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Review Article

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From Thermopiles to Marathon: Teaching the theory of evolution through a short tour to paleontology of Greece

Kyriacos Athanasiou [1]*

[1] University of Athens, Athens, GREECE
***Corresponding Author:** kathanas@ecd.uoa.gr

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ABSTRACT

The present work is an attempt at a bibliographic overview in the field of paleontology and specifically in the field of fossils regarding their value and connection with history and mythology, and how it has been used to teach theory of evolution through natural selection (TENS) in a university course. To make our case, we use as our paradigm two well-known historical locations of Greece, namely Thermopiles and Marathon. The area of Marathon includes the location of Pikermi, which is very well known for its fossils that historically have been one of the first locations rich in fossils that have been studied so extensively. Before we make a short tour of other similar locations of the Greek peninsula that are good cases for teaching evolution using paleontology, we present an example of how fossils can be formed via sedimentation. For that, we are using the case of Thermopile, while in antiquity was chosen as the field of the famous battle as it was a very narrow strip of land between the mountain and the sea, nowadays, due to sedimentary alluvial deposits, has become a rather large field. To make the reader familiar with the fossils found around Greece and their topology, we present a short tour and some history about the fossils found throughout its territory. And finally, we argue about how the fossils and the museum education could be used to prepare the pupils for first contact with TENS.

Keywords: Pikermi fossils, museum education, paleontology, evolution teaching

INTRODUCTION

How Fossils Are Formed: The Case of Thermopile Area

It is well known to most teachers of biology and evolution that one very effective tool to teach evolution through natural selection is the use of fossils in their teaching. Indeed, in a previous communication, we have suggested the idea (Katakos & Athanasiou, 2020). Another interesting detail related to the previous one is the fact that students have difficulty answering the question "how the fossils are formed". Indeed, as a professor of various biology courses based on evolution, with a service in the university that exceeds 30 years (Athanasiou, 2022), I rarely or never get a nearly correct answer from the student's audience, when I address the question "*how, in your opinion, the land usually extends into the waters of the sea or a lake?*" We know that the condition for a fossil to form is the occurrence of sedimentation over decades or centuries. One such case is the case of the area of Thermopylae, which in antiquity was a narrow strip of land, while nowadays extends to an area of some square kilometers, due to sedimentary layers. Thus, we use the case to explain some phenomena related to the formation of fossils before we introduce the very well-known fossils found in Marathon that are now known as the *Pikermi fossils*.

Some Ancient Greek History

We all know from history that the king of the Persians Xerxes in the year 480 BC wanted to punish the Greeks for the defeat that had preceded it in the battle of Marathon, some 10 years earlier. The Battle of Thermopylae between the Achaemenid Persian Empire under Xerxes I and an alliance of Greek city-states led by Sparta under Leonidas I. So, the area of Marathon is very well known for the Battle of Marathon, the victory of the Greeks, and the Marathon run, in memory of the Athenian runner named Pheidippides who carried the message of victory to the Athenians, he run promptly the 44 km that is the distance between Marathon and Athens, before he dies out, spelling the word "*Nenikikamen*", which means "we won". We must add at this point that, the area of Marathon is well known to geologists and paleontologists for another important fact, as well: at some region in the Marathon valley exists the Pikermi area, where some of the most well-known fossils have been found, and the area has been named as the acropolis of paleontology [We come to this point later in the discussion].

Due to all these events that preceded, the very king of the Persians decided to punish the Greeks. For that reason, he

Figure 1. Contemporary picture from the location known as Straits of Thermopylae (Source: https://www.alithia.gr/magazine/psyhagogia/taxidia/thermopyles-poy-vrisketai-steno-poy-egine-i-istoriki-mahi-kai-pos-einai)

started running a campaign with hundreds of thousands of soldiers. The rest of the history is quite well known as historical events: the decision of the king of Sparta an attempt to stop Xerxes and his hordes of Persians, his answer "*molon lave-come and take*", the famous battle, the sacrifice of the 300 Spartan soldiers of Leonidas, and so on. The scope of the paper is not, of course, to present ancient history, but to combine the well-known historical place of Thermopylae with the mechanism by which fossils are formed.

Thus, it is time to move forward to our critical point, related to the case: The two significant questions we always present to our students' audience:

First question:

1. Why the king Leonidas of Sparta chose Thermopile to give his battle?

The answer to this question comes promptly from most of the students in an easy way:

> Because Thermopiles, in that era formed a narrow path, between the mountain and the sea, and so, it was easier for a small army to face a huge one.

When we come to the group of next questions, the correct answers are not so frequent:

2. Have you been to Thermopylae lately? If no, look at the picture in **Figure 1**.
   a. Do the Straits of Thermopylae exist today*?*
   b. *If no, how did the sea come to stand, nowadays, some ten km away from the mountain?*

Sediments as the Mechanism of Fossils' Formation

When we come to this point, students are ready to understand one of the main mechanisms of fossil formation, namely, the sedimentation and burial in layers of inorganic and organic matter. This happens usually, due to the existence of a river in the area, that strays solid materials throughout thousands or millions of years, accompanied by the confinement of solid remnants of living organisms, the fossilization, and the emergence of the fossil due to geological phenomena, etc. Of course, we remind them of the existence of the river *Sperchios* that runs nearby, and we always combine our lesson with the well-known description of the case of Grant Canyon-Green River in the USA (US National Park Service, n. d.).

METHODOLOGY

The Marathon (Pikermi) Fossils

The major area of Marathon, as mentioned earlier, is well known globally for the famous battle. What is not known to many is the fact that the area is very familiar to geologists and paleontologists for the richness in fossils that have been found within a range of 20 km of the location, where the famous Battle of Marathon took place. One such point is the Pikermi location, which for reasons explained later in the paper, has been named as the *acropolis of paleontology* (Kathimerini, 2017).

Why Pikermi Was Named as the "Acropolis of Paleontology"

The heritage of fossils in Greece was discovered about two centuries ago by Greek and foreign scientists. Pikermi is considered one of the key reference localities of the European continental Upper Miocene (Roussiakis et al., 2019) due to the diversity of its faunal composition and the fact that it represents the type locality of several *Turolian* vertebrate genera and species. The significant palaeoecological context of the locality has led to the establishment of the term "*Pikermian biome*". As for the fossils discovered in the 19th century on Greek soil, they seem to have provided the impetus for further engagement with paleontology and its integration into the educational field. More specifically, in 1835 when the English archaeologist G. Finlay (1799-1875) was looking for ancient finds in Pikermi, he found some fossilized bones to which he did not give much weight. At the same time and in the same spatial area, a Bavarian soldier found bones of animals, on the edge of which some crystals shone. Considering that they were diamonds, he took some of them and sought the advice of Wagner (1839). He concluded that it was the petrified jaw of a monkey that had lived millions of years before in the area. This discovery significantly affected the society of paleontology as Marinos and Symeonidis (1975) point out and from this point onwards several excavations followed in Pikermi with the Greek team of Professor Mitsopoulos taking over the baton of the excavation and delivering it to the University of Athens where it is found until today (Mitsopoulos, from Symeonidis, et al., 1973).

In the years 1855, 1862, and 1869 the French expedition with Professors Gaudry (1862-1867) and Larter carried out substantial excavations, and the former published a monograph on the recording of Pikermi fauna (Gaudry, 1862-1867). In correspondence between Gaudry (1862-1867) and Darwin (1868), the two researchers exchange views on the extinctions of species and the decisive role they play in the evolution of species. As Gaudry (1862-1867) is referring to "missing links between species that survived and others that have disappeared", seems to give decisive answers to Darwin's (1868) questions concerning the extinction of certain species

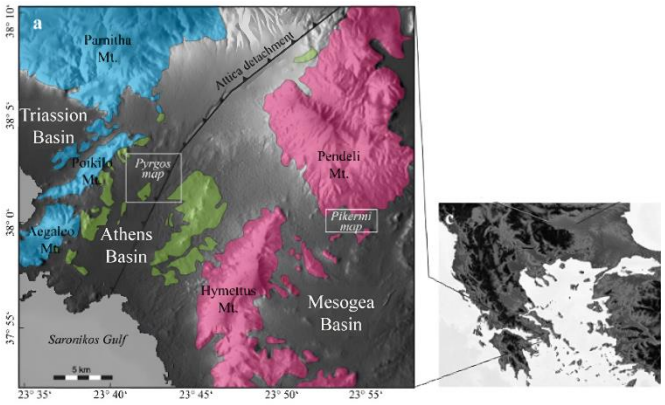

Figure 2. Map of Pikermi (near Marathon) area, showing Mt. Pentelikon as mentioned by Darwin (Source: https://novoscriptorium.com/2019/06/25/)

that had troubled him about theory of evolution by natural selection. As Apostolidis points out in an article in the Greek magazine "Ilissos'' in 1871, "*Gaudry (1862-1867) discovered in Pikermi, Attica, many fossils of peculiar animals, which prove the unity of many mammalian relatives or others very repugnant to each other*." Therefore, the publication of Gaudry's (1862-1867) findings from the Pikermi offered the opportunity to complete Darwin's (1868) evolutionary tree of life and greatly influenced his work. Moreover, in 1885 the Austrian researchers Neumayer and Van Tausch carried out further research in the Pikermi area for the Academy of Vienna (Roussiakis et al., 2019; Theodorou et al., 2010; Woodward, 1901).

Darwin (1868) recognized the importance of Pikermis' fossils and expressed his gratitude to Gaudry (1862-1867) through a letter that was written on November 17th, 1868, responding to him very gracefully:

> "On my return home after a short absence I found your note of November 9th, and your magnificent work on the fossil animals of Attica. I assure you that I feel very grateful for your generosity, and for the honor, which you have thus conferred on me. I know well, from what I have already read of extracts, that I shall find your work a perfect mine of wealth. One long passage, which Sir C. Lyell quotes from you in the 10th and last edition of the "principles of geology" is one of the most striking, which I have ever read on the affiliation of species."
>
> "In how different a light does the question of the nature of species now present itself to us from that in which it appeared only twenty years ago, before we had studied the fossil remains of Greece and the allied forms of other countries. How clearly do these fossil relics point to the idea that species, genera, families, and orders now so distinct have had common ancestors. The more we advance and fill up the gaps, the more we feel persuaded that the remaining voids exist rather in our knowledge than in nature. A few blows of the pickaxe at the foot of the Pyrenees, of the Himalaya, of Mount Pentelicus in Greece, a few diggings in the sandpits of Eppelsheim, or in the Mauvaises Terres of Nebraska, have revealed to us the closest connecting links between forms, which seemed before so widely separated. How much closer will these links be drawn when Paleontology shall have escaped from its cradle!".

From the year 1971 onwards, the second period of excavations began in Pikermi, which has been named the "*acropolis of paleontology*", where, as the supervisor of the studies, Professor N. Symeonidis, characteristically mentions, "on a surface of ten square meters, about 1,200 pieces of bones, skulls, donkeys were included." Through these findings, scholars from all over the world gathered valuable information about the evolution of species, geography, and biodiversity that prevailed in the wider region in the past. As he observes, "*the earth is a book, whose pages are its layers and its letters are the fossils*" (Symeonidis et al., 1973) and it appears that valuable and until that moment, unexplored treasures emerged on the surface (Marinos & Symeonidis, 1975).

Figure 2 shows the map of Pikermi.

Fossils Were Known to Classical Philosophers and Writers of the Greek Antiquity

Fossils are considered important keys to the exploration and study of the history of the Earth. They are the links in the chain of evolution of organisms in time and a station for geological research. The discovery of fossils has its roots in antiquity. Recent studies show that as early as the 8th century BC, the ancient Greeks linked the discovery of fossils that they found in Greece with the existence of mythical creatures. Monsters, hybrids, and giants are just some of the versions of species that were the main protagonists of myths and writings about the origin and evolution of life on the planet. In each mythical narrative, a key role was played by a particular creature, which was part of the heroes' adventure. *Hesiod*, the famous ancient Greek poet, writer, and mythographer (7th century BC) presents in his work *Theogony* myths concerning the creation of the world, gods, titans, and giants, which attests to the knowledge of the existence of various organisms before human appearance and their involvement in the formation of legends and stories (Dowden, 2011). However, in ancient *Ionians* about 700 years before the birth of Christ, several Greek philosophers began to observe the properties of the universe and to understand that the world is governed by natural laws. Some of them such as *Thales of Miletus* (640a-550 BC), *Pythagoras* (580-500 BC), and *Herodotus* (484-425 BC) will also realize that fossils are related to remnants of existing organisms.

Plutarch, the well-known ancient Greek writer, and politician (45-120 AD) observed some fossilized bones found in the village of *Mytilinioi* of Samos Iceland (Solounias & Dawson-Saunders, 1988), refers to the bones of the *Amazons* (mythological women fighters), while *Pausanias*, the ancient Greek traveler and geographer (110-180 AD) encounters in a sanctuary of ancient God *Asclepius*, some huge bones, which, according to him, belonged to giants who protected his mother, the goddess *Rhea*. In 675 BC, when the Greek traveler, *Aristaeus*, visited Scythian nomads in the Gobi deserts, the nomads told him about an area beyond Sidonia where griffins defended gold from the nomads. *Aristaeus* wrote that the nomads would battle the griffins and that Issedonian accounts

portrayed these creatures as lion-sized, with curved beaks like eagles (Mayor et al., 2014).

In 1922, the American adventurer Roy Chapman Andrews followed caravan trails through China to the *Gobi Desert* and found the fossilized remains of various dinosaurs, like *Protoceratops* (the size of a lion) griffin, as described by the Scythian nomads and *Psittacosaurus* (which has a prominent beak). These fossil bones combine to form the image of the Greeks, Romans, and other cultures (Kostopoulos & Koufos, 2015; Solounias & Mayor, 2004).

Early Pikermi Excavations After the Greek Revolution

Of course, Pikermi is not the only treasure of fossils that have been discovered throughout Greece. Before we proceed to that, let us describe the background of the Pikermi discovery, to make the reader familiar with the fact that the vast majority of the Pikermi fossils have been transferred to natural museums all over Europe. We must mention that the contemporary history of the Greek state begins in the year 1821, which is the year of the revolution against the Ottoman occupation that started almost 400 years earlier, with the fall of the Byzantine Empire. Thus, the year 1835 AD, which is the year of Pikermi's discovery, finds Greece in her very early years after liberation from the Ottoman occupation, after a devastating revolution and war for liberation. A liberating war that led the already poor country to famine and despair. Consequently, the country lacked any native scientists, academics, and archeologists that might have done any excavations and studies on the fossils found. Therefore, the discovery, evaluation, and study of Pikermian fossils could be made only by foreign scientists, like Roth, Wagner (Roth & Wagner, 1854) or Gaudry (1862-1867). With the consequence that most of the fossils were exported to France, Austria, England, etc., and they are exhibited in the Museums of Natural Science of them (Kyrikou, 2021).

Nevertheless, other important fossil findings were found later in Pikermi in a second period of excavations that took place mostly by Greek paleontologists (Roussiakis & Iliopoulos, 2004). In 1853, Hercules Mitsopoulos, professor of natural sciences at the University of Athens, led the first excavations carried out by a Greek team. In 1854, the physician Aristeides Chairetis undertook a minor excavation and sent some material to the Natural History Museum of Paris, which became the subject of a scientific communication by the renowned zoologist Georges Louis Duvernoy at the French Academy of Sciences (from Roussiakis et al., 2019). This was followed by a plethora of excavations not only in Pikermi but all-around Greece, and the discovery of very important fossil locations and sites of great paleontological interest. Probably, it is worth mentioning that one very important finding among them was the one of the *Graecopithecus freybergi* hominin, dating to 7.2 million years ago, that according to an international team of researchers, the findings entirely change the beginning of human history and place the last common ancestor of both chimpanzees and humans–the so-called Missing Link–in the Mediterranean region (Böhme et al., 2017).

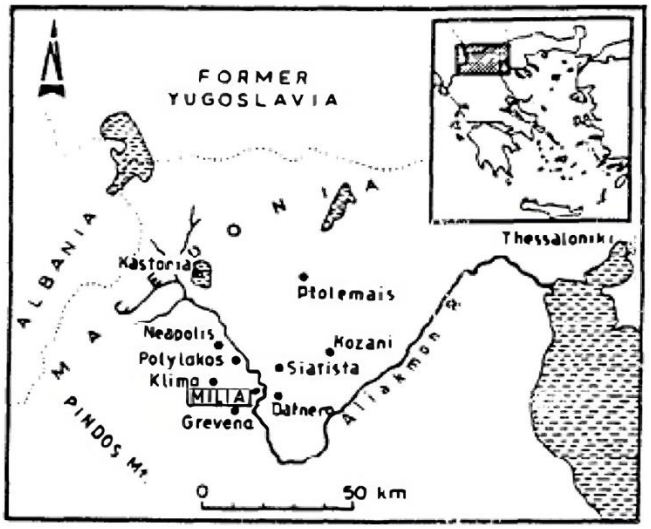

Figure 3. Geographical location of Milia-near Grevena, W. Macedonia in N. Greece (Tsoukala, 2000)

Some Other Places with Important Fossils Found Throughout the Greek Territory

As we have already mentioned in this work, many other locations and sites of paleontological importance have been found around Greece during the last century. In northwestern Greece and more specifically in *Tychero* of Alexandroupolis, the oldest Greek petrified forest is located. It is an excellently preserved natural landscape with obvious details of trunks, leaves, and barks of fossil trees. Also, due to the tropical climate prevailing in the region and the high temperatures thousands of years ago, fossilized leaves of cinnamon, vine and coffee tree are observed (Mposkos et al., 2018). Thus, "*it is considered as a unique natural monument, which belongs to the Greek mineralogical and geological heritage"* (Voudouris et al., 2007). In W. Macedonia, and especially in the villages of *Nostimo* in *Kastoria* and in *Amyntaio* in *Florina*, a wealth of paleontological material has been discovered. In the area of *Nostimo*, fossils concern marine organisms, plants and animals dating back to 20 million years. The findings in this particular location indicate that there were quite active volcanoes, and that the prevailing climate was tropical. The discovery of fossilized bones makes a great impression, as sharks, mussels and stars are found in the area leading to the conclusion that the area was covered by sea (Sakellariou & Galanidou, 2015).

In a previous our communication we had the opportunity to refer to refer to an educational visit of students to another area of Paleontological importance in Western Macedonia in Northern Greece, namely Milia in Grevena (**Figure 3**), where among the other findings, the excavations revealed the most spectacular exhibit the 5.02 m tall tusk of the three million years mastodon *Mammut borsoni*. There exist today the Museum of Paleontology of Milia and the Environmental Education Center of Grevena, which is a center affiliated to the museum of Milia (Kouzas & Athanasiou, 2019; Lazaridis et al., 2019; Tsoukala et al., 2018).

In the northern part of the island of *Evia*, at the location *Kerasia*, the petrified forest of the area is found with huge, petrified trunks occupying a large part of the site and dating back to seven million years ago (Kampouridis et al., 2020;

Roussiakis et al., 2021). An important feature of the petrified forest are also traces of animals that nowadays are combined with jungle conditions. Hyenas, giraffes, gazelles and rhinos lived about seven million years ago in this place. In *Kimi* of *Evia*, eastern part of the island, numerous fossils of plants and animals are found. Ancestors of today's hippos, pythons and turtles make their appearance in the area offering information material on flora and fauna that prevailed at this point 16-20 million years ago (Kostopoulos & Koufos, 2015).

Another remarkable geological monument is the petrified palm- forest in *Vatika*, Peloponnese. It dates to two-three million years and is remarkable is the way the forest is fossilized. As the sea level rose, the forest was covered by seawater and then sea urchins, mollusks and algae lived there. It seems that, after the forest was covered by sediments and sand, it was petrified through the process of calcification. That is, the matter of the organisms and plants that were there was replaced by calcium carbonate. This fossilization process makes the findings of the area rare and of great paleontological importance (https://www.geocaching.com).

One of the most important geotopes, on a global level, is the petrified forest of Lesvos-Iceland, which has been declared a monument of nature and is included in the network of protected areas by the program "Nature 2000" (UNESCO, 2000). The fossilization of the forest occurred due to the intense volcanic and seismic action in the area about 20 million years ago. During the eruptions of volcanoes, large quantities of ash and lava covered the forest and in combination with the absence of oxygen formed suitable fossil conditions. The findings found in it concern both plant and animal species. In the first category there are pine trees, cypresses, palm trees, tiles, and oaks. In the category of animal organisms dominates the fossil and more specifically the fossilized jaw of a proboscis that lived in the forest. It is the ancestor of today's elephant and its presence on the island indicates its movement from Africa to Europe.

The first references to the fossils of Lesvos can be found in Theophrastus' works. *Theophrastus* of *Eresos*, who was born was born circa 371 BC in the Petrified Forest of Lesvos, was one of the greatest thinkers, scientists, and philosophers of antiquity and the first scientist to consider fossils to which he devoted special attention. A charismatic, observant, and systematic genius, he is unquestionably considered the founder of many branches of science, such as botany, ecology, and mineralogy. Diogenes Laertius refers to an index of approximately 240 works attributed to Theophrastus. The topics of these works are drawn from many areas of cognition, metaphysics, logic, ethics, politics, rhetoric, poetry, and the natural sciences. Later, the first scientific references to the Petrified Forest were made by the Austrian botanist Franz Unger (1800-1870), who made the forest known to the scientific community. Unger described the fossilized trunks in his books on the Past World (1841-1847) and in articles describing his trip to Greece (1862). Unger's publications inspired large numbers of researchers to visit Lesvos and the Petrified Forest in the 19th century to study the natural monument (Smith, 2021; Zouros, 2021).

The area of Mytilinioi on the Island of Samos has located another point of great paleontological interest. It was discovered in the 19th century by Italian explorers, who located and transferred their findings to the University of Padua in 1852 (Solounias & Mayor, 2004). The fossils mainly concern bones of mammals that lived six-eight million years ago in the area and more specifically they are hyenas, giraffes, and antelopes. The island of Samos has given its name to two species, the traces of which were found on the island. These are the *Samotherium*, which is classified in the genus of giraffes and the *Samokeros*, which concerns the genus of cattle. This is evidenced by the fact that in the village of *Thymiana* on the island of *Chios* fossils from early species of mammals were found that lived at that time in the region of Aegis. These are the earlier species of the pig, rhinoceros, horse, deer, and canine-dog and it could be said that through these fossils the map of the ecosystem of that time era in *Aegis* is formed and the protagonists of environmental history are completed. Today, these findings are found in the Museum of Paleontology and Geology of the University of Athens and in the Museum of Geology and Paleontology of the Department of Geology of the Aristotle University of Thessaloniki-Greece (AUTH) (Solounias & Ring, 2007).

CONCLUSION

Fossils, Mythology, History, and Education: A Proposal

In a previous communication of ours that has been published in this Journal, we presented an educational intervention about a way of using Paleontology and the visit to one of the corresponding sites in Greece, as described here, namely, the Museum of Paleontology of *Milia* in *Grevena, W. Macedonia*, Greece (Kouzas & Athanasiou, 2019; Vlachos & Tsoukala, 2015) for teaching more efficiently TENS. Furthermore, in another publication of ours (Kalakos & Athanasiou, 2020) we have presented evidence of how useful Paleontology as a teaching tool is, in general, for making students of various levels of study, to be more ready and predisposed to accept and understand TENS. This is a finding that may lead to the conclusion that the "geological argument" is especially strong in the process of accepting the TENS and suggest that they might, therefore, be used more often in the teaching of evolution. With this in mind, we have been implementing for the last 20 years a series of courses taught in department of pre-school education, The National and Kapodistrian University of Athens, a biology course, that uses evolution as its unifying theory (Athanasiou, 2022).

More specifically, an introductory course in biology for non-biology-major students has been organized and applied in which the teaching of THES occupied a central role. The course has been taught for ten consecutive academic semesters during which quantitative and qualitative research procedures were applied, aiming to answer questions related to the teaching of biology. The main issue that was examined, is the feasibility of teaching biology in an alternative way: Is it possible, useful, and applicable, for example, to teach biology, in such a way as to put in the center of biology's introductory courses the evolution as their unifying theory? What is the reception of such a practice by the students? Did they understand basic concepts of biology as the result of evolution and not as procedures leading to it? Can we change the structure of the curriculum and biology textbooks to fulfill

such a rationale? The answers to all these questions were rather positive, according to the response of the students themselves in surveys we conducted after the end of some of the teaching semesters. We assess that much of the success of this course can be attributed to the fact that we used the fossils and the "*geological argument*" as one of our main teaching tools. Analytically, students became familiar in the beginning with the concept of fossils through the didactic example "From Thermopile to Marathon''. Hence, firstly they were taught the way by which fossils are formed, and consequently, they were presented with the "Pikermi fossils". In some cases, a visit to the area of the Marathon and the Pikermi museum was organized. To follow, an online short tour of some of the paleontological locations that are described earlier, like the *Lesvos Fortified Forest*, the Grevena/Milia founding, etc. (Vlachos et al., 2018; Vlachos & Tsoukala, 2015).

Another issue that could be brought up at this point concerns the connection of fossils with mythology within the framework of education, especially preschool and early-school education. The fossils could form the basis for making pupils acquainted with the appearance of life on the planet but also be linked to history and mythology. However, this seems to be missing as a didactic approach from ours and many other education systems (Fragouli, 2018, Kanari & Souliotou, 2020). Therefore, it is suggested that the formation of an educational material in which the fossils, e.g., of Lesvos, Samos and Pikermi are highlighted and connected with the presence of myths and stories related to the fossils that were known in antiquity in these areas. Thus, it might be rather useful in connecting Mythology and History with Science and Biology Education. A rather good idea might be to formulate an educational program for the exploration by the students at the primary school of fossils and their association with mythology. There will also be a virtual museum, where information and data will be provided for the connection of fossils and mythological creatures. Thus, it will help pupils of the present to understand the approach of the people of the past regarding the findings unknown to them, whose presence was inexplicable, and on the other hand, the appearance, and the way of origin of myths and legends related to some imaginary creatures.

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Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to author.

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