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Paper to be presented at UNESCO-IGCP-659 session

## The AD 365 Crete earthquake/tsunami submarine impact in the Mediterranean region

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**Abstract.** The Calabrian and Hellenic subduction systems accommodate Africa Eurasia plate convergence in the Mediterranean Sea and are site of large earthquakes in the forearc region facing the northern African coasts. Some of the historical earthquakes were associated with the generation of tsunami waves affecting the entire Mediterranean basin. We investigated the submarine effects of the AD 365 Crete earthquake on the sedimentary record through the integrated analysis of geophysical data, turbidite deposits, and tsunami modeling. Seismic reflection images show that some turbidite beds are thick and marked by acoustic transparent layers at their top. Radiometric dating of the most recent of such megabeds, the Homogenite/Augias turbidite (HAT), provide evidence for synchronous basin-wide sedimentation during a catastrophic event which occurred in the time window AD 364–415, consistent with the AD 365 Mw = 8.3–8.5 Crete earthquake/tsunamis. The HAT (up to 25 m thick) contains components from different sources, implying remobilization of material from areas very far from the epicenter. Utilizing the expanded stratigraphy of the HAT, and the heterogeneity of the sediment sources of the Mediterranean margins, we reconstructed the relative contribution of the Italian, Malta and Africa margins to the turbidite deposition. Our sedimentological reconstructions combined with tsunami modelling suggest that the tsunami following the Crete earthquake produced giant turbidity currents along a front over 2000 km long, from northern Africa to Italy. Our cores suggest that during the last 15,000 yrs only two similar turbidites have been deposited in the deep basins, pointing to a large recurrence time of such extreme sedimentary events.

**Keywords:** AD 365 Crete earthquake, tsunami, slope failures, seismo-turbidite, tsunami modeling.

## 36 **1 Introduction**

37 Extreme submarine geo-hazards, such as strong earthquakes and tsunamis, have re-  
 38 peatedly affected the Mediterranean regions. A record of these past events can be  
 39 provided by large-volume turbidites in the marine sedimentary record as the result of  
 40 catastrophic failure of submarine slopes. The central Mediterranean Sea is located  
 41 between the Calabrian and Hellenic subduction systems that were struck repeatedly  
 42 by strong tsunamigenic earthquakes [1]. During the late Quaternary turbidite deposi-  
 43 tion dominates in the deep basins, where earthquake-triggered mass flows deposits  
 44 represent more than 90% of the total sedimentation during historical times [2,3]. Some  
 45 of the turbidites are up to 20 m thick and marked by the acoustic transparency of the  
 46 upper mud layer in the seismic sections. The most recent of these mega-beds, the  
 47 Homogenite/Augias turbidite (HAT) is observed over a wide area of the Central and  
 48 Eastern Mediterranean Sea. The original hypothesis attributed the HAT to the 3500 yr  
 49 BP Minoan eruption of Santorini and related tsunamis [4]. However, the turbidite  
 50 composition and structure, as well as radiometric dating and age modeling, revealed  
 51 that it was not triggered by the Santorini event but by the later AD 365 Crete earth-  
 52 quake/tsunami [3,5]. We present the analysis of seven sediment cores containing the  
 53 complete record of the HAT in different physiographic and oceanographic settings  
 54 including basins offshore Africa. Sedimentology was integrated by tsunami modelling  
 55 to verify the possible role of tsunami propagation and impact on the coastal regions in  
 56 the destabilization of continental slopes.

## 57 **2 Materials and Methods**

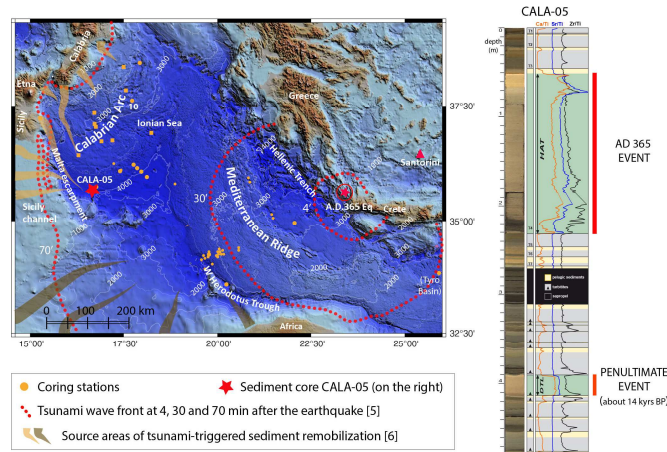
58 Our high-resolution study combines the interpretation of seismic reflection profiles,  
 59 multibeam data and the analyses of sediment cores. Cores were collected with a 1.2 t  
 60 gravity corer and a 2.3 t piston corer. The cores were analyzed through a multi-proxy  
 61 approach involving X-ray images, texture, geochemistry, organic matter, micropale-  
 62 ontology and mineralogical analyses. Results of radiometric dating obtained from  
 63 pelagic sediments interbedded between re-sedimented deposits were used to define an  
 64 age model and a chronological framework.

## 65 **3 Results**

66 Seismic reflection profiles show that the megabed is present in many different basins  
 67 of the Central-Eastern Mediterranean Sea. These range from the 4,000 m deep abyssal  
 68 plain to shallower slope basins, including the Calabrian Arc and the Mediterranean  
 69 Ridge, the Tyro Basin SE of Crete and the Western Herodotus trough offshore Cyre-  
 70 naica (Fig.1). The thickness of the turbidite varies between 0.1 to more than 25 m in  
 71 the different basins.

72 Radiometric ages obtained from pelagic sediments deposited after the cata-  
 73 strophic event suggest that all the turbidites collected in different physiographic set-  
 74 tings were deposited synchronously in the time window AD 364–415. Sedimentology  
 75 and geochemistry of the cores identified different turbidite units whose composition

76 widely varies as confirmed by geochemical analyses. Further micropaleontological  
 77 and mineralogical analyses suggest that the sediment sources are compatible with  
 78 Greece, the Malta escarpment, Southern Italy, and Africa.



79 **Fig. 1.** a) Shaded relief map of topography/bathymetry of the central and eastern Mediterranean Sea. b) Photograph of sediment core CALA-05 with sedimentary facies and major XRF  
 80 geochemical elements. Modified from [6]  
 81  
 82  
 83

84 Tsunami modelling allows verifying a possible correlation between tsunami  
 85 propagation and the generation of turbidity currents. Starting from some reasonable  
 86 hypothesis for the parent fault of the 365 earthquake [5], numerical simulations of the  
 87 tsunami propagation help deduce the main paths of tsunami energy focussing, and  
 88 quantifying the spatial distribution of the extreme particle velocities. The latter can be  
 89 used to estimate the shear stresses induced by the tsunami on the ocean bottom and  
 90 along the coastal regions, providing a rough estimation of the destabilisation and  
 91 transport power of the tsunami waves and currents.

## 92 4 Discussion

93 The HAT was triggered by an event taking place in the time window AD 364-  
 94 415 which was capable of initiating simultaneously sediment transport in widely separated  
 95 sedimentary basins. The lithology, structure and regional occurrence of the  
 96 megabed place the triggering mechanism within narrow constraints: it affected every  
 97 basin of the Central Mediterranean and its provenance varied in different parts of the  
 98 basin margins. The only historical earthquake potentially capable of generating such  
 99 devastating effects from Greece to the African margins during the given time interval,  
 100 is the exceptionally strong Crete 365 AD earthquake.

101 The  $M=8.3-8.5$  AD 365 Crete earthquake [5] occurred on a major reverse  
 102 fault, dipping beneath Crete. Seismic shaking from this earthquake, although excep-  
 103 tional, was probably unable to triggering mass movements 700 km from the epicenter,  
 104 in flat and stable areas of the Sicily Channel and Africa continental shelves. The areal

extent of the megabed as shown by our radiometric dating supports the hypothesis that it was the tsunami following the Crete earthquake that triggered giant turbidity currents (Fig. 1). The 365 AD Crete tsunami wave caused local reworking during its transit towards West. When the tsunami hit the shallow continental shelves of Italy and Africa triggered gigantic turbidity flows that transported shallow water detritus to the deep basins along a front from Calabria to Africa. The magnitude of the parent earthquake and the extent of the ensuing tsunami impact make this event comparable, at least as a first approximation, to more recent giant subduction-zone earthquake-generated tsunamis (2004 Sumatra and 2011 Tohoku-Oki), whose effects as regards sediment mobilization can then be used as terms of comparison for our investigations.

## 5 Conclusions

The earthquake and tsunami of 21 July 365 AD have stimulated discussions between historians, archaeologists and geophysicists mainly because historical records are not always concordant in chronology and extent of reported damages. However, an unusual event with magnitude  $> 8.5$  was proposed [7] with a tsunami spread across the Mediterranean Sea [5,8]. The detailed sedimentological and chronostratigraphic analysis of deep-sea cores allow to reconstruct sedimentary processes that generated the deposit. Our results suggest that the HAT deposition was related to multiple turbidity currents triggered by the tsunami waves hitting the continental shelves of Italy, Malta and Africa along the continental margins for more than 2000 km.

The synchronous deposition of the HAT over an area larger than 150,000 km<sup>2</sup> implies an exceptional event triggering catastrophic failure of submarine slopes in the Mediterranean Sea basins including the African coasts.

## References

1. Maramai A., et al. The Euro-Mediterranean Tsunami Catalogue. *Annals of Geophysics*, v.57, n. 4 (2014)
2. Polonia et al., Turbidite paleoseismology in the Calabrian Arc Subduction Complex (Ionian Sea). *Geochemistry Geophysics Geosystems*, v.14, p.112-140 (2013a).
3. Polonia, A. et al. Mediterranean megaturbidite triggered by the AD 365 Crete earthquake and tsunami: Scientific Reports, 3, Article number 1285, doi:10.1038/srep01285 (2013b).
4. Kastens, K.A. & Cita, M.B. Tsunami-induced sediment transport in the abyssal Mediterranean Sea. *Geol. Soc. Am. Bull.* **92**, I, 845–857 (1981).
5. Shaw et al., Eastern Mediterranean tectonics and tsunami hazard inferred from the AD 365 earthquake. *Nat. Geosci.* **1**, 268 – 276 (2008).
6. Polonia A., et al. Did the AD 365 Crete earthquake/tsunami trigger synchronous giant turbidity currents in the Mediterranean Sea? *Geology*, DOI: 10.1130/G37486.1 (2016).
7. Stiros, S.C., The 8.5+ magnitude, AD365 earthquake in Crete: Coastal uplift, topography changes, archaeological and historical signature: *Quaternary International*, v. 216, no. 1, p. 54–63 (2010).
8. Tinti S., et al. Scenarios of giant tsunamis of tectonic origin in the Mediterranean. *ISET Journal of Earthquake Technology*, v. 42, n. 4, p. 171-188 (2005).