Reply to "Comment on 'The 373 B.C. Helike (Gulf of Corinth, Greece) Earthquake and Tsunami, Revisited' by Stiros (2022)" by Dora Katsonopoulou and Ioannis Koukouvelas

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Abstract

This reply is a response to a comment criticizing a recent article proposing a new scenario for the 373 B.C. earthquake, derived from ancient texts. This earthquake and a following tsunami are reported to have destroyed Helike and Boura, two ancient Greek towns, which then were found submerged into the Gulf of Corinth, punished by Poseidon, an ancient Greek god. The comment contested the new scenario that these ancient texts reflect a later legend, of Roman times. The comment is unsubstantiated, because (1) ruins of the two towns, invisible till recently, have been found in archaeological excavations, without any signs of a marine regression, while no significant marine regression is derived from sedimentological data; (2) Helike and Boura were town–states consisting of smaller villages, located at elevations above 20 and 500 m, respectively, and their subsidence into the sea was impossible; (3) ancient authors writing shortly after 373 B.C. ignore the loss of Helike and Boura; and (4) ancient texts reporting the loss are much later, of Roman times (>200 yr after 373 B.C.), and they reflect a local legend and manipulated or forged ancient texts, for example by pseudo-Aristotle. The scenario proposed in *Seismological Research Letters* represents the only realistic explanation for the ancient texts referring to the 373 B.C. earthquake.

Overview

Ancient authors report that Poseidon, God of seas and earthquakes, punished two sinful cities, Helike (located a few kilometers from the coast) and Boura (located in the mountains) with a cataclysmic earthquake and a tsunami; as a consequence, the two towns disappeared under the waters of the Gulf of Corinth, Greece, in 373 B.C.

These ancient texts have excited much interest in the search of the two towns in the last 50 yr. This was because no building remains, especially of Helike, had been found, and hence the ancient texts appeared to reflect true effects and not another myth of the ancient Greek and Roman World. However, recent archaeological excavations have brought to light remains of the two towns on land, some shown in photos in Stiros (2022; hereafter, S). Therefore, one would expect that the case would have been closed, and the main remaining problem would have been to explain when and how the legend of cataclysmic effects in 373 B.C. was born and developed.

This was in fact a main output of S, who concluded that these ancient texts reflect a much later legend of earthquake catastrophe, of the Roman times, >300 yr after 373 B.C. This result was based on a new approach, classification of the relevant ancient reports and of their details as a function of time since the earthquake (Stiros, 2020). Results of previous studies, especially from the Greek Archaeological Service, mostly ignored by other investigators (see S for details), were also taken into consideration.

The previous conclusion was supported by interdisciplinary evidence. For example, stratigraphic data showing no significant crustal deformation of the Helike delta plain (Engel *et al.*, 2016), and analysis of coins indicating that ancient Helike existed as an independent town–state producing coins for many decades after its alleged loss (Weir, 2017).

It is important to clarify that ancient Greek town–states consisted of several small towns and villages spread in broad areas covering areas of tens of square kilometers at minimum. For this reason, an ancient Greek town–state could not have been "lost in the sea" or "swallowed by a chasm" during a single earthquake; this is indeed what modern seismology predicts for such cases. The "loss" of Helice and Boura, therefore, represents one of the numerous ancient legends involving crime and punishment by gods, a legend probably related to an earthquake to which Aristotle assigned no noteworthy destructions.

Unfortunately, the comment of Katsonopoulou and Koukouvelas (2022), thereafter K&K, disputes these crystal-clear conclusions and various points of S, confusing the reader. In particular, the comment avoids focusing on a basic point:

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That remains of ancient Helike and Boura have been found without any sign of subsidence in the sea, so that any reports of their "loss" under the sea can only represent an ancient legend. This is especially striking for Boura, which was located in the mountains, but it was reported by several famous authors of Roman times (Seneca, Ovid, Pliny, Diodorus, etc., see table 1 in S) to have been submerged into the sea and/or to have been attacked by a tsunami.

Two other basic problems in K&K can be noticed. (1) The comment simply repeats ancient texts without any evaluation and investigation whether they can have a physical basis. (2) Most of the arguments in the comment are not consistent with main results of the "Helike Project." In particular, although K&K support the idea of a major seismic drowning of the Helike, Koukouvelas *et al.* (2020) are explicit that in 373 B.C. the tsunami had minor, if any, impacts, and that no coastal subsidence occurred. It is not easy to explain this inconsistency.

I believe that this overview fully covers the comment, but in order not to leave any reasonable doubts about the validity of the conclusions of S, the basic claims of K&K are examined subsequently.

Criticism of K&K to Analysis of Ancient Texts by S

The main argument of K&K: a forged text

K&K argued that there exist ancient sources dated shortly after 373 B.C. which mention the catastrophe of Helike, and they argue that "Stiros attempts to discredit Aristotle [who is regarded as a contemporary source of information for Helike, my addition] by attributing the text mentioning the names of both cities to a later fabrication – pseudo-Aristotle. (p. 7)" As is clearly explained in S, the "loss" of Helike and Boura is nowhere mentioned in the genuine works of Aristotle who was writing some decades after 373 B.C.; the "loss" of the two towns is only mentioned in the book "de Mundo" ("on the Cosmos", synoptic reference: Mu. 396a in the Comment) which is wrongly presented by K&K as an authentic work of Aristotle. De Mundo is clearly a later, forged text. To avoid any doubts, in the Introduction of the Harvard-Loeb edition-translation of this text, selected because K&K refer to it, it is stated: "it is almost universally agreed that this treatise [De Mundo, my addition] is not a genuine work of Aristotle. … The probability is that it was a deliberate forgery" in Roman times" (Furley, 1955). Hence the argument of K&K is false and confirms the idea that the postulated "loss" of Helike and Boura was ignored by authors of the Greek period (i.e., for about 200 yr after 373 B.C.), as first noticed by careful investigators, for example Petropoulos (1983).

The second main argument of K&K: physically impossible and inconsistent with their results

According to a surviving text of Strabo (first century A.D.), Eratosthenes, a famous third century B.C. geographer, is supposed to have seen ferrymen serving the submerged area of Helike, and K&K present this text as evidence of major coastal subsidence in 373 B.C. As explained in S, this indirect reference to Eratosthenes is not confirmed by any other textual evidence, and it can only reflect a later, local legend involving Eratosthenes, a famous person in antiquity, to give weight to the story. The original text of Strabo was probably "it is said that Eratosthenes reports that …" (i.e., reflecting a rumor, to adopt the term of Weir, 2017) which was changed to "Eratosthenes reported that…." This change in ancient Greek was derived from a change of one single alphabet letter, and it was due to a slip of the pen in repeated handwritten copies for >1000 yr, until a last copy of the manuscript of Strabo, partly destroyed by aging and mice, was found, completed, and published (compare with Sánchez Vendramini, 2018). This clarification prevents from assuming that Eratosthenes, who was the first to measure the radius of the Earth, reported unrealistic catastrophic events. If a seismic subsidence had indeed disrupted a coastal road in the Helike area, the simplest solution would have been a short by-pass road along the coast, not a ferry.

If, however, K&K still believe that the information on subsidence and ferrymen is valid, they should draw on a map the approximate limits of the submerged area and the depth of the water and explain the itinerary of the ferrymen. They should also explain how this scenario is consistent with the recent results of Helike Project summarized in Engel *et al.* (2016) and Koukouvelas *et al.* (2020) who exclude the possibility of any significant coastal change in 373 B.C.

One could assume that the error of K&K with historical data is that they insist on a formalistic interpretation of ancient texts. This is definitely not the case, because Koukouvelas *et al.* (2020) propose that ancient authors who reported coastal subsidence and tsunami were in fact meaning river flooding; or in other words, K&K argue that the ancient authors could not realize the difference between marine effects and river flooding effects.

Criticism of K&K to Archaeological Evidence

"S" is criticized because he "makes selective use of archaeological finds from the Helike area to suggest that they either predate or postdate the 373 event." This is not correct. For example, Figure 4c in "S" shows an excavation covering many centuries of continuous occupation before and after 373 B.C. Some emphasis given in S on undisturbed layers predating and postdating 373 B.C. represents a typical stratigraphic argument for an overall crustal stability and of course a basic argument against the possibility of a major crustal deformation in 373 B.C.

Criticism of K&K concerning Paleoseismic Data and Their Implications

Local hazards

K&K suggest that S "considers that there was no risk of the city's loss in this area due to local hazards."

It was clearly explained in S that ancient Greek towns–states, including Helike, consisted of several villages and small towns spread into different geomorphic environments at distances of several or tens of kilometers. For this reason, it was impossible for a whole town–state to be "lost" during a single earthquake as noticed in the overview. Any ancient town–state could of course have been destroyed by an earthquake (in fact a destruction layer is shown in a figure in S), but definitely it could not be "lost" or submerged into the sea, especially if it was at an elevation of >20 m (case of Helike) and of >500 m (the case of Boura).

1861 and 373 B.C. earthquakes

In 1861, an earthquake produced subsidence of a coastal strip of unconsolidated alluvium in the Helike area, and this is regarded by K&K as "analogous to the ancient 373 B.C. event." This comparison is out place. Coastal slumping caused by an ordinary earthquake (the 1861 earthquake of magnitude 6.4 derived from macroseismic observations; Ambraseys, 2009) has nothing to do with a cataclysmic ground subsidence implied by K&K (drowning of inhabited land at an elevation of >20–30 m for Helike and of >500 m for Boura).

Earthquakes and cult of Poseidon

K&K argued that the cult of Poseidon in Helike was due to frequent earthquakes because Poseidon was the god of earthquakes and waters. This is not correct. According to ancient texts, the cult of Poseidon was imported with the people who colonized Helike many centuries before 373 B.C., and this is confirmed by excavation data showing older shrine remains beneath the temple of Poseidon at Helike (Gadolou, 2011; Kolia, 2011).

Fault pattern in the Helike area

"S" is criticized that two different faults, the Helike and the Aigion Faults are mentioned as a single fault. This argument is typically correct. However, these two faults are among stepped faults that are likely to represent segments of a broader fault (or fault zone) along the south coast of the Gulf of Corinth.

Long faults are necessary to explain large-scale effects such as the impressive bulge-type Quaternary and Holocene uplift along the >100-km-long south coast of the Gulf of Corinth. This uplift is characterized by a mean rate of >3 mm/yr for the last 6000 yr (Stewart and Vita-Finzi, 1996; Pirazzoli *et al.*, 2004) and is also reflected in the 4 m uplift of the harbor of Aigeira, 25 km east of Helike, since Roman times (Stiros, 1998). Interestingly, certain authors of Roman times include also Aigeira in the towns submerged in 373 B.C. (see table 1 in S); this is another proof that the loss of the two towns reflects a later legend.

Were repeated earthquakes in the Helike area ignored?

K&K in their Abstract suggest that "Stiros …wrongly concludes that the area did not experience repeated earthquake phenomena." This is not correct; in various points in S frequent earthquakes in the study area and the wider area were mentioned, whereas figure 4d in S shows the destruction layer from a possible earthquake at around 290 B.C.

Citation of Previous Studies

A final point worthy of notice is the allegation that S ignored the publications of the Helike Project, but he mentions 50 yr old articles. This allegation is out of place; 5 out of 44 references in S were from the Helike project. Certain key older articles such as Anderson (1954) and Rizakis (1995) were also cited because they fully cover the study of ancient Helike from the typical historical point of view, they are online accessible to the international audience of Seismological Research Letters (SRL), and in addition, they have fed later investigators. I am afraid that ignoring these references would violate publication ethics.

Conclusions

- The allegations of K&K are unsubstantiated, no cataclysmic effects occurred in the Gulf of Corinth in 373 B.C., and the arguments and conclusions of S are in line with valid results of the Helike project (Engel *et al.*, 2016; Weir, 2017).
- The arguments of K&K are in variance with their recently published results that no important coastal changes occurred in the Helike area in 373 B.C. (Engel *et al.*, 2016; Koukouvelas *et al.*, 2020).
- Ancient texts referring to earthquakes and to other natural events should not be considered as a "holy book," and they should be evaluated using valid archaeological, seismological, and other scientific data, but in a way respecting ancient authors.

Addendum

In their comment, K&K exploit the mutual convergence process in the Discussions in SRL, and they added some paragraphs. Hence this comment became a comment both to the published article and to the reply. The good thing is that in these last paragraphs of the comment, there are included arguments, which in fact confirm the validity of the arguments of S. Just three points.

1. In the last but one paragraph, K&K cite a sentence from Weir (2017) to support the idea of destruction of Helike by a dreadful tsunami. However, this sentence was followed by the expression "But even if one is unwilling to support *so daring a hypothesis*, ……" (my emphasis), indicating the view of this author. This critical sentence was omitted, biasing the reader.
2. Although K&K try to support the idea of a dreadful tsunami as noticed earlier, in the same paragraph, they jump at the idea that the 373 B.C. tsunami was minor. However, in the

last paragraph, they do not hesitate to criticize S for "neglecting … historical sources reporting the 373 B.C. Helike earthquake and tsunami." Avoiding these inconsistencies, it can be argued that if this tsunami was minor, why was it reported by ancient authors for centuries? Either the tsunami was important (and hence it had left traces, which, however, do not exist), or it was just a later legend, as S showed.

3. In the last paragraph, the argument that historical sources are neglected by S is wrong. Several tables in S indicate that ancient sources were systematically examined and evaluated. Unfortunately, K&K cannot understand that while ancient manuscripts represent a wonderful source of seismological information, they mix reality with fiction (legends for gods, heroes, etc.), and in addition, they have been corrupted because of repeated copying over the centuries (see Sánchez Vendramini, 2018). For this reason, ancient manuscripts must be "filtered" and evaluated before any use. This is exactly what S has done.

Data and Resources

The source of all data used is indicated in references. Ancient texts discussed were obtained from searches in the Library of the British School at Athens, the Loeb Classical Library (www.loebclassics.com/), and the Perseus Digital Library (www.perseus.tufts.edu/hopper/). All websites were last accessed in February 2022.

Declaration of Competing Interests

The author acknowledges that there are no conflicts of interest recorded.

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