Mediterranean Archaeology and Archaeometry, Vol. 6, No 1, pp. 61-88

NATURAL CATASTROPHES IN THE GREEK AND ROMAN WORLD: LOSS OR GAIN? FOUR CASES OF SEAQUAKE-GENERATED *TSUNAMIS*[1]

Manolis I. Stefanakis

Lecturer in Classical Archaeology,
Dept. of Mediterranean Studies,
University of the Aegean

e-mail: stefanakis@rhodes.aegean.gr

Received: 25-2-2006
Accepted: 18-5-2006

ABSTRACT

The question set by this paper is whether the impact of natural catastrophes on civilizations is twinfold: very much a loss for the victims who suffered as a result of the destruction, but a gain, an advantage, for later generations and modern sciences. I concentrate on a certain series of catastrophes, caused by the sudden, geologically-related, calamity, the seaquake-generated wave, known as *tsunami*, from the early Classical period to late antiquity. Four *tsunami* events will be examined here, in 479 BC at Potidaia, in 373 B.C. in the Corinthian Golf, the 66 and in 365 AD at Phalasarna.

KEY-WORDS: Natural catastrophes, *tsunamis*, Phalasarna, Heliki, Potidaia.

INTRODUCTION

Among geological sudden calamities,[2] seismic activity (earthquakes or seaquakes), comes first. A great number of earthquakes have taken place in the eastern Mediterranean caused by repeated collisions between the African, the Eurasian and several smaller plates.[3] In many cases such seismic activities cause large areas of the sea floor at plate boundaries to rise or subside, disturbing the water above, thus generating *tsunami*.[4] In coastal areas the height of *tsunamis* can reach 9 meters or more, and they can move inland several hundred meters with great force causing losses in property and life. They also cause rapid

changes in water level and unpredictable dangerous currents in harbours.[5]

The inhabitants of Mediterranean coastal areas have suffered a lot by the impact of *tsunamis*.[6] Greece and surrounding areas have experienced about seventy major *tsunamis* since 479 BC.[7] The coastal and surrounding areas of Turkey have been affected by more than ninety *tsunamis* during a period of 3000 years,[8] Italy has been affected by seventy major *tsunamis* during the last 900 years,[9] and Cyprus and eastern Mediterranean by quite a few.[10]

The oldest, both legendary and archaeologically attested *tsunami* in the Aegean, caused by the major eruption of Thera and the collapse of a mountain into a caldera, 15 km in diameter, is assumed, by many, to have destroyed the entire Minoan fleet as far away as Crete (105 km). At its source the wave was estimated in excess of 46 m high. The *tsunami* is assumed to have also destroyed ships and killed many inhabitants along the shorelines in Asia Minor and the eastern Mediterranean area.[11]

In the historical era many more such natural catastrophes have been reported by ancient sources.[12] Four cases from the Greek and Roman era will be examined here, one dating in the early classical period, one in the late classical and two in the Roman imperial period. The perception of them by contemporary civilizations and their consequences will be examined, while their impact, then and today, will be evaluated.

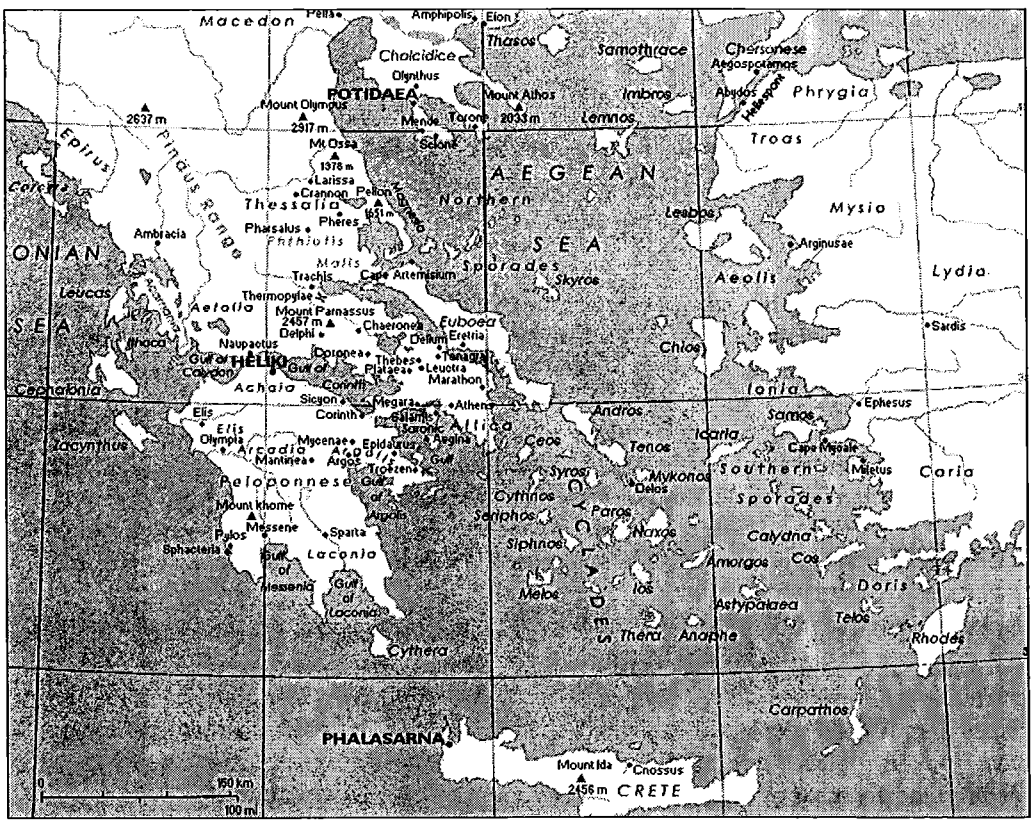

Fig. 1 Map of eastern Mediterranean.

FOUR CASES OF MAJOR *TSUNAMIS* IN THE GREEK AND ROMAN ERA IN THE MEDITERRANEAN

CASE 1: POTIDAIA, 479 BC.

Event evaluation:[13]
Submarine earthquake
Seismic intensity in MM: **7.0**
Surface-wave magnitude: **unknown**
Focal depth (in km): **shallow**[14]
Tsunami intensity (in Ambrasey's 1962 scale): **3**
Reliability of the *tsunami* event: **3**
Tsunami magnitude (in the Murty-Loomis scale): **3**

The facts

The *tsunami* at Potidaia, Chalcidike, in northern Greece **(fig. 1)** in 479 BC, is the world's oldest reliably known/historically attested *tsunami* in history.[15]

The result

The Persian army, under the command of Artabazos, suffered a major catastrophe.[16]

The ancient perception

We know from Herodotus[17] that after the naval battle of Salamis, Xerxes departed for Persia, leaving behind Mardonios, who would spend the winter in Thessaly and would re-invade Attica next spring. Artabazos with an army of 60,000 men escorted Xerxes up to Sestos. On his way back to Thessaly he stopped over in the Chalcidike in order to bring over the Persian side, again, the rebel cities of Potidaia and Olynthos. Potidaia resisted for 3 months and did not surrender. Only Olynthos was taken by force and all its people were put to knife by the Persians.[18]

«*After 3 months of siege of Potidaia*», narrates Herodotus, «*a noticeable withdrawal of the sea was observed, which lasted for many hours. As soon as the Persians saw the sea becoming shallow, they started crossing the area to get over to Pallene. But they did not had enough time, because having crossed only the 2 fifths of the distance, the sea flooded back, in a way that nobody had ever witnessed before, although tides were usual in the area. Of the Persians, those who could not swim, were drowning, and those who could swim were killed by the Potidaians, who retaliated from vessels. And the inhabitants of Poteidaia said that the cause of this sea flood and the loss of Persians was the asebeia of the Barbarians, who commited sacrilege against the temple and the statue of Poseidon outside the city*».[19]

It is very important to note here that the *tsunami* was not at all bad for the Greeks, or at least is not reported as such. Not only were the Greeks accustomed to such natural tidal phenomenon, but the Persians, and their king Xerxes in particular, who had been very disrespectful of Greek religion and temples during his campaign, deserved to be destroyed anyway. Therefore it was very natural and a matter of time not only for him, but for his army too, to be punished by the gods with some natural catastrophe.[20]

Losses and gains

The *tsunami*, in 479 BC was definitetly a huge loss for the Persians themselves, since within a few hours they lost many souls and an important battle. It was also perceived as a «curse», by the Greeks; But the «curse» was not on them but on the Persians, who in the eyes of the Greeks, evoked it with their nasty behaviour and the sacrilege of the temple of Poseidon.[21] But does Herodotus give a reasonable picture? He often, as we know, explained natural catastrophes through their result and not looking for the generative causes of the phenomenon itself.

Therefore he justified each catastrophe by referring to the «will of a god» behind it, who acts to the benefit of the Greeks and against the Persians.[22]

The *tsunami* was perceived as a «blessing» only by the Greek side, and first of all by the Poteidaeans, who, after a three-month siege, were unexpectedly saved from it, and were even given the chance to win the battle. It was definitely a gain for contemporary Greeks in general in many ways:

It was an event that strengthened their self-esteem and their belief in the gods, since they saw what they believed to be «miracle of divine vengeance» in response to the sacrilege of the Persians.[23] From a political point of view, this was also one more blow against the already damaged power of the Persians in Greece, and an important Persian loss before the final encounter at Plataia the next Spring. Artabazos, who returned from Sestos with 60,000 men[24] ended up with 40,000 men at Plataia,[25] part of the loss probably to be blaimed upon the *tsunami* at Potidaia.

CASE 2: CORINTHIAN GULF, 373 BC[26]

Event evaluation:[27]
Submarine earthquake
Seismic intensity in MM: **9±1**
Surface-wave magnitude: **6.6+**
Focal depth (in km): **15-**
Tsunami intensity (in Ambrasey's 1962 scale): **5**
Reliability of the *tsunami* event: **4**
Tsunami magnitude (in the Murty-Loomis scale): **4**

The Fact

During a night in winter 373 BC a catastrophic earthquake shook the western Corinthian Gulf and a destructive sea inundation submerged Helike, a major city of Achaia, and Bura on the southwest shore of the Gulf of Corinth, Greece **(fig. 1)**. After the earthquake drowned Helike, the submerged delta became dry land again, because of the deposition of river sediments and local tectonic uplift.[28]

The Result

A large area was destroyed by the strong earthquake, submerged because of ground failure and coastal subsidence and inundated by a high *tsunami*, leading to total loss of the cities of Helike and Boura.

The ancient perception

Ancient sources describe the destruction quite vividly[29]:

In the late 1st century BC or the early 1st century AD, *Strabo* (63/4 BC - c. AD 24), citing the earlier *Eratosthenes* (276-194 BC), who had visited the destroyed site of Helike and the even earlier *Herakleides* (390-322 BC), whose generation lived during the destruction, mentions the *tsunami* following the tectonic earthquake: «*...Herakleides states that the distruction took place at night, in his time and, although the city was twelve stadia [2 km] distant from the sea-shore, the whole area, together with the city disappeared; and two thousand men, who were sent by the Achaeans, were unable to recover the corpses...the destruction was a result of the anger of Poseidon...*».[30]

Pausanias, who visited the site in the second half of the 2nd century AD wrote: «*...This was the type of earthquake that overturns the ground, and together with that, they say, another disaster happened to Helike in the winter: namely, the sea surged against a great part of the land and encircled the whole of Helike. And the flood so covered the grove of Poseidon that only the tops of the trees remained visible. Because when the god suddenly quaked, the sea*

advanced together with the earthquake, and the wave dragged down Helike with its entire people. The ruins of Helike are also visible, but not so plainly now as they were once, because they are corroded by the salt water».[31]

Diodoros of Sicily in the first century BC wrote: «*The blow came at night, so that... the majority who were caught in the houses was lost, and when day came some dashed from the ruins and, when they thought they had escaped the danger, met with a greater and still more incredible disaster. For the sea and the wave rose to a vast height, and as a result all the inhabitants together with their land were inundated and disappeared. Two cities in Achaea bore the brunt of this disaster, Helike and Boura. Before the earthquake Helike was the mightest among the cities of Achaea.*»[32]

Roman writers Ovid (43 BC-17 AD)[33] and Pliny,[34] commermorate the event, while according to Aelian (170-235 AD): «*...an earthquake occurred at night, the city subsided and a huge sea-wave flooded the area and Helike disappeared, while ten Spartan boats, which happened to be at anchor, were lost together with the city*».[35]

Ancient (mainly late Hellenistic and Roman) writers were well aware of the subsidence that can be caused by an earthquake and the tidal wave that follows a seaquake, while both the description of the land subsidence and the high *tsunami*, which completed the covering of the site with seawater, are quite vivid. According to tradition, the ten Spartan ships sunk along with the city of Helike, which seemed a minor incident against the disaster, that had engulfed the open country and cities. The area was so inaccessible that two thousand men, sent as a gesture of humanitarian assistance to the suffering territory by the Achaeans, were unable to offer any help, not even to recover the dead bodies.

The archaeological evidence

According to the excavators, research in the coastal plain between the Selinous and Kerynites Rivers, 1 km inland from the present shore, at Rizomylos, has uncovered remains of classical buildings buried under thick lagoonal deposits. The research reveals evidence of destruction by an earthquake, dated, on the basis of associated pottery and other finds, to the first quarter of the fourth century B.C. The remaining corner of one building showed one of its walls thrown down in the seaward direction, consistent with destruction by the backwash from a *tsunami*. The site is buried in strata containing brackish water microfauna, indicating that it was long covered by the waters of an inland lagoon. Thus the city did not sink into the depths of the Corinthian Gulf, as previously believed, but was submerged by an inland lagoon, which later silted over. This appears to explain the ancient reports that the ruins of Helike were long visible under water.[36]

Losses and gains

A very important point, mentioned by almost all the sources, is the religious explanation of the incident, according to which the catastrophe was something more or less expected, since the Acheans had acted with *hybris* and *asebeia* against the will of god Poseidon, who is also the master of the Sea and the earthquake.[37] «*The elimination was a godly action...for they did not respect the gods...*» narrates Diodorus.[38] According to tradition, Helikians, because of an old enmity, slaughtered the Ionians, who had arrived in their city and sacrificed at the altar of Helikonian Poseidon. «*Because of that*» carries on Diodorus, «*Poseidon, they say, got very upset and avenged the disrespectful cities with earthquake and cataclysm, and that*

this disaster was done by Poseidon there is evidence since this god is the master of earthquakes and cataclysms».[39]

The destruction of Helike was a huge loss for its people: the vast majority of its population was inundated and disappeared with the city and the temple of Helikonian Poseidon. The event was bad even for the distant Spartans since ten of their ship happened to be in port at Helike at that time.

The only benefit, that one may consider due to this disaster is for modern archaeology. Ancient accounts give the impression that the submerged ruins of Helike were never salvaged, quarried or looted and therefore modern archaeology, may bring to light a site that could have much to offer to our knowledge about classical antiquity.

PHALASARNA, WESTERN CRETE[40]

Two major earthquakes generated *tsunamis* that hit the western coast of Crete in the 1st and 4th centuries AD. The archaeological site of Phalasarna on the western extremity of Crete **(fig. 1)** remains the best witness to both those catastrophes.

CASE 3: 1ST SEAQUAKE-INDUCED *TSUNAMI*, WEST OF CRETE, 66 AD.

Event evaluation[41]
Submarine earthquake
Seismic intensity in MM: **8+**[42]
Surface-wave magnitude: **6.0+**
Focal depth (in km): **shallow**[43]
Tsunami intensity (in Ambrasey's 1962 scale): **3**
Reliability of the *tsunami* event: **4**
Tsunami magnitude (in the Murty-Loomis scale): **unknown**

The fact

In AD 66, a large-scale seaquake took place and a *tsunami* was generated in the area of western Crete.[44]

The Result

Phalasarna was affected and its already blocked harbour was further silted by washed off terrestrial sediments. Building ruins swept out and deposited in the harbour.

The ancient perception

Philostratus (ca 200 AD), in his *Life of Apollonius*, speaks about the Temple of Aesculapius at Lebena, in the South-central Crete, where, *«while Apollonius and many of the priests of the shrine were discussing,*

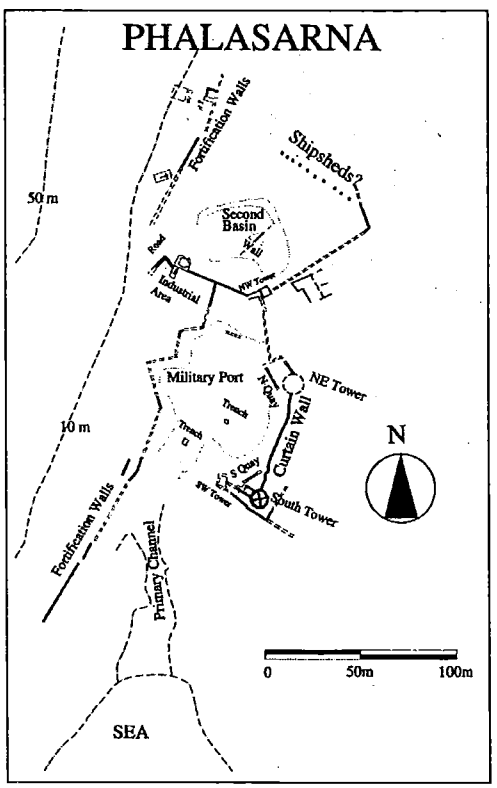

Fig. 2 Phalasarna: Plan of ancient harbour (after Hadjidaki and Iniotakis 2000, 61, Fig. 2).

around noon, a strong earthquake shook the whole island followed by a strong noise coming from the earth and the sea retreated 7 stadia (ca. 1,2 km)... Some days later people arriving from Kydonia (in Western Crete) announced that at that day, around noon, an isle arose from the sea between Thera and Crete.»[45]

It is also reported in *Suda* (10th cent. AD) that «...*during the reign of Claudius Ceasar, Crete was severely affected by an earthquake, during which many tombs were opened...*» and it was then that from a tomb came out a copper box containing the works of Diktys of Crete, on the Trojan War.[46]

The archaeological evidence

At Phalasarna (**fig. 2**) the excavation test-trenches in the main channel and in the middle of the harbour have provided very useful information, not only as to the depth of the harbour entrance and lagoon,[47] but mainly on its political and geological history.

The Hellenistic prosperity of Phalasarna did not last long. It appears to have come to an abrupt end, caused most probably by the Romans, in 68 B.C., during the expedition of Metellus to crack down on piracy in the Mediterranean. Evidence of such destruction and more specifically of the blockage of the channel that led to the port was found during the excavation of the channel trench in 1987 (**fig. 3**). It is probable that Metellus, before attacking Kydonia, destroyed Phalasarna, rendering its port useless, so that he would not leave a hostile harbour at his rear, at a distance of less than one day sail, an act which was consistent with the practice of Romans to punish their enemies with an individual destruction, at the beginning of an expedition, in order to discourage future resistance. After the destruction, the traces of re-habitation of the site are meagre, since the harbour, which

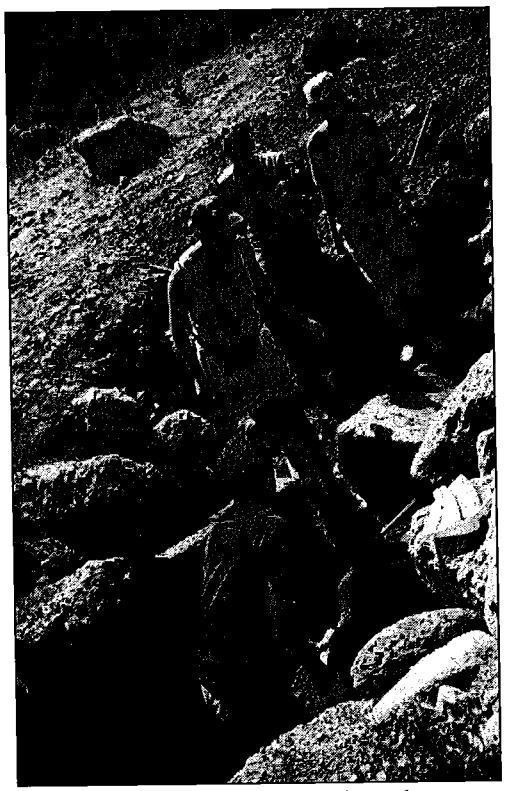

Fig. 3 Phalasarna: Channel trench.

was an element of vital importance for the city, was unusable.[48]

Ever since, Phalasarna appears to be forgotten. Therefore the port was definitely not operational in the era of Dionysius of Kalliphon, Ptolemaeus, or Strabo, who commemorate her port in their works. That shows that many geographical and topographical accounts written during Roman era used to borrow information from earlier sources, without bringing them up to date.[49]

The harbour trench helped in understanding the process of harbour silting thereafter (**fig. 4**). The silting of the harbour started gradually, shortly after the blocking of its entry, as shown by the concentration of deeper water species *Cerastoderma Glaucum* (**fig. 5**) at a stratum lying 20 cm above today's sea level.

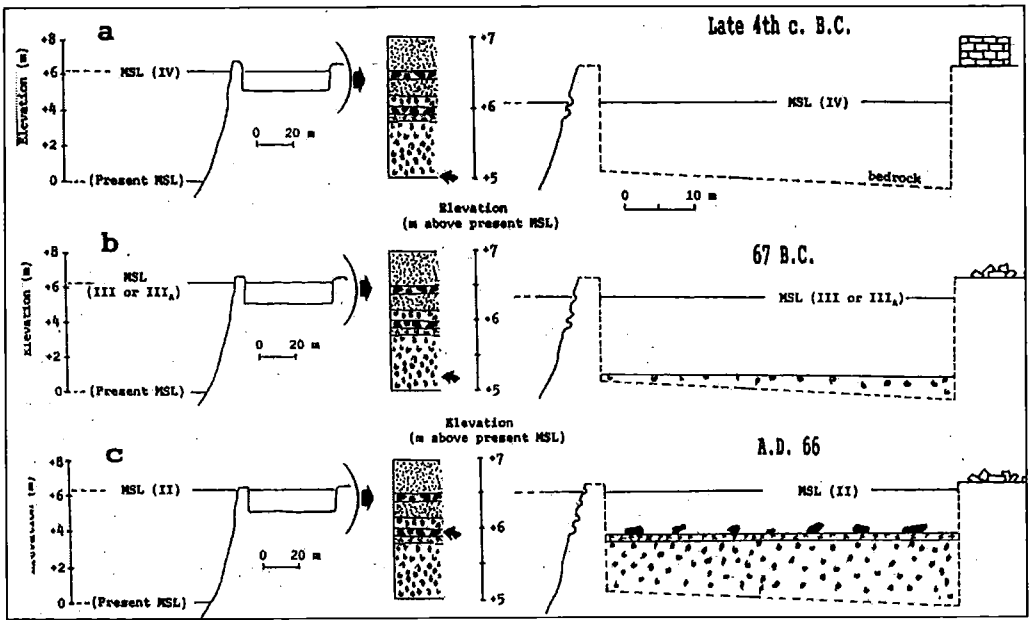

Fig. 4 Phalasarna: silting of the harbrour from the 4th cent. BC, until 66 A.D. (after Pirazzoli *et al.* 1992, 388, fig. 8a).

Radiocarbon dating gave dates between 41 BC and 145 AD for its formation. Above this stratum, a deposition of terrestrial sediments, debris and rounded blocks of stone, washed from the surrounding area of the city, forms a distinctive layer, at +5,70-+5,90 m above sea level, showing the arrival of a *tsunami*, probably the one that hit Phalasarna after the tectonic seaquake of 66 AD. Some 20 cm higher, on top of the *tsunami* sediments, a layer containing *Hydrobia Acuta*, dated between 54 BC and 137 AD, verify that the stratum beneath originates from the 66 AD *tsunami*.[50]

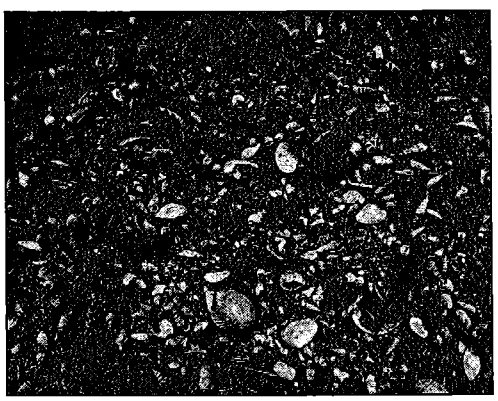

Fig. 5 Phalasarna: harbour trench, deep sea deposits (foto: Kretiko Panorama).

From +6.0m up and for about 15cm, marine sediments carry on, denoting that sea-water was still coming in the harbour. Soon, however, before 169 AD, the harbour entrance was completely blocked and only occassionally stormy sea waves would enter the silted harbor.[51]

Losses and gains

In the case of Phalasarna in particular, no damage to the city is mentioned by any ancient source, with respect to the two intense earthquakes and the *tsunami* strikes.

That seems correct since excavational evidence and geological studies have proved that by the time of the great earthquake the

earlier famous closed port of the city was blocked, abandoned and eventually silted. The *tsunami* wave, however, completed the destructions Romans had already done to the city, since, during its violent withdrawal, the wave swept anything left on the land and dropped it into the harbour basin, thus removing all the remains from the site and completing the silting of the harbour.

CASE 4: 2ND EARTHQUAKE-INDUCED *TSUNAMI*, SOUTHWEST OF CRETE, 21ST JULY, 365 AD.

Event evaluation[52]
Submarine earthquake
Seismic intensity in MM: **10**[53]
Surface-wave magnitude: **8**
Focal depth (in km): **shallow**[54]
Tsunami intensity (in Ambrasey's 1962 scale): **5**[55]
Reliability of the *tsunami* event: **unknown**
Tsunami magnitude (in the Murty-Loomis scale): **unknown**

The fact

A powerful tectonic seaquake took place during the night on the 21st of July 365 AD, a result of the crashing of the African tectonic plate with the Eurasian tectonic plate and the sinking of the former under the latter, westwards of Crete; it is reported by many ancient sources. According to seismic studies on Crete and Antikythera, the epicentre of the seaquake was between the SW edge of Crete and the Hellenic trench.[56]

The result

After the earthquake a huge *tsunami* was generated, the biggest reported in and near Greece, claiming thousands of lives and causing widespread devastation in various parts of eastern Mediterranean from Sicily, the Ionian Islands, Epidamnus in the Adriatic, the southern Peloponnese, west and south Crete, Alexandria in the Nile Delta. Destructions from the same event are referred in North Africa areas such as Leptis Magna, Oea and Sabartha.[57]

Many Cretan cities were destroyed.[58] The harbour of Phalasarna was transformed into a piece of dry land due to the raising of the western coast of Crete by 6,4 to 9 meters above sea level (**fig. 6**) within a day[59] and deposited the last ruins at the site, with other terrestrial sediments and rubble in the harbour basin.

The ancient perception

Even though there are no ancient sources referring to the distruction of the area of Phalasarna, the great earthquake and the *tsunami* that followed have been reported by various authors. The most fascinating report is that of Ammianus Marcelinus (ca. 330-na 392) who witnessed the destruction. He describes it as a catastrophe «*...similar to which cannot be found neither in the legends, nor in real history.... ?he sea retreated and the water was drown back so far that the bottom of the sea was exposed. Anyone could see that way stuck in the mud many creatures of the water and many sea mountains and gorges, which earlier were completely covered by water, but now became visible as the sun beams were lighting them for first time ever.*

Many boats were lying on the seabed and many people were wandering around the shallow waters that were left, collecting fish and other sea creatures, but the sea waves returned, very tall, and rushed over the shallow waters on the islands and lowlands, razing to ground many buildings or anything that would be on their way. Tremendous amounts of water killed in their return many thousands of people.

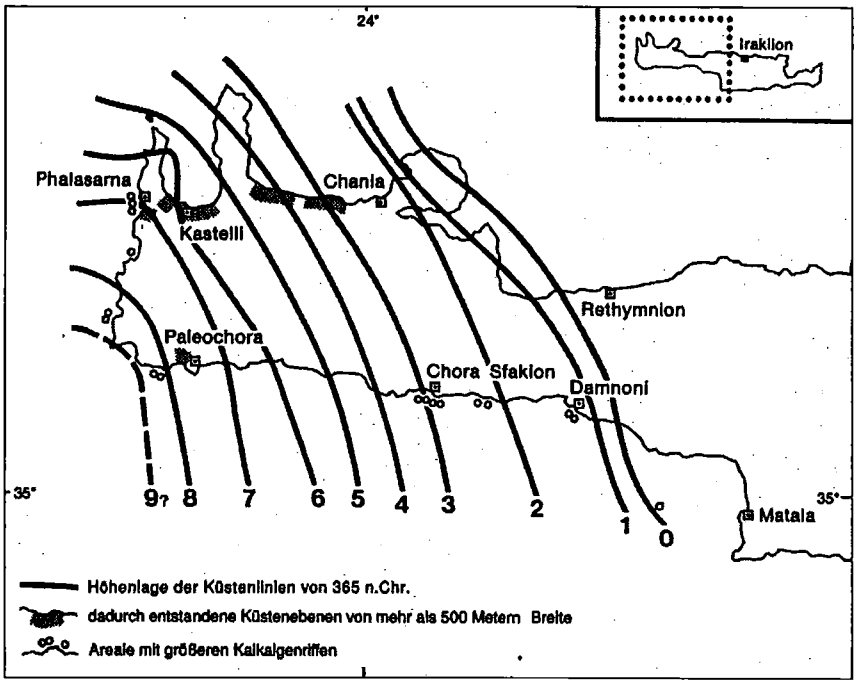

Fig. 6 Elevation of western Crete (after Kelletat 1991).

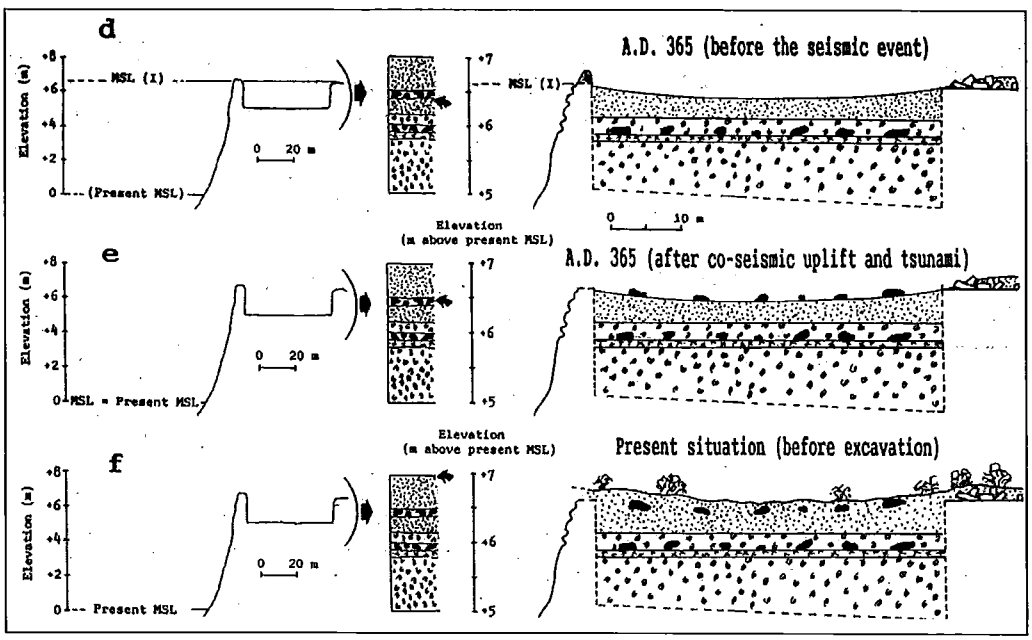

Fig. 7 Phalasarna: silting of the harbrour from 365 A.D. until present (after Pirazzoli *et al.* 1992, 389, fig. 8b).

And when the rage of water stopped, some destroyed vessels came to sight and the corpses of shipwreckers. Some big boats were thrown by the waves over the roofs of houses, as happened in Alexandria, and other were dashed over a distance of two miles inland...».[60]

The archaeological evidence

Seismic research and radiocarbon analysis at the harbour of Phalasarna date the incident to 1530 (± 40) years before today, that is to say, with all reservations, in 365 AD.[61] Latest research however, on the western Crete uplift, focusing on the Sphakia shoreline, has produced a date between AD 480 and 550, making possible that the major uplift has not been detected in archaeological record.[62]

This *tsunami* is probably responsible for the upper –second– layer of blocks in the stratigraphy of the sediments at +6,4-+6,7 m., in the harbour area (**fig. 7**), it does not however seem to have entered further into the town. Although the 365 AD *tsunami* was stronger than the 66 AD one, its effects were relatively limited in the Phalasarna sediment stratigraphy.[63] This has been assumed to happen, if the same seismotectonic movement that generated the *tsunami* had also uplifted western Crete. If that assumption is correct then the Phalasarnian coast was already uplifted 6.6 m (**fig. 8**) shortly before the *tsunami* hit the coast.[64]

Losses and gains

Like the earlier tsunami and from the point of loss of lives, properties and monuments, the calamity that stroke Phalasara in 365 AD had even less destruction to cause and cannot therefore fall within the category of catastrophes and losses for the site in question.[65] Thus the only true loss for the Phalasarnians was the Roman destruction, while the natural disasters that followed in the next centuries only added to the site's disturbance, leaving to us today an even more disturbed site to search, excavate and study, making archaeological research much more complicated.

On the other hand, the natural catastrophe of that time became a «blessing» for modern archaeology since the uplift of western Crete coast by 6-9

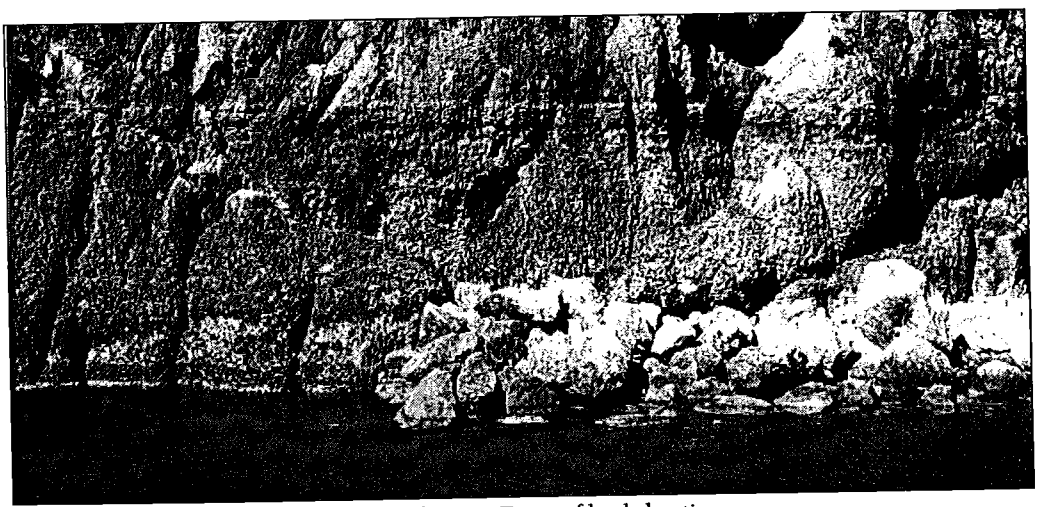

Fig. 8 Phalasarna: Traces of land elevation.

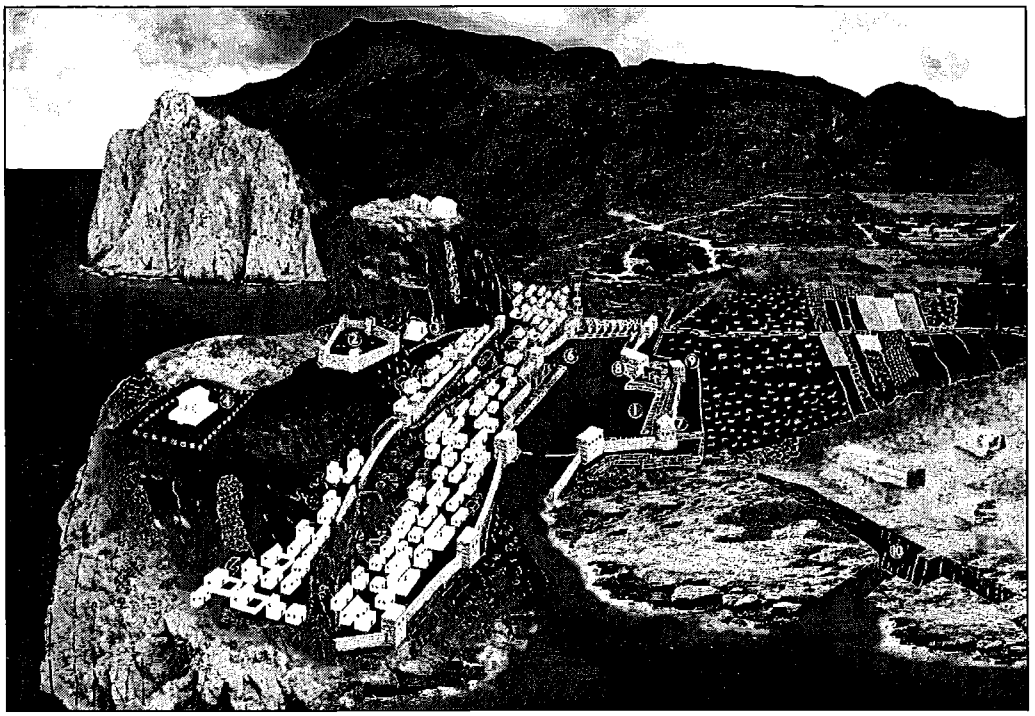

Fig. 9 Reconstruction of ancient Phalasarna (graphics: Kretiko Panorama).

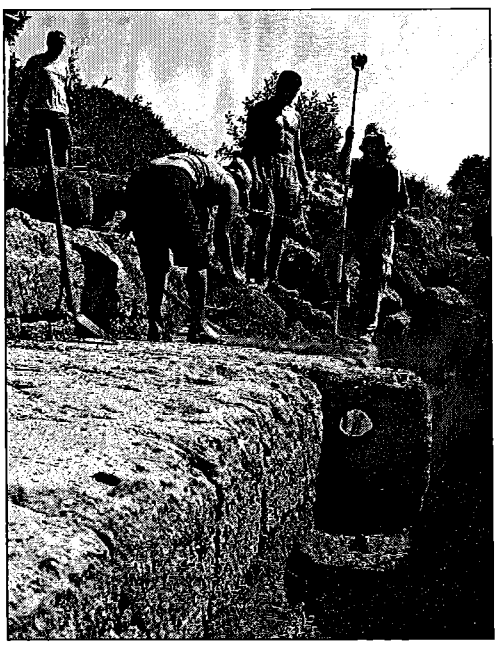

Fig. 10 Phalasarna: The eastern quay.

meters above sea-level offers a unique opportunity since the partly artificial harbour channels, basin and installations have become part of the land and are preserved from the catastrophic salty environment of the sea. Thus today we obtain gradually a clear view of a partly artificial harbour of the Hellenistic era, as parts of the Hellenistic quays have come to light, giving much useful information on harbour architecture and use and harbour defensive constructions (**fig. 9-11**).[66]

At the same time the *tsunamis* created two stratigraphically clearly visible levels consisting marine shells, sand and building ruins, which sealed all levels below them and preserved everything from any later deposited layers of earth, giving us thus an extremely secure chronological dating for the course of the site through centuries and its geological history (**fig. 12**).

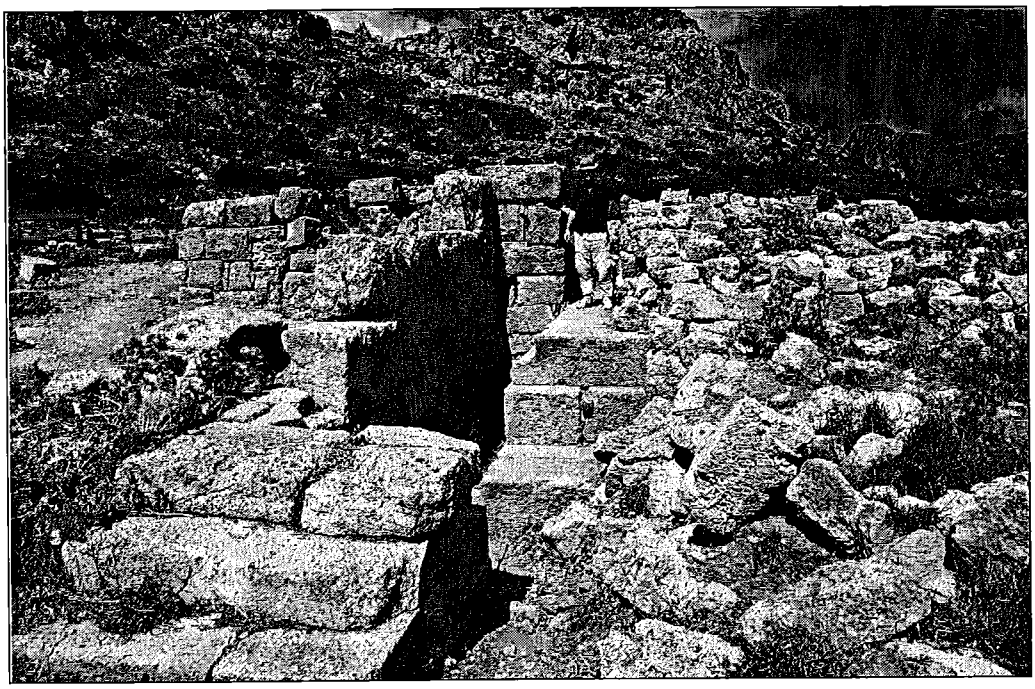

Fig. 11 Phalasarna: The north tower (foto: Kretiko Panorama).

TSUNAMI LOSSES AND TSUNAMI GAINS

Major natural catastrophes that have occurred over historical time illustrate the force of nature and its impact on civilizations. For most of human history, they have been interpreted in a religious context, treated as «curses», regarded as direct punishments by the gods in response to human *hybris* or *asebeia*, but seldom seen as natural phenomena.[67] The first two, earlier, case studies in this paper belong to such a godly punishment category, while for the last two, no such interpretations exist, possibly because of their later occurance date.

Natural disasters have always struck humanity unexpectedly and mercilessly, with many, harsh, consequences, immediate and long term. Among the first, loss of life and loss of property can be listed as the most important, while famine,

Fig. 12 Phalasarna: harbrour trench, the 66 AD *tsunami* layer (foto: Kretiko Panorama).

diseases, post-disaster stress and cultural disaster follow in long run. In most of the cases the role of the state in disaster management has been marginal, since the actual capacity of an ancient state to mitigate disasters in far-flung areas of its territory was limited for a number of

reasons: lack of effective forcasting and prediction, communication, transportation, facilities, economic and technological resources.[68] Regardless of their devastating result, in most cases natural disasters were regarded in Antiquity and much of the Middle Ages in religious terms, as a form of devine reward and punishment, either in form of revenge, or, alternatively as a relief, a salvation, release from difficulties, a positive reception of one's prayers to the gods, a «blessing»[69]

For centuries, natural catastrophes retained more or less their orginal characterisation, but often are remembered as «curses» within the spheres of legend or history, with the constant fear of new imminent, large-scale disaster. This eternal negative view towards natural disasters has to do with two human elements: a) the human perception of events and ideas by contrast, resulting in disasters, having been a constant companion of humanity, «*never stand out, while the rare good times being retained in the collective memory. Equally, there has been a universal appeal of the golden past, although all the evidence points to the fact that such a past was rather a myth than a reality*» and b) «*the existence of groups of people, which have an interest in perpetuating a sense of crisis*».[70]

Despite the fact, however, that all these past catastrophes are today regarded as most unfortunate incidents, they were, at the same time, often treated by both ancient and modern societies as valuable benefits for a number of reasons:

a) Their study and added experience through time has been extremely useful as far as mitigation and protection against natural disasters is concerned.[71]
b) Some of them «*trigger changes, while others are catalysts for change already under way*».[72] They practically allowed the emergence of new and more advanced cultures and civilizations, providing new experiences for the development of science and technology.[73]
c) They have contributed a great deal to the knowledge of antiquity by helping, in many cases, to preserve intact, doomed and forgotten civilizations. They have been assisting archaeologists to interpret and reconstruct the past, explain cultural and socio-economic change in ancient civilizations.[74] In many cases, archaeology even comes to substantiate mythological tales.[75]
d) Due to natural disasters (including droughts, famine, pandemics and, of course, war) human population has been checked, at about a few million, throughout much of history.[76]

The information we gather from ancient natural disasters gives us, however, only a minor idea of the impact they had in the local people, in human constructions and the environment, while the data are not enough to estimate the total losses any *tsunami* may have caused. Having though obtained much experience through centuries of similar events and observation, modern science can give us an idea of the mass destruction a major *tsunami* may cause. A medium *tsunami*, for every metre of beach, pours on the emerged area about 5000-10000 cubic metres of water with a varying discharge from around 25 to 50 mc/sec, for an inclusive period between 60 and 120 seconds. The most frequent geoenvironmental impact have been the destruction of the beaches by bioclastic sand, soil erosion, soil and water table salinisation, accumulation of sand and brackish mud on the emerged earth and partial destruction of the coral barriers.[77]

There is no need however to go far back in time. In 2004, December 26, a seaquake of 8.9 magnitude (similar in magnitude to

that in Phalasarna in 365 AD) sent a *tsunami* propagating through the full depth of the overlying ocean at high speed. A trillion tons of water was driven towards southeast Asia's coastline (Indonesia, Sri Lanka, Thailand, India, Maldives and Somalia) in a long, low-amplitude wave traveling at up to 900 km/h across the Indian Ocean. Casualties amounted to more than 200.000 deaths and around 500.000 injured. Five million souls were left homeless, without food and water, in an area spanning over 5,000 km, while many were and still are at risk from the aftermath of the *tsunami*: slow killers such as diseases, famine, and psychological problems related to post-traumatic stress disorder and reactive depression.[78]

GENERAL BIBLIOGRAPHY-ABBREVIATIONS

Alexander, D. (1998[2]) *Natural Disasters*, London.

Altinok, Y. and Ersoy, S. (2000) Tsunamis Observed on and Near the Turkish Coast, *Natural Hazards* 21. 2-3, 185-205.

Ambraseys, N.N. (1960) The seismic sea wave of July 9th 1956. In the Greek Archipelago, *Journal of Geophysical Research* 84, 1561-1568.

Ambraseys, N.N. (1962) Data for the investigation of seismic sea waves in the eastern Mediterranean, *Bulletin of the Seismological Society of America* 52, 895-913.

Ambraseys, N.N. (1963) Seismic sea wave in the Gulf of Corinth, *Bulletin of the Seismological Society of America* 53(4) 849.

Antonopoulos, J. (1992) The Great Minoan Eruption of Thera Volcano and the Ensuing Tsunami in the Greek Archipelago, *Natural Hazards* 5, 153-168.

Antonopoulos, J.A. (1979) *Catalogue of Tsunamis in the Eastern Mediterranean from Antiquity to Present Times*, Annali di Geofisica, *32 113-130.*

Antonopoulos, J.A. (1973) Tsunamis *of Eastern Mediterranean from Antiquity until Today*, Athens (in Greek)

Antonopoulos, J.A. (1978) Contribution to the knowledge of tsunamis in the eastern Mediterranean from ancient times until the recent, *Annales Geology Pays Hellenic* 29, 740-757 (in Greek).

Antonopoulos, J.A. (1980) Data from the investigation of seismic sea-wave events in the eastern Mediterranean from the birth of Christ to 1980 AD (six parts) *Annali di Geofisica* 33 (1-5) 141-248.

Antonopoulos, J.A. (1992) The great Minoan eruption of Thera volcano and the ensuing tsunami in the Greek Archipelago, *Natural Hazards* 5, 153-168.

Atlas (2002): *Atlas of the Geological Monuments of the Aegean, Athens* (in Greek).

Bawden, G and Reycraft, R. (eds) (2001) *Environmental Disaster and the Archaeology of Human Response, Anthropological Papers* (Maxwell Museum of Anthropology) 7.

Bolt, B.A. (1978) *Earthquakes*, San Francisco.

Bond, A. and Sparks, R.S.J. (1976) The Minoan eruption of Santorini, Greece, *Journal of the Geological Society of London* 132, 1-16.

Brauch, H.G. (2003) Urbanization and natural disasters in the Mediterranean. Population growth and climate change in the 21st century. In Kreimer. Alcira; Arnold, Margaret; Carlin, Anne (Eds.) The Future of Disaster Risk Building Safer Cities. December 2002. Conference Papers (Washington, D.C. World Bank, 170-183.

Bryant, E. (2001) Tsunami *The Underrated Hazard*, Cambridge.

Caputo, M. and Caputo, R. (1989) Contribution for the study of tectonic activity of the Mediterranean Sea from volcanic activity at sea and new islands emerged in historic times, *Science of Tsunam Hazards* 7(2) 79-102.

Chaniotis, A. (1998) Willkommene Erdbeben. In Olshausen and Sonnabend 1998, 404-416.

Cita, M.B., and Aloisi, G. (2000) *Deep-sea tsunami deposits triggered by the explosion of Santorini (3500 y BP) eastern Mediterranean.* Sedimentary Geology *135, 181-203.*

Comninakis, P.E. and Papazachos, B.C. (1982) *A catalogue of historical earthquakes in Greece and the sourrounding area 479 B.C.-1900 A.D.*, Univ. of Thessaloniki Geophys. Lab. Publ. No.5, 24.

Cox, D.C. (1984) Importance of local contemporary reports of effects of historical tsunamis in tsunami risk analysis, *Science of* Tsunami *Hazards* 2(2) 67-70.

Cutter, S.L. (ed) (1993) *Environmental Risks and Hazards*, Englewood Cliffs, NJ, 33-54.

Dawson, A.G., Dominey-Howes, D.T.M., Smith, D.E., Hindson, R.A., and Dawson, S. (1995) GITEC Final Scientific Report (Chapter Three) In Tinti, S. (ed.) *The Genesis and Impact of Tsunamis on the European Coasts, Final Scientific Report. A Report for the Directorate General* XII (Science, Research and Development) *Climatology and Natural Hazards*, The European Union.

Dawson, A.G. (1996) The geological significance of tsunamis, *Zeitschrift für Geomorphologie. N.F.*, Suppl.-Bd. 102, 199-210.

de Boer, J.Z. and Sanders, D.T. (2004) *Earthquakes in Human History The Far-Reaching Effects of Seismic Disruptions*, Princeton.

Diamond, J. (2004) *Collapse. How Societies Choose to Fail or Succeed*, New York.

Di Maro, R. and Maramai, A. (1992) Tsunamis in the Mediterranean and Pacific areas. An analysis, *Science of* Tsunami *Hazards* 10(1) 35-50.

Di Vita, A. (1986) I terremoti a Gortina in eta romana e proto-bizantina una nota, *Ann. Sc. Archeol. Atene and Missioni Italia Oriente*, Roma, 57-58 (1979-1980) 435-440.

Dominey-Howes, D.T.M. (1996a) *The Geomorphology and Sedimentology of Five Tsunamis in the Aegean Sea Region, Greece.* Unpublished Ph.D. Thesis, Coventry University.

Dominey-Howes, D.T.M. (1996b) Sedimentary deposits associated with the July 9th 1956 Aegean Sea tsunami, *Physics and Chemistry of the Earth* 21(12) 51-55.

Dominey-Howes, D.T.M. (1998) Assessment of tsunami magnitude and implications for urban hazard planning in Greece, *Disaster Prevention and Management* 7(3) 176-182.

Dominey-Howes, D.T.M. (2002) Documentary and geological records of tsunamis in the Aegean Sea region of Greece and their potential value to risk assessment and disaster management, *Natural Hazards* 25, 195-224.

Dominey-Howes, D.T.M., Dawson, A.G. and Smith, D.E. (1998) Late Holocene coastal tectonics at Phalasarna, western Crete: a sedimentary study. In Stewart, I.A. and Vita-Finzi, C. (eds) *Coastal Tectonics.* Geological Society of London, Special Publication, 146, 343-352.

Dominey-Howes, D.T.M., Papadopoulos, G.A., and Dawson, A.G. (2000a) Geological and historical investigation of the AD 1650 Mt. Columbo (Thera Island) eruption and tsunami, Aegean Sea, Greece, *Natural Hazards* 21, 83-96.

Dominey-Howes, D., Papadopoulos, G.A. and Dawson, A.G. (2000b) *Geological and historical investigation of the 1650 Mt. Columbo (Thera Island) eruption and tsunami, Aegean Sea, Greece.* Natural Hazards, *21 83-96.*

Driessen, J. and MacDonald, C.F. (2000) The eruption of the Santorini volcano and its effects on Minoan Crete. In McGuire, W.J., Griffiths, D.R. , Hancock, P.L. and Stewart, I.S. (eds) *The Archaeology of Geological Catastrophes*, Geological Society, Special Publications, 171, 81-93.

Druitt, T.H., Mellors, R.A., Pyle, D.M., and Sparks, R.S.J. (1989) Explosive volcanism on Santorini, Greece, *Geological Magazine* 126(2) 95-126.

Druitt, T.H. and Francaviglia, V. (1992) Caldera formation on Santorini and the physiography of the islands in the Late Bronze Age, *Bulleting of Volcanology* 54, 484-493.

Flemming, N.C. (1978) Verbal communication following the paper Yokoyama, I. 1978, Tsunami caused by the Thera eruption. In Doumas, C. (ed.) (1980) *Thera and the Aegean World II*, 277-283 - reported in C. Doumas (ed.) (1980) *Thera and the Aegean World II*, 360.

Francaviglia, V. (1990) Sea-borne pumice deposits of archaeological interest on Aegean and eastern Mediterranean beaches. In Hardy, D.A. and Renfrew, A.C. (eds) *Thera and the Aegean World III*, Volume Three, Chronology, 127-134.

Fritzalas, C.I. and Papadopoulos, G.A. (1988) Volcanic risk and urban planning in the region of Santorini volcano, south Aegean, Greece. In Marinos, P.G. and Koukis, G.C. (eds) *Proceedings of the International Symposium on the Engineering Geology and Ancient Works, Monuments and Historical Sites, Preservation and Protection*, 1321-1327.

Frost, F.J. (1989) *The last days of Phalasarna,* Ancient History Bulletin *3, 15-17.*

Frost, F.J. (1997) Tectonics and history at Phalasarna. In Swiny, S., Hohlefelder, R.L. and Swiny, H.W. (eds) 1997 *Res Maritimae: Cyprus and the Eastern Mediterranean from Prehistory to Late Antiquity*, Atalanta, 107-115.

Frost, F.J. and Hadjidaki, E. (1990) Excavations at the Harbour of Phalasarna in Crete, *Hesperia* 59, 513-27.

Frost, F.J. and Hadjidaki, E. (1993) Phalasarna, *Archeologikon Deltion* 43 (1988) *?2-Chronicles*, 559-60 (in Greek).

Fytikas, M., Kolios, N., and Vougioukalakis, G. (1990) Post-Minoan volcanic activity on the Santorini volcano. Volcanic hazard and risk, forecasting possibilities. In Hardy, D.A., Keller, J., Galanopoulos, V.P., Flemming, N.C. and Druitt, D.H. (eds) *Thera and the Aegean World III*, Volume Two, Earth Sciences, 183-198.

Galanopoulos, A.G. (1957) The seismic sea wave of July 9, 1956, *Praktika Academias. Athenon* 32, 90-101 (in Greek).

Galanopoulos, A.G. (1960) Tsunamis observed on the coasts of Greece from antiquity to the present time, *Annali di Geofisica* 13, 369-386.

Galanopoulos, A.G., Delibasis, N., and Comninakis, P. (1964) A tsunami generated by an earth slump set in motion without shock, *Annales Geologic Pays Hellenic* 16, 93-110.

Giannelli, G. (1961[4]) *Trattato di Storia* Greca, Rome.

Gondicas, D.G. (1988) *Recherches sur la Crète Occidentale*, Amsterdam.

Guidoboni, E., Comastri, A. and Traina, G. (1994) *Catalogues of Ancient Earthquakes in the Mediterranean Area up to the 10th Century.* Instituto Nazionale di Geofisica, Roma.

Hadjidaki, E. (1988) Preliminary Report of Excavation at the Harbour of Phalasarna in West Crete, *American Journal of Archaeology* 92, 1988, 463-79.

Hadjidaki, E. (1989/90) Phalasarna, *Kretike Estia* 3, 256-260 (in Greek).

Hadjidaki, E. (1990) Excavations at the classical and Hellenistic harbor at Phalasarna, west Crete, Greece *Acts of the 6th International Cretological Congress*, v.1, 1990, 355-361.

Hadjidaki, E. (1992a) Hellenistic Cretan piracy. In Spence, R.B. and Nelson, L.L. (eds) *Scholar, Patriot, Mentor, Historical Essays in Honor of Demetrije Djordjevi?*, N. York 1992, 51-62. (also, in *Vestnik Drevnej Istorii)* 2, 1992, 154-161).

Hadjidaki, E. (1992b) Phalasarna, *Archeologikon Deltion* 42 (1987) *B2-Chronicles*, 566-567 (in Greek).

Hadjidaki, E. (1993) Phalasarna, *Archeologikon Deltion* 43 (1988) *B2-Chronicles*, 559-560 (in Greek).

Hadjidaki, E. (1994/5) Phalasarna, *Kretike Estia* 5, 230-236 (in Greek).

Hadjidaki, E. (1996) The Hellenistic Harbour of Phalasarna in Western Crete A Comparison with the Hellenistic Inner Harbour of Sraton's Tower. In, Raban, A. and Holum, K.G. (eds.) *Caesarea Maritima. A Retrospective after Two Millenia*, 1996, 53-64.

Hadjidaki, E. (1997) Phalasarna, *Archeologikon Deltion* 47 (1992) *B2-Chronicles*, 697-700 (in Greek).

Hadjidaki, E. (1998?) Phalasarna, *Archeologikon Deltion* 48 (1993) *B2-Chronicles*, 588-589 (in Greek).

Hadjidaki, E. (1998?) Phalasarna, *Kretike Estia* 2, 287-290 (in Greek).

Hadjidaki, E. (2001) The Roman Destruction of Phalasarna, *Archaeology of the Roman Empire a Tribute to the Life and Works of Professor Barri Jones, BAR International Series* 940, 2001, 155-66.

Hadjidaki, E.. Iniotakis, K., Sotirakis, D. (1996) Depiction of military vessel. In relief, on an inscription stele from western Crete, *Enalia* IV.3.4, 38-41 (in Greek).

Hadjidaki, E. and Iniotakis, C. (2000) Hellenistic ceramics from Phalasarna, *The Ancient World* 31.1, 2000, 54-73.

Hadjidaki, E. and Stefanakis M.I. (2003/4) The secrets of Phalasarna, *Kretiko Panorama* 2, Dec. 2003-Jan. 2004, 100-135 (in Greek).

Hanson, B. (2005) Learning from Natural Disasters, *Science*, Vol. 308, Issue 5725, 1125, 20 May.

Harrison, G.W.M. (1993) *The Romans and Crete*, Amsterdam.

Hebenstreit, G. (1997) A long-term perspective. In Hebenstreit, G. (ed.) *Perspectives on* Tsunami *hazard reduction observations, theory and planning*, Kluwer Academic, 205-214.

Heck, N. H. (1947) List of seismic sea waves, *Bull. Seism. Soc. Am.* 37, 269–286.

Heiken, G. and McCoy, F. (1984) Caldera formation during the Minoan eruption, Thera, Cyclades, Greece, *Journal of Volcanology and Geothermal Research* 89, 8441-8462.

Heiken, G. and McCoy, F. (1990) Precursory activity to the Minoan eruption, Thera, Greece. In Hardy, D.A. , Keller, J., Galanopoulos, V.P., Flemming, N.C. and Druitt, T.H. (eds) *Thera and the Aegean World III*, Vol. 2, Earth Sciences, 370-376.

Helly, B. (1998) La sismiceté est-elle un object d'etude pour les archéologues? In Olshausen and Sonnabend 1998, 169-189.

Hiller, S. (1975) Die Explosion des Vulkans von Thera, *Gymnasium* 82, 32-74.

Istoria (1971): *Istoria tou Ellinikou Ethnous*, vol. B, Athens (In Greek).

Iida, K. (1958) Magnitude and energy of earthquakes accompanied by tsunamis and tsunami energy, J. *Earth Sciences, Nagoya Univ.* 4, 1-43.

Jackson, J. (1994) Active tectonics of the Aegean region, *Annual Review of the Earth and Planetary Sciences* 22, 239-271.

Jacques, F., et Bousquet, B. (1983) Le cataclysme du 21 Juillet 365 Phénomène régional ou catastrophe cosmique?, Tremblements de Terre. Histoire et Archéologie, *Antibes, 183-193.*

Jacques, F. and Bousquet, B. (1984) Le raz de marée du 21 juillet 365- Du cataclysme local à la catastrophe cosmique, Mélanges de l'École Française de Rome 96 *423-461.*

Kanamori, H. (1972) Mechanism of tsunami earthquakes, *Phys. Earth Planet Interiors* 6, 346-359.

Katsonopoulou, D. (1995) Helike. *Archaeologia 54, 40-45 (in Greek).*

Katsonopoulou, D. (1998) The first excavation at Helike Klonis Field [in Greek]. In Katsonopoulou, D., Soter, S. and Schilardi, D. (eds) *Ancient Helike and Aigialeia Proceedings of the Second International Conference, Athens, 125-145.*

Katsonopoulou, D. (1999) Mycenaean Helike. In *Meletemata Studies in Aegean Archaeology presented to M. Wiener, Aegaeum 20, 409-413.*

Katsonopoulou, D. (2002) Helike and her territory in the light of new discoveries. In Greco, E. (ed.), Gli Achei e l'identita etnica degli Achei d'occidente, Tekmeria *3, 205-216. Paestum.*

Katsonopoulou, D. and Soter, S. (2003) Classical Helike and Its Early Bronze Age Predecessor, Archaeological Institute of America *2003 Annual Meeting Program, Session 4D Bronze Age Archaeology in the Peloponnese.*

Keller, J., Rehren, Th., and Stradbauer, E. (1990) Explosive volcanism in the Hellenic Arc a summary and review. In Hardy, D.A., Keller, J., Galanopoulos, V.P., Flemming, N.C. and Druitt, D.H. (eds) *Thera and the Aegean World III*, Volume Two, Earth Sciences, 13-26.

Kelletat, D. (1998) Geologische Belege katastrophaler Erdkrustenbewegungen 365 AD im Raum von Kreta. In Olshausen and Sonnabend, 156-161.

Koenig, R. (2001) Modeling a 3600-Year-Old Tsunami Sheds Light on the Minoan Past, *Science*, Vol 293, Issue 5533, 17 August, 1252.

La Moreaux, P.E. (1995) Worldwide environmental impacts from the eruption of Thera, Environmental Geology 26172-181.

Lafond, Y. (1998) Die Katastrophe von 373 v. Chr. Und das Verschwinden der Stadt Helike in Achaia. In Olshausen and Sonnabend 1998, 118-123.

Lallemant, S., Truffert, C., Jolivet, L., Henry, P., Chamot-Rooke, N., and De Voogd, B. (1994) Spatial transmission from compression to transition in the western Mediterranean Ridge accretionary complex, *Tectonophysics* 234, 33-52.

Lamberton, R. (1999) Review of Olshausen and Sonnabend 1998, *Bryn Mawr Classical Review* 1999.04.24.

Le Pichon, X. and Angelier, J. (1979) The Hellenic Arc and trench system a key to the neotectonic evolution to the eastern Mediterranean area, *Tectonophysics* 60, 1-42.

Le Pichon, X. and Angelier, J. (1981) The Aegean Sea, *Philosophical Transactions of the Royal Society of London. Series A* 300, 357-372.

Legrand, Ph. E. (1932-46) *Herodote Histoires*, Paris, Societe d'Edition Les Belles Lettres.

Lehmann-Hartleben, K. (1923) Die antiken Hafenanlagen des Mittelmeeres, *Klio* XIV, 67-74.

Liritzis, I., Katsanopoulou, D., Soter, S. and Galloway, R.B. (2001) In search of ancient Helike, Gulf of Corinth, Greece, *Journal of Coastal Research 17.1, 118-120.*

Lockridge, P.A. (1990) Nonseismic phenomena in the generation and augmentation of tsunamis, *Natural Hazards* 3, 403-412.

Lohmann, H. (1998) Die Santorin-Katastrophe-en archäologischer Mythos?. In Olshausen and Sonnabend (1998), 337-363.

Marinatos, S. (1939) The volcanic destruction of Minoan Crete, *Antiquity* 13, 425-439.

Marinatos, S. (1960) Helice a submerged town of Classical Greece. *Archaeology* 13, 186-193.

Marinatos, S. (1964) Archaeology and modern technique. *Fulbright Review 1*, 41-44.

Marinos, G. and Melidonis, N. (1971) On the strength of the sea quakes (tsunamis) during the prehistoric eruptions of Santorini. *ACTA of the First Internationa Scientific Congress on the Volcano of Thera*, Athens, Greece, 1969, 277-282.

Marzolff, P. (1998) Archäeologische Aspekte von Naturkatastrophen. In Olshausen and Sonnabend 1998, 275-283.

McCoy, F.W. and Heiken, G. (2000) Tsunami generated by the Late Bronze age eruption of Thera (Santorini) Greece, *Pure and Applied Geophysics* 157, 1227-1256.

McCoy, F.W. and Heiken, G. (2000/02) The Late-Bronze Age explosive eruption of Thera (Santorini) Greece Regional and local effects, *Volcanic Hazards and Disasters in Human Antiquity (Special Papers) Geological Society of America 345.*

McKenzie, D.P. (1972) Active tectonics of the Mediterranean region, *Geophysical Journal of the Royal Astronomical Society* 30(2) 109-185.

Meszaros, S. (1978) Some words on the Minoan tsunami of Santorini. In C. Doumas (ed.) (1980) *Thera and the Aegean World II*, 257-262.

Minoura, K., Imamura, F., Kuran, U., Nakamura, T., Papadopoulos, G.A., Takahashi, T. and Yalciner, A.C. (2000) Discovery of Minoan tsunami deposits, *Geology* 28(1) 59-62.

Mitra, B.S. (2002) Dealing with Natural Disaster Role of the Market. In Machan, *T.R. (ed.), Liberty and Hard Cases*, Hoover Institution Press Publication No. 492, Leland Stanford 2002, 35-58.

Mylonopoulos, J. (1998) Poseidon, der Erderschütterer. Religiöse Interpretationes von Erd- und Seebeben. In Olshausen Sonnabend (1998), 82-89.

Olshausen, E. and Sonnabend, H. (eds) (1998) *Stuttgarter Kolloquium zur historischen Geographie des Altertums 6, 1996 Naturkatastrophen in der antiken Welt. Geographica Historica* 10. Stuttgart.

Ortolani, F., Pagliuca, S., D'Agostino, G. (2005) Tsunami and Rapid Catastrophic Environmental Change. The Hazard Along the Italian Coastal Area. In A.M. Michetti, F. Aligi Pasquare, S. Haldorsen, S. Leroy (organisers) *Dark Nature -Rapid Natural Change and Human Responses*, Como, Italy, September 6-10, 2005.

Page, D. (1970) The Santorini volcano and the destruction of Minoan Crete, *The Society for the Promotion of Hellenic Studies*, Supplementary Paper 12, 1-45.

Papadopoulos, G.A. (1989) Seismic and volcanic activities and aseismic movements as plate motion components in the Aegean area, *Tectonophysics* 167, 31-39.

Papadopoulos, G.A. (1993) On some exceptional seismic (?) sea-waves in the Greek Archipelago, *Science of* Tsunami *Hazard* 11, 25-34.

Papadopoulos, G.A. (1996) Recent Developments in the tsunami research in Greece a short review. In *Study on Regional and Historical Change of Tsunami Disasters - In commemoration of the 1993 Hokkaido Nansei-oki Earthquake Tsunami.* Special Publication of the Faculty of Policy Studies, Iwate Prefectural University, Japan, 1-7.

Papadopoulos, G.A. (1998a) *A tsunami catalogue of the area of Greece and the adjacent seas.* Institute of Geodynamics, National Observatory of Athens, Publication Number 8.

Papadopoulos, G.A. (1998b) A reconstruction of the great earthquake of 373 B.C. in the western gulf of Corinth. In Katsonopoulou, D., Soter, S. and Schilardi, D. (eds.) *Helike II-Ancient Helike and Aigialeia, Proceedings of the 2nd International Conference, Aighion 1-3 Dec. 1995*, 479-494.

Papadopoulos, G.A. (ed.) (2000) *Historical Earthquakes and Tsunamis in the Corinth Rift, Central Greece*, Institute of Geodynamics, National Observatory of Athens, Publication Number 12.

Papadopoulos, G.A. (2001) Tsunamis in the East Mediterranean A catalogue for the area of Greece and adjacent seas. *Proceedings of the IOC/IUGG International Workshop Tsunami Risk Assessment Beyond 2000 Theory, Practice and Plans*, Moscow, June 14-16, 2000, 34-43.

Papadopoulos, G.A. (2003a) Tsunami Hazard in the Eastern Mediterranean Strong Earthquakes and Tsunamis in the Corinth Gulf, Central Greece, *Natural Hazards* 29.3, 437-464.

Papadopoulos, G.A. (2003b) Quantification Of Tsunamis A Review, *NATO Advanced Research Workshop on Underwater Ground Failures on Tsunami Generation, Modeling, Risk and Mitigation*, May, 23-25, 2001, Istanbul, 285-291.

Papadopoulos, G.A. (forthcoming a) Large tsunamigenic Earthquakes and volcanic eruptions in the Mediterranean Sea from antiquity to present, comm. at the international conference *The Impact of Natural Catastrophes on Ancient Mediterranean Civilizations*, Rhodes 28-30 October 2005.

Papadopoulos, G.A. (forthcoming b) Tsunamis in the East Mediterranean. *In Physical Geography of the Mediterranean Sea. Oxford.*

Papadopoulos, G.A. and Chalkis, B.J. (1984) Tsunamis observed in Greece and the surrounding area from antiquity up to the present times, *Marine Geology* 56, 309-317.

Papadopoulos, G.A. and Dermentzopoulos, Th. (1998) A tsunami risk management pilot study in Heraklion, Crete, *Natural Hazards* 18, 91-118.

Papadopoulos, G.A. and Vassilopoulou, A.(1998) *Historical and archaeological evidence of earthquakes and tsunamis felt in the Kythira strait, Greece.* Institute of Geodynamics, National Observatory of Athens, Publication Number 9.

Papadopoulos, G.A. and Imamura, F. (2001) A proposal for a new tsunami intensity scale, *Proceedings of the International* Tsunami *Sympocium 2001, Seattle, Washington, Aug. 7 -10, 2001*, 569- 577.

Papadopoulos, G.A. and Pavlides, S.B. (1992) The large 1956 earthquake in the south Aegean macroseismic configuration, faulting and neotectonics of Amorgos Island, *Earth and Planetary Science Letters* 113, 383-396.

Papazachos, B.C. and Comninakis, P.E. (1971) Geophysical and tectonic features of the Aegean arc, *Journal of Geophysical Research* 76, 8517-8533.

Papazachos, B.C., Koutitas, Ch., Hatzidimitrou, P.M., Karakostas, B.G. and Papaoioannou, Ch. A. (1985) Source and short distance propagation of the July 9th 1956 southern Aegean tsunami, *Marine Geology* 65, 343-351.

Papazachos, B.C., Kiratzi, A. A., Hatzidimitriou, P.M., and Karacostas, B.G. (1986) Seismotectonic properties of the Aegean area that restrict valid geodynamic models, *2nd Wegener Conference*, Dionysos, Greece, 14-16 May 1986, 1-16.

Papazachos, B.C., Koutitas, Ch., Hatzidimitrou, P.M., Karakostas, B.C., and Papaioannou, Ch. A. (1986) Tsunami hazard in Greece and the surrounding area, *Annales Geophysicae* 4b (1) 79-90.

Papazachos, B.C. (1988) Active tectonics in the Aegean and surrounding area. In J. Bonnin *et al.* (eds) *Seismic Hazard in Mediterranean Regions,* Kluwer Academic Publishers, Dordrecht, 301-331.

Papazachos, B. and Papazachos, K (1989) *The Earthquakes in Greece*, Thessaloniki (in Greek).

Papazachos, B.C. and Dimitriou, P.P. (1991) Tsunamis in and near Greece and their relation to the earthquake focal mechanisms, *Natural Hazards* 4, 161-170.

Pararas-Carayannis, G. (1992) The tsunami generated from the eruption from the volcano of Santorini in the Bronze Age, *Natural Hazards* 5, 115-123.

Pashley, R. (1837) *Travels in Crete* 2, London.

Pedersen, G., Gjevik, B., Harbitz, C.B., Dybesland, E., Johnsgard, H., and Langtangen, H.P. (1995) *Tsunami case studies and model analysis Final GITEC Report.* Reprint Series No. 4, *Mechanics and Applied Mathematics*, University of Oslo.

Perissoratis, C. and Papadopoulos, G.A. (1999) Sediment slumping in the south Aegean Sea and the case history of the 1956 tsunami, *Marine Geology* 161, 287-305.

Pichler, H. and Schiering, W. (1977) The Thera eruption and late Minoan -IB destructions on Crete, *Nature* 267, 819-822.

Pichler, H. und Schiering, W. (1978) Der Ausbruch des Thera-Vulkans um 1500 v. Chr. Archäologische Datierung, Eruptionsverlauf und Auswirkungen auf die minoische Kultur Kretas *Die Naturwissenschaften* 65, Jahrgang Heft 12, Dezember, 605-610.

Pirazzoli, P.A., Ausseil-Badie, J., Giresse, P., Hadjidaki, E., and Arnold, M. (1992) Historical environmental changes at Phalasarna Harbour, west Crete, *Geoarchaeology* 7(4), 371-392.

Pomerance, L. (1970) *The Final Collapse of Santorini (Thera) Studies in Mediterranean Archaeology* vol. XXVI Göteborg.

Price, S., Higham, T., Nixon, L., Moody, J. (2002) Relative sea-level changes in Crete: reassessment of radiocarbon dates from Sphakia and west Crete, *ABSA* 97, 171-200.

Reck, H. (1936) Der fruhgeschichtliche Bimssteinausbruch Santorins und das caldera problem. In H. Reck (ed), *Santorin - Der Werdegang eines Inselvulkans und sein Ausbruch 1925-1928* 1, 81-187.

Sigurdsson, H., Carey, S. and Devine, J.D. (1990) Assessment of mass, dynamics and environmental effects of the Minoan eruption of Santorini volcano. In D. A. Hardy, J. Keller, V. P. Galanopoulos, N. C. Flemming, and T. H. Druitt (eds) *Thera and the Aegean World III*, Volume Two, *Earth Sciences*, 100-112.

Simoes, J.Z., Afilhado, A., and Mendes Victor, L. (1992) Assessing the tsunami risk using instrumental and historical records, *Science of Tsunami Hazards* 10(1) 3-8.

Soloviev, S.L. (1990) Tsunamigenic zones in the Mediterranean Sea, *Natural Hazards* 3, 183-202.

Soloviev, S.L., Solovieva, O., Go, C., Kim, K., and A. Shchetnikov (2000) *Tsunamis in the Mediterranean Sea 2000 B.C.- 2000 A.D., Kluwer.*

Sonnabend, H. (1998) Hybris und Katastrophe. Der Gewaltherrscher und die Natur. In Olshausen and Sonnabend (1998) 34-40.

Soter, S. (1998) Holocene uplift and subsidence of the Helike Delta, Gulf of Corinth, Greece. In Stewart, I. and Vita-Finzi, C. *(eds.) Coastal Tectonics, Geological Society, London, Special Publications 146, 41-56.*

Soter, S. (1999) Macroscopic seismic precursors and submarine pockmarks in the Corinth-Patras Rift, Greece. *Tectonophysics 308, 275-290.*

Soter, S. and Katsonopoulou D. (1999) Occupation horizons found in the search for the ancient Greek city of Helike, *Geoarchaeology 14, 531-563.*

Soter, S., Blackwelder, P., Tziavos, C., Katsonopoulou, D., Hood, T. and Alvarez-Zarikian, C. (2001) Environmental analysis of bore hole cores from the Helike Delta, Gulf of Corinth, Greece. *Journal of Coastal Research 17, 95-106.*

Soter, S., Katsonopoulou, D., Koukouvelas, I. (2002) Archaeological evidence of earthquakes in the area of Helike, Achaia, Greece from the Early Bronze Age to Late Antiquity. In Leroy, S. and Stewart, I. (Organizers) *Environmental Catastrophes and Recoveries in the Holocene,* August 29 - September 2, 2002, Department of Geography & Earth Sciences, Brunel University, Uxbridge.

Spyropoulos, P.I. (1997) *The Chronicle of Earthquakes in Greece*, Athens (in Greek).

Stefanakis M.I. (2006) Phalasarna un port antique, un espace d'échanges en Méditerranée, in F. Clément, F. Tolan and J. Wilgaux (eds), *Espaces d'échanges en Méditerranée (Antiquité et Moyen-Age) Contacts, échanges et transferts dans le monde méditerranéen pendant l'Antiquité et le Moyen Age*, Rennes, 41-75.

Stepper, R. (1998) Die Darstellung von Naturkatastrophen bei Herodot. In Olshausen and Sonnabend 1998, 90-98.

Stiros, S. (1996) Identification of earthquakes from archaeological data Methodology, criteria and limitations. In Stiros, S. and Jones, R. (eds) *Archaeoseismology*, British School at Athens, Fitch Laboratory Occasional Paper 7, 129-152.

Stiros, S. (2001) The AD 365 Crete earthquake and possible seismic clustering during the 4-6th centuries AD in the Eastern Mediterranean a review of historical and archaeological data, *Journal of Structural Geology* 23, 545-562.

Stiros, S.C., Marangou, L., and Arnold, M. (1994) Quaternary uplift and tilting of Amorgos Island (southern Aegean) and the 1956 earthquake, *Earth and Planetary Science Letters* 128, 65-76.

Stiros, S.C. and Papageorgiou, S. (2001) Seismicity of western Crete and the destruction of the town of Kisamos at AD 365 Archaeological evidence, *Journal of Seismology* 5, 381-397.

Tainter, J. (1988) *The Collapse of Complex Societies, Cambridge.*

Tarn, W.W. (1908) *The Fleet of Xerxes, Journal of Hellenic Studies 28, 202-233.*

Thommeret, Y., J. Thommeret, J. Laborel, L.F. Montaggioni, and P.A. Pirazzoli (1981) Late Holocene shoreline changes and seismo-tectonic displacements in western Crete (Greece) *Z. Geomorphol. Suppl., 40 127-149.*

Tinti, S. and Maramai, A. (1996) Catalogue of tsunamis generated in Italy and Cote d'Azur, France a step towards a unified catalogue of tsunamis in Europe, *Annali di Geofisica* 39, 1253-1299.

Tinti, S., Baptista, M.A., Harbitz, C.B., and Maramai, A. (1999) The unified catalogue of tsunamis a GITEC experience. *Proceedings of the International Conference on Tsunamis, Paris, 26th-28th May 1998*, 84-99.

Tinti, S., Maramai, A., Graziani, L. (2004) The new catalogue of Italian Tsunamis, *Natural Hazards* 33.3, 439-465.

Torrence, R. and Grattan, J. (2002) The archaeology of disasters past and future trends. In Torrence, R and Grattan, J (eds), *Natural Disasters and Cultural Change, Proceedings of the World Archaeological Congress 4, University of Cape Town, 10th - 14th January 1999*, London -N.York.

Tzedakis, I. (1969) Antiquities and monuments of western Crete, *Arhceologikon Deltion* 24, 433-434 (in Greek).

Walser, G. (1984) *Hellas und Iran. Studien zu den griechisch-persischen Beziehungen vor Alexander*, Darmstadt.

Warren, P.M. (1990/91) The Minoan civilisation of Crete and the volcano of Thera, *Journal of the Ancient Chronology*, Forum 4, 29-39.

Whelan, F. and Kellat (2002) Geomorphic evidence and relative and absolute dating results for tsunami events on Cyprus, *Science of Tsunami Hazards* 20.1, 3-18.

Wilcken, U. (1962[9]) *Griechische Geschichte*, München.

Yokoyama, I. (1980) The tsunami caused by the prehistoric eruption of Thera. In C. Doumas (ed.) *Thera and the Aegean World II, 2nd International Scientific Congress*, Santorini, August 1978, 1277-283.

Zangger E. (1998) Naturkatastrophen in der ägäischen Bronzezeit. Froschungsgeschichte, Signifikanz und Beurteilungskriterien in Olshausen and Sonnabend 1998, 211-241.

ANCIENT SOURCES

Aelianus, *De Natura Animalium*
Ammianus Marcelinus, *Historiae*
Diodorus Siculus, *Geographica*
Herodotus, *Historiai*
Ovid, *Metamorphoses*
Pausanias, *Graeciae Descriptio*
Philostratus, *Vita Apollonii*
Plini, *Historia Naturalis*
Strabo, *Geographica*
Suda Lexicon
Malalas Joannes, Chronographia

WEB-SITES

Focosi: Mass peacetime natural catastrophes/disasters at:
http://www.focosi.altervista.org/naturalcatastrophes/html (d.o.a.: 04.02.06)

ENDNOTES

[1] Many thanks are owed to Dr. Elpida Hadjidaki, Dr. Gerassimos Papadopoulos and Dr. Alan Johnston for their kind contribution, useful remarks and corrections.

[2] The ferocity of nature, which is here examined as «natural catastrophes», has being described by two different terms: Natural cataclysms, «*major natural phenomena that have been part and parcel of the planet Earth since its beginning*» and natural disasters, a term «*applied to something that has suffered some adverse consequences from a natural hazard, and has been proved disastrous to people (similar events in uninhabited parts of the world would not be called disasters)*» (Mitra 2002, 36). Natural catastrophes are generally divided in two major categories with respect to their origin: geological (geophysical) disasters and weather-related (hydro-meteorological) disasters and are further divided in two types according to their impact: sudden calamities, such us earthquakes, volcanic activity, *tsunamis*, rock shifts, wavy sea, floods, etc. and slow killers, such as droughts, diseases and famine. In the first case the disaster is immediate and fierce, in the second, the impact is slow and disaster is completed within a span a time. On the above see Brauch 2003, 178-179; also Focosi.

On the perception, the division of natural catastrophes and the use of term *semeion* by the ancient Greeks, see Chaniotis 1998, 404-405

[3] It is the result of forces deep within the Earth's interior that continuously affect the surface of the Earth. The energy from these forces is stored in a variety of ways within the rocks. When this energy is released suddenly, for example by shearing movements along faults in the crust of the Earth, an earthquake results. 90% of the world's earthquakes occur in specific areas that are the boundaries of the Earth's major crustal plates (fucosi). See also de Boer and Sanders 2004.

[4] Submarine landslides, which often accompany large earthquakes, as well as collapses of volcanic edifices, can also disturb the overlying water column as sediment and rock slump downslope and are redistributed across the sea floor. Similarly, a violent submarine volcanic eruption can create an impulsive force that uplifts the water column and generates a *tsunami*. On generative mechanisms of *tsunamis* see Dominey-Howes 2002, 201 with latest bibliography. On *tsunami* earthquakes see Papazachos and Dimitriou 1991, 163-164. On the geological processes responsible for earthquakes in general and their aftereffects see de Boer and Sanders 2004.

[5] On *tsunamis* in general, the areas of the world in which they occur and the disasterous impact which follows in their wake, see Bryant 2001. Focosi. Papazachos and Dimitriou 1991, 163-4

[6] On a *tsunami* catalogue of the Mediterranean Sea see Soloviev *et al.* (2000).

[7] Papazachos and Dimitriu 1991, 161-170. *Tsunami* catalogues for the area of Greece, have been published by several authors (Heck 1947; Galanopoulos 1960; Ambraseys 1962; Antonopoulos 1980; Papadopoulos and Chalkis 1984; Papazachos *et al.* 1986; Papazachos and Papazachou 1989, 1997; Soloviev 1990; Papadopoulos 1993a, 1998a, 2001). For the tectonic components of the Aegean region see Dominey-Howes 2002, 196-199 with latest bibliography.

[8] Altinok and Ersoy 2000, 185 – 205.

[9] Ortolani *et al.* 2005. Tinti *et all.* 2004.

[10] Whelan and Kelletat 2002

[11] On the impact of the volcanic eruption of Thera between 1650 and 1450 BC see, Papadopoulos (forthcoming a). Minoura, Imamura, Kuran, Nakamura, Papadopoulos, Takahashi and Yalciner 2000; Dominey-Howes 2002, 212-215; Koenig 2001; McCoy and Heiken 2000; La Moreaux 1995; Antonopoulos 1992; Pichler und Schiering 1978; Pichler and Schiering 1977; Hiller 1975. Pomerance 1970, has suggested that the collapse of Thera and the resulting *tsunami* devastated not only Crete, but

the entire East Mediterranean basin at the end of the Late Helladic IIIB ceramic phase; Marinatos 1939. On the origins and mechanisms of volcanism in general and its effects on societies, cultures, and the environment since antiquity, beginning with the Thera volcanic eruption during bronze age, see Zeillinga de Boer and Sanders 2002.

[12] See for example Strabo (1.3.17, 11-16), citing Democles who «*speaks about certain great earthquakes, some of which took place long ago in the areas of Lydia and Ionia, affecting even the area of Troad to the north, and which [earthquakes] caused the submerging of villages and even the Mount Sipylus was shattered, during the reign of Tantalus. And swamps became lakes, and a huge sea wave [tsunami] submerged Troy.*» (transl. by author), or Pliny (2.93), writing about «*Cities which have been absorbed by the sea: Pyrrha and Antissa, Elice and Bura. From the island of Cea the sea suddenly tore off 30,000 paces with many persons on them. In like manner it carried off Eleusina in Boeotia, and half of the city of Tyndaris in Sicily*». (transl. by author).

[13] According to Papadopoulos 2001, based on the revised *GITEC catalogue of tsunamis in the East Mediterranean*. On the quantification of *tsunamis* see Papadopoulos and Imamura 2001 and Papadopoulos 2003b.

[14] According to Papazachos and Papazachos 1989, 113, the focal depth was at less than 10 km

[15] Antonopoulos 1973; Bolt 1978. On the subject of «reliability of occurance» for *tsunami* events in antiquity see the discussion by Dominey-Howes 2002, 215-217.

[16] Sonnabend 1998, 35-36; On the Persian fleet see, Tarn 1908, 202ff. Wilcken 1962, 140; Giannelli 1961, 212.

[17] Herodotus 8, 129.1-2

[18] For further details on this historical events see *Istoria* 1971, 340. Legrand 1932-46, 121, n. 2).

[19] Herodotus 8.129, 2-17. All translations from ancient sources are by the author, unless otherwise stated

[20] Sonnabend 1998, 35-36. Mylonopoulos 1998, 87. On the cases of Xerxes, Nero and Justinian, who exhibited *asebeia* and were subsequently punished by natural catastrophes by the gods, see also Walser 1984, 49-52.

[21] Mylonopoulos 1998, 87-88.

[22] For the way Herodotus treats natural catastrophes in his *Histories* see Stepper 1998. On the ways natural catastrophes could be explained in ancient Greece see Sonnabend 1998.

[23] Herodotus 8.129.1. See also Mylonopoulos 1998, 87.

[24] Herodotus 8.126, 5.

[25] Herodotus 9.66, 7-8.

[26] On the seismicity of the Corinthian Gulf, as well as the latest *tsunami* Quick-Look Catalogue, see Papadopoulos 2003, 437–441. On *tsunami* catalogues especially on the area of the Corinthian Gulf see also Papadopoulos 2000a, Papadopoulos *et al.* 2000.

[27] According to Papadopoulos 2003a, 440. Papadopoulos 2001. Papadopoulos 2000

[28] On the event see Papadopoulos 1998b, Papadopoulos 2003a and Papadopoulos 2000.

[29] See also Lafond 1998, 120.

[30] Strabo 8.7.2, 21-39

[31] Pausanias 7.24, 5-13.

[32] Diod. 15.48.1, 6-49, 4, 9

[33] Ovid 1.263

[34] Pliny 2.93.

[35] Aelianus 11.19

[36] On the research and excavation at the site of ancient Helike see Katsonopoulou and Soter 2003; Soter *et al.* 2002; Liritzis *et al.* 2001, 118-120.

[37] See also Mylonopoulos 1998, 88. On earthquakes as punishment and godly signs, see also Chaniotis 1998, 410-113.

[38] Diodorus 15.48.4, 7-8

[39] Diodorus 15.49.4, 1-4

[40] Currently excavated under the direction of Dr. Elpida Hajidaki, with the participation of the author and of Prof. N. Sekunda of the Institute of Archaeology, Gda?sk Universtity, Polland.

[41] According to Papadopoulsos 2001.

[42] According to Papazachos and Papazachos 1989, 113, 227, the earthquake magnitude was estimated at 7.

[43] According to Papazachos and Papazachos 1989, 227 the depth was less than 10 km.

[44] Dominey-Howes 2002, 210-212; Di Vita, 1986; Guidoboni *et al.*, 1994.

[45] Philostratus, 4.34, 34-51.

[46] Suda, sv. *Diktys*α See also Malalas, 132.22-133.2.

[47] On the channel trench see Hadjidaki 2001, 159; Pirazzoli *et al.* 1992, 377; Hadjidaki 1992b, 567; Hadjidaki 1990, 360; Hadjidaki 1988, 475-6.

[48] For the blockage of the channel and its relation with the Roman invasion see Hadjidaki 2001, 159; Frost 1997, 110; Frost and Hadjidaki 1990, 527 and n. 22; Frost 1989, 15-17; Hadjidaki 1988 (a or b??), 476.

[49] In medieval times its location was unknown and only in 1837 the English traveller R. Pashley identified its ruins, not, however, the harbour, which was now 100 m away from the sea. This was identified in 1860 by another Englishman, Capt. T.A.V. Spratt.

[50] Pirazzoli *et al.* (1992), 386; Dominey-Howes 2002, 211-212; Dominey-Howes *et al.* (1998)

[51] Pirazzoli *et al.* (1992), 386-7.

[52] According to Papadopoulos 2001.

[53] According to Papazachos and Papazachos 1989, 113 and Papazachos and Dimitriou 1991, 167, the earthquake magnitude was estimated at 8.2, while Stiros and Papageorgiou 2001 came up with an intensity of 11 by examining the effects of the earthquakes on human structures and their environment at Kissamos. On the method, which can identify ancient earthquakes and help define their parameters such us intensity, magnitude, epicenter, etc., see also Stiros 1996.

[54] Less than 10 km, according to Papazachos and Papazachos 1989, 229

[55] According to Papazachos and Papazachos1989, 113, 229, TI was estimated at 6.

[56] Pirazzoli *et al.* 1992, 372-3, 387, with all relevant bibliography; Kelletat 1998, 156; Stiros and Papageorgiou 2001, 383. See also Hadjidaki 2001, 155-157; Frost 1997, 112-114; Hadjidaki 1990, 358 and Hadjidaki 1988, 446, n. 6; *Atlas* 2002, 229. For a general overview of the seaquake, see Jacques and Bousquet 1983, 183-193; Papazachos 1989, 229-230; Spyropoulos 1997, 39-42. On the Hellenic trench see Papazachos and Dimitriou 1991, 166-167; Le Pichon and Angelier 1979.

[57] Price *et al.* 2002, 180 and n. 32; Stiros and Papageorgiou 2001, 392, with further bibliography. Also, Papazachos and Dimitriu 1991, 162. Kelletat 1998, 160. Antonopoulos 1973. Dominey-Howes 2002, 208-210.

[58] On the distruction of the city of Kisamos in west Crete by the same earthquake see Stiros and Papageorgiou 2001, 381-397.

[59] Price *et al.* 2002, 171-173 and 175-177, 195-200 with more specific observations at Sphakia shoreline; Kelletat 1998, 159-161, and Abb. 2. Pirazzoli *et al.* 1992, 372-3, 387. See also Hadjidaki 2001, 155-157; Frost 1997, 112-114; Hadjidaki 1990, 358 and Hadjidaki 1988, 446, n. 6; *Atlas* 2002, 229. Stiros and Papageorgiou 2001, 384.

[60] Ammien Marcellin 26.10, 15-19.

[61] Pirazzoli *et al.* 1992. See also Price *et al.* 2002, 187 with previous estimations.

[62] Price *et al.* 2002, 187-195, 200. The research contacted has been based on the Bayesian approach and new calibration data. If this is proved to be correct in the future, then it will reinforce the results of the research of Dominey-Howes *et al.* 1998, who found no evidence of a tsunami dating around AD 365 in their analysis of putative tsunami deposits in Phalasarna harbour.

[63] On the tsunami layer and its contents in fossil fauna see Price *et al.* 2002 178-179; Pirazoli *et al.* 1992; Dawson1996, 204-205.

[64] Pirazzoli *et al.* 1992, 387-390.

[65] This does not of course apply to other, populated cities of Crete, which were heavily damaged. See for example Stiros and Papageorgiou (2001), with respect to the nearby Kissamos.

[66] On the Phalasarna harbour, defensive constructions and other installations in general, see Stefanakis (2006) with all relevant bibliography.

[67] On the «Physiker» ancient authors, who perceive natural disasters simply as phenomena of the nature and the «Denker», who perceive them as godly punishments, see Lafond 1998, 121-122.

[68] Mitra 2002, 52. The most vulnerable profession to natural disasters in antiquity were traders, for their wealth depended on overseas trade and their property was exposed not only to natural calamities, such as stormy seas but also to banditry. The risk being so high, the traders adopted various financial strategies. See Mitra 2002, 53. For the earliest records of private intitatives to mitigate risks from disasters in antiquity, in the form of insurance as a financial tool, to offset different forms of hazards, see Cutter 1993, 33-54.

[69] See also Chaniotis 1998, 406-407

[70] On these opinions see Mitra 2002, 40.

[71] On the potential value of case studies to disaster management, see Dominey Howes 2002. Although previous research has adopted a simplistic approach, correlating the scale of the event with the scale of human response, Hanson 2005 demonstrated that diverse human cultures had well-developed and coherent strategies which facilitated their response to extreme natural events.

[72] Zeillinga de Boer and Sanders 2004. But, they add, *«they lead to a sequence of other events that can last for centuries»*.

[73] On the short and long-term consequences of extreme natural events on patterns of cultural change see Torrence, R. and Grattan, J., 2002, where the authors, by studying the impact of hazards upon human cultures in a wide variety of contexts, explore theoretical issues and provide the conceptual tools to determine when a natural event becomes a cultural disaster. See also Tainter 1988 and Diamond 2004.

[74] On interpretive failures of archaeologists see Helly 1998; Zangger 1998 and Lohmann 1998.

[75] Mitra 2002, 35. On natural disasters and archaeology see also Bawden and Reycraft 2001. On siences and archaeological interpretation of past natural disasters see Marzoff 1998.

[76] Mitra 2002, 35. Human population begun to increase only during the last two millennia, closing up in the past few centuries, as a result of unprecedented economic development.

[77] Ortolani *et all.* 2005

[78] For more details on the aftermath and the consequences of the great Sumatra tsounami see Focossi.