north-eastern striking fracture, cutting both the deposits and manufacts, described in the historical accounts for the 1908 earthquake.

These results call for a reconsideration of the historical seismicity of the area and especially on their attribution to seismic sources. This is particularly true for the 17 AD and 4th cent. events for which limited knowledge exists. In fact, different authors interpret the 4th cent. events as ancestor of the 1908 or 1783 event providing indication on the repetition of large events on the causative faults; whereas the 17 AD earthquake is considered a minor shock, roughly located in the northern side of Mt. Etna with an maximum intensity of VIII-IX MCS and M_{aw} = 5.14 (Working group CPTI, 2004) and information on related tsunami is not reported by historical sources.
Revising these interpretations on the light of the results of this work is critical for the re-assessment of the seismogenic significance of the faults around the Strait of Messina.

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