Reply to the Comment on “Lost tsunami by M.T.Pareschi et al.”, by Luigi Vigliotti, Paper doi:10.1039\2007gl031155

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Mt. Etna Holecene tsunami

About 8.3 ka ago a devastating tsunami flooded the coasts of the Eastern Mediterranean Sea [“Lost tsunami” by *Pareschi et al*., 2006c]. That tsunami was triggered by a landslide from the collapse of the eastern flanks of Mt. Etna volcano (Sicily, Italy), in turn inducing: i) a scar on volcano slopes, named Valle del Bove, ii) inland deposits (Chiancone and Milo units), dated > 7.6 – 8.3 ka cal B.P. [*Calvari and Groppelli*, 1996; *Calvari et al.,* 1998], and iii) offshore landslide deposits [*Pareschi et al*., 2006a]. The tsunami had a large impact, effecing southern Italy, western Greece and North Africa (including Tunisia to Libya, Egypt, southern Turkey, Syria, Lebanon and Israel. In Israel the tsunami ravaged the Neolithic village of Atlit-Yam, caused the death of villagers and animals, filling a water well and destroying village huts [*Pareschi et al*., 2006c; 2007]. An early Holocene sea level rise, dated 8,350-8,250 calendar year B.P., matches the timing of the Mt.Etna tsunami, the consequent flooding of coastal areas led to the sudden loss of land favoured by early farmers and initiated an abrupt expansion of activity across Europe [*Turney and Brown,* 2007].

Mt. Etna’s Holocene tsunami occurred during the deposition of Sapropel S1 [*Pareschi et al*., 2007]. Sapropel formation appears to be closely linked with an increased discharge of freshwater from rivers, enhancing water column stability and increasing ocean surface productivity. The resultant decreased ventilation and anoxia improved preservation of C_{org}, which characterizes Sapropel S1 deposits [*Mercone et* *al*., 2000 and ref. therein]. In some cores of the Eastern Mediterranean Sea, the upper stratum of the Sapropel S1 unit reveals oxidation; the black colour of C_{org} is therefore not a reliable means to identifying Sapropel S1 boundaries. Mercone et al. [2000] proposed the combined use of Ba/Al ratio and accelerator mass spectrometry (AMS) radiocarbon data to delimit Sapropel. This information, as also noted by Vigliotti [2007], constrains Sapropel S1 deposition from ~9500 to 6000-5300 ago (uncorrected conventional radiocarbon years B.P.).

Homogenite

Tsunamis are long waves, and their overpressure can liquefy soft marine sediments on marine slopes if maximum tsunami wave heights are high enough [*Pareschi et al*., 2006b]. For example, a tsunami wave of almost 3 m can destabilize soft marine sediments with a cohesion of 1 kPa on 2-degree slopes. Generally, a cohesion from a few to one tenth kPa characterizes pelagic-hemipelagic ooze [*Pareschi et al., 2006b* and references therein]. A volcanic landslide tsunami is expected to have a more severe impact on marine slopes than a tsunami triggered by an earthquake (coseismic tsunami). In the former case, in fact, tsunami waves can be some/several meters high in the open sea, depending on landslide volume and velocity, distance from the source, and sea water depth. In turn, on slopes, tsunami-destabilized pelagic and the hemipelagic sediments generate sediment flows which terminate at local sea floor minima [*Pareschi et al*., 2006c].

Sea floor modifications often record the occurrence of high-wave paleo-tsunamis better than alongshore tsunami deposits. Inland paleotsunami deposits, in particular those adjacent to the coastline, can be difficult to detect because of their similarity to storm deposits and the disturbing/erasing effects related to sea level changes, wave erosion, etc. [*Pareschi et al*., 2006c].

In “Lost tsunami”, Pareschi et al. [2006c] suggests that Mt.Etna’s Holocene tsunami event was the trigger of some seismically-transparent deposits, called “*Homogenite*”, found in pounded (with different feeding systems) basins of the Calabrian and Mediterranean Ridges, and (as megabeds) in the Sirte and Ionian abyssal planes, where they occur as megatubidets [*Kesten and Cita*, 1981; *Cita et al.*, 1996¸ *Hieke and Werner*, 2000].

Homogenite seems to occur above the Sapropel S1 dark layer, also if, in some cores, the basis of *Homogenite* was not reached, and no dating is available to constrain these deposits as due to a single trigger located in late Holocene.

Vigliotti says that, because Mt.Etna landslide dates > 7600 yr. B.P., and the top of Sapropel is youger, Mt. Etna landslide cannot be the trigger of *Homogenite*. However, available dating on Sapropel top boundary refers to cores where *Homogenite* is not present.

Since today, Cita, Camerlenghi and co-workers [*Kasten and Cita*, 1981; *Cita et al.*, 1996; *Cita and Rimoldi*, 2005; *Cita et al*., 2007] have related the *Homogenite* of the Ionian Sea to the 1600 B.C. Santorini volcanic eruption (Santorini Island, South Aegean Sea). However, recently simulated tsunami scenarios [*Pareschi et al*., 2006b] have discounted this hypothesis. Also dozens of cores retrieved from the margin of the Cretan Basin (hundreds of kilometres closer to Santorini Island than to the Ionian cores with *Homogenite*) provide no evidence at all of massive sediment remobilization in relation to the passage of a “Santorini tsunami” [*Anastasakis*, 2007].

On the contrary, numerical simulations described by us in [Pareschi et al., 2006c] show that a 10-25 km^3 landslide from Mt. Etna, entering the Ionian Sea with an initial velocity of 20-100 m/s, would trigger tsunami waves high enough to liquefy soft marine sediments (with a supposed cohesion of 1 kPa) on the slopes of the small closed basins located in the cobblestone topography of the Calabrian and Mediterranean Ridges [*Pareschi et al*., 2006a, 2006c].

Till now, for the *Homogenite* of the Calabrian and Mediterranean Ridges, Cita and co-workers did provide neither general morphological maps with the distribution of cores with *Homogenite*, nor AMS dating of deposits above and below *Homogenite*, or the position of the A.D. 79 Vesuvius volcano ash layer or other ones (G. Zanchetta, personal communication). They also did not discuss the presence of possible Sapropel S1 oxidised layers by means of Ba/Al profiles.

The attribution of *Homogenite* to late Holocene is based on the absence of a visible, black (= not oxidized) S1b layer above *Homogenite* and the presence of a lighter-coloured layer below *Homogenite* and above Sapropel. However its formation is compatible a date in early Holocene, coeval with the Mt. Etna tsunami. A possible explanation is that *Homogenite* oxidized adjacent strata or C_{org} was oxidized in more tsunami-oxygenated waters, etc. Moreover, pelagic *Homogenite* deposits of the cobblestone topography of the Calabrian and Mediterranean Ridges might have a different trigger and dating in respect to the *Homogenite* of the larger megaturbidite beds of the Ionian and Sirte abyssal plains. In fact, these megabeds may have been triggered by more than one event, where some local basal debris flows induced by the Mt.Etna tsunami are in turn covered by a much wider megaturbidite deposit possibly triggered by an earthquake. A megabed of comparable volume to the Ionian megaturbidites was indeed triggered by the 1929 Grand Bank earthquake [*Piper et al.*, 1999].

Again, no dating is available for the deposits [*Reitz et al*., 2006] discussed in Vigliotti's comment, i.e. depositional layers some centimetres in thickness located in the Ionian Sea, that could possibly be correlated with the megaturbidites of the Ionian and Sirte Abyssal Plains (because of an African shallow water provenience inferred by aragonite content).

The 365 A.D. hypothesis

Because there are no constraints on dating, Vigliotti hypothesized that the 365 A.D. earthquake of Crete was the trigger of *Homogenite*. In Vigliotti's scenario, this earthquake triggered a megatsunami which in turn induced the deposition of both: i) the *Homogenite* of the Ionian and Sirte abyssal plain megaturbidites and ii) the *Homogenite* in the cobblestone topography of the Ionian Sea.

We provide three considerations that argue against Vigliotti's hypothesis:

First, numerical simulations by Lorito et al. [2007] show that the tsunami triggered by the 365 A.D. 8.4 M_w earthquake, located in the Hellenic Arc, triggered sub-metric maximum wave heights in the areas of the Calabrian and Mediterranean Ridges, where *Homogenite* is located. This would make it impossible for the 365 A.D. tsunami to induce liquefaction of soft marine sediments. Lorito et al. [2007] estimate that the 365 A.D. tsunami mainly impacted the coasts of Crete and those of North Africa, in agreement with causalities at Alexandria (Egypt) reported by the Roman historian Ammianus Marcellinus in his book *Res gestae libri XXXI*. However, we observe that the high number of causalities mentioned by Ammianus Marcellinus could have been largely overestimated, with uncertainties of one order of magnitude or more, because at that time no sure counting methodologies of causalities were available.

Second, although tens of large co-seismic tsunamis have crossed the Mediterranean in the past centuries [*Guidoboni et al*., 1994; *Guidoboni and Comastri*, 2005; *Lorito et al*., 2007], no multiple seismically transparent layers that would be associated with such events and formation of *Homogenite* are detectable in the cobblestone topography of the Mediterranean and Calabrian Ridges [*Hieke and Werner*, 2000; *Hieke*, 2000].

Third, no field evidence for an A.D. 365 tsunami impacting the Ionian Sea is recorded along the coasts of Western Greece [*Vött et al*., 2007], and no significant sea-level increase, destroying possible tsunami deposits, occurred in the last 2 thousand years [*Pirazzoli*, 2005]. Moreover, the Roman historian Ammianus Marcellinus was still alive and actively writing in A.D. 365. The first sack of Rome by Visigoth Barbarians headed by Alaric occurred half a century later, in A.D. 410. It is improbable that, in his book *Res gestae libri XXXI*, Ammianus Marcellinus would have overlooked a megatsunami which simultaneously impacted all the coasts of the Eastern Mediterranean Basin, including the very populated coasts of eastern Sicily and South Italy. Note that megatsunami waves high enough to liquefy soft marine sediments in the open Ionian sea are expected to induce tsunami run-ups at least 10 m high along all the coasts of Ionian sea.

As a conclusion, neither the 1600 B.C. Santorini tsunami, nor the 365 A.D. tsunami’s were the trigger of the *Homogenite* of the Ionian Sea. In cores where *Homogenite* is present no information is available about: i) dating, ii) volcanic ash layer markers, iii) AMS data, vi) the presence of possible oxidized sapropel S1 layers, or v) a sure temporal correlations among *Homogenites* of different sites. In the future, we hope that new cores will be collected across the Ionian sea to constrain the problem with improved field data. Given that, in Pareschi et al. [2006], we demonstrate by numerical simulations that the 8.3 ka ago Mt. Etna tsunami was a very plausible trigger of *Homogenite* in the basins of the Calabrian and Mediterranean Ridges.

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