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for management of future coastal change

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Using Boulders Accumulations as Tsunami indicators: an hydrodynamic approach

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Introduction

The impact of tsunamis on Mediterranean coasts has been neglected in the study of coastal morphology and dynamic notwithstanding the fact that such high-magnitude low-frequency events are considered likely to have played an important role in their evolution. On the other hand the presence of a lot of human settlement along the rocky coast suggests a particular attention in the study of paleo and historical tsunami to define the coastal risk and hazard for the coastal use capability.

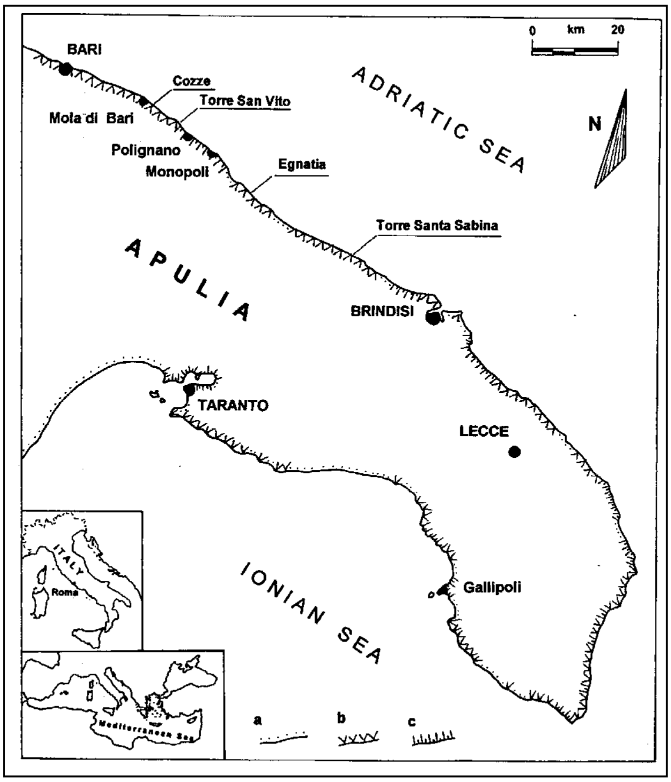

Figure 1. Position of areas along the Adriatic coast of Apulia characterised by the presence of boulders accumulated by tsunami and storm waves.

Main morphological effects of tsunamis on rocky coast are represented by the detachment of large boulders in the nearshore zone and their deposition farther inland (Dawson, 1994; 2000), and by the sculpturing of bedrock resulting in the production of both smooth, small scale forms and large scale features as well (Bryant and Young, 1996; Bryant, 2001).

Large boulders deposition due to historical tsunami has been observed along numerous coastal tracts all over the world (Moore and Moore, 1984; 1988; Nakata and Kawana, 1993; Young et al., 1996; Hearty, 1997; Hearty et al. 1998; Sheffers, 2002).

In particular, since the lack of more detailed evidence, Bourrouilh – Le Jan and Talandier (1985) suggest that blocks carved by mesolittoral-infralittoral zone at Rangiroa - Tuamotu, SE Pacific - could be ascribed also to catastrophic events as hurricanes. A hydrodynamic approach to determine whether tsunami - or cyclone-generated waves were responsible for the deposition of fields of well-imbricated boulders (up to 290 tonnes in weight) along the coast of Cairns inside the Great Barrier Reef, Australia. was adopted by Nott (1997)

Along the Mediterranean coast, Heck (1947) reports large boulders associated with a tsunami occurred during the great earthquake in 1908 AD at the strait of Messina (Sicily). Dominey–Howes et al. (1998) mention deep water foraminifers as well as several small boulders in the ancient harbour of Falasarna (western Crete) that were most likely moved by a tsunami in the year 1660 AD. According to Mastronuzzi and Sansò (2000) slabs of Pleistocene calcarenites, up to 80 tonnes in weight, were carved and scattered along the Ionian coast of Apulia (southern Italy) up to 1.8 m a.m.s.l. and positioned as much as 40 metres inland; their presence is assumed to be directly related to a tsunami which was most likely caused by a submarine landslide triggered by the 5th of December 1456 earthquake.

Kelletat and Schellmann (2002), indicated that tsunamis occurred on Cyprus island during last few centuries, moved extremely large volumes of coarse clastic material including large boulders weighing over 20 tonnes.

Finally, Pirazzoli & Morhange (pers. comm., 2001) point out the presence of large boulders along the Lebanon coasts.

Field Evidence

Recent survey of boulder accumulations along gently slope rocky coast of the Adriatic coast of southern Apulia point out that major storm can carve slabs of calcarenites and mobilise them on the surf platform. The collated data suggest that large boulders accumulations are to be considered the cumulative effects of several extreme storm waves events superimposed on the earlier effects of one or two tsunami run-up events.

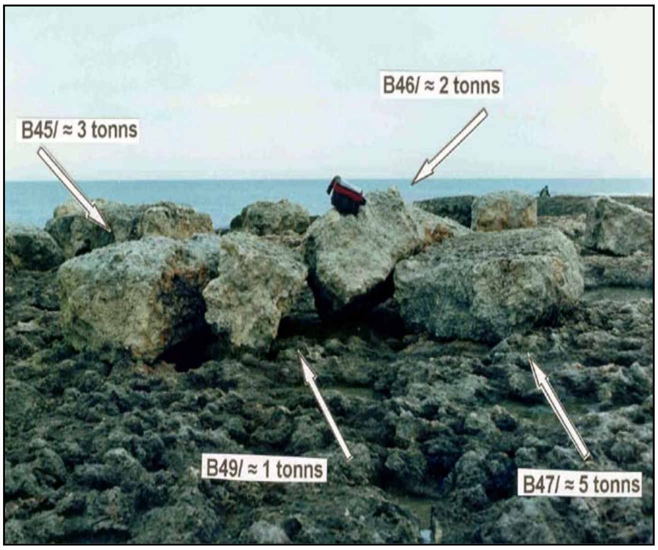

Figure 2. In Torre Santa Sabina locality a row of embricated boulders is formed by tsunami- (B46 and B47) and storm-accumulated boulders (B49 and B45).

In particular, in Santa Sabina locality, between Bari and Brindisi, the 4th of January 2002 a severe sea storm was produced by strong NE winds whose velocity exceeded 30 knots.

The National Wave Measuring Service (*Servizio Ondametrico Nazionale*) buoy at Monopoli, few kilometers to the NW of T.S. Sabina area, recorded waves marked by significant height up to 4.8 m and peak period of 8.3 seconds propagating with N43E direction. These wave statistics indicate this extreme event as among the most severe storms at sea recorded along this coastal area since the ninenties.

During the sea storm one single boulder was detached, transported landward for about 1.6 m and deposited at 0.5 m of altitude. The boulder has triangular shape and weighs 1.4 tonnes. The biogenic colonization present at the base of the boulder indicates that it was carved out from the midlittoral-sublittoral zone, and that it overturned during transportation.

During another storm at sea occurred on the 12th of January 2003 the boulder was moved once again by storm waves with a significant wave height of 4 m and peak period of 9.1 seconds propagating in N49E direction (data from Monopoli buoy/National Wave Measuring Service).

The boulder was transported for about 20 m in NE-SW direction, stopping against an imbricated boulders group; they formed a new poliphasic row with imbricated element on the contrary to the ipothesis that row are made by only one tsunami events. Moreover, in the same locality a row is made by four boulders - weighing up to 8 ton - aged by ^{14}C between 1200±60 conventional years BP and modern age, then shaped by four different extreme events.

Discussion

The research carried out on boulder accumulations on the Adriatic coast of Apulia indicates that certain particular aspects of boulder accumulations such as imbrication, arrangement in groups or rows, etc., are not distinctive of tsunami run-up, given that these features can also be accounted for by the action of storm waves.

Figure 3. The way of the boulders carried away on surf bench by storm wave on January 12th, 2003.

A hydrodynamic approach to determine whether tsunami- or storm-generated waves were responsible for the deposition of boulders accumulation is proposed.

On the basis of wind data recorded during last fifty years by the Aereonautica Militare Italiana metereological stations placed along the Apulian coasts (Termoli, Bari Palese, Brindisi, Leuca, Ginosa marina), major storms which struck the different coastal tracts have been identified. Wave characteristics (wave length, peak period, and so on) related to these major storms have been calculated and mapped for the entire coast of Apulia.

The weight of largest boulders that can be moved by waves induced by the calculated extreme storm waves is deduced for each coastal tracts recurring to formulas widely used for the planning of sea-defences which take into account storm waves characteristics, coastal bottom slope and boulder geometry.

In this way, the presence of boulders weighing more than the calculated value mark out coastal tracts struck by tsunamis or very extreme storm waves.

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