NATIONAL TECHNICAL UNIVERSITY OF ATHENS

SCHOOL OF RURAL, SURVEYING AND GEOINFORMATICS ENGINEERING

GEOINFORMATICS POST-GRADUATE PROGRAMME

WEB-GIS AND DIGITAL CARTOGRAPHY APPLICATIONS FOR THE DEVELOPMENT OF AN INFORMATIVE ONLINE PLATFORM (STORY MAP) FOR NORTHEASTERN ATTICA, GREECE.

MSc Final Thesis

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Acknowledgments

The following dissertation has been carried out at the Department of Cartography, School of Rural, Surveying and Geoinformatics Engineering of the National Technical University of Athens. During the writing of this I have received a great deal of support and assistance.

First of all, I would like to thank and express my gratitude to the first supervisor of this work, Dr. Eleni Tomai from NTUA. I thank her for providing me with precious and determining information regarding cartographic applications and Story Maps and for her patient assistance during the development process of the one presented in this thesis.

Furthermore, I would like to acknowledge my second supervisor, Dr. Varvara Antoniou from NKUA. She provided me with an inspirational framework and a motivational way of thinking not only to complete this thesis but throughout both of my undergraduate and postgraduate studies. I thank her for guiding me through the process of scientific thinking and for assisting me during my entire academic course.

Also, I would like to express my gratitude to the president of the post-graduate program, Professor Marinos Kavouras, the third member of the examining committee. He gave me the chance to realize my initial idea into the final results of this thesis, through the cooperation of the two academic institutions that guided my restless mind towards science, NKUA and NTUA. His insightful feedback pushed me to sharpen my thinking and bring my work to a higher level.

In addition, I thank with all my heart the members of my family, including my parents and sister, as well as my grandparents. It is due to their consistent feedback and immeasurable support that I managed to success in my studies and become who I am. They are my cornerstone for accomplishing everything that I have achieved so far. My parents' vital support during the field excursions (and their assistance in the field as well) can't be stretched enough.

Finally, I could not exclude the support I received from my friends inside and outside the university, Frank, Vivian, George M. (who assisted me in one of the field excursions at Penteli), Konstantina, George S. and Athena. They provided stimulating discussions as well as happy distractions to rest my mind outside of this thesis.

Abstract

In the 21st century, societies are exposed to a wealth of information related to different topics, including data arising from many scientific fields. However, it is the management and perception of these data that will ultimately render them useful to as many people as possible. More understandable and functional data can lead to significant advancements, not only in each related field of expertise, but also in the education system of the broader public. This is particularly useful when it comes to the dissemination of scientific data, thus it is essential to prioritize the development of innovative and effective approaches for conveying scientific research findings to the public. This thesis takes on this challenge and focuses on disseminating knowledge pertaining to the geological heritage of Penteli Mountain and the Marathon region, with its intricate interconnection to cultural heritage, a connection arising from the historical development and interaction of human civilizations with their respective natural environments. The goal is accomplished through the creation of a Story Map, an online interactive platform combining informative text along with multimedia content (photos and videos), as well as interactive 2D and 3D maps. The content is organized in various categories, based on the topic of interest, including the geology, biodiversity and cultural heritage of the study area, while also containing a number of selected paths of interest that aim to connect the platform's users to the real world by motivating them to visit the area themselves. Hence, an extensive comprehension of the area's geological structure and its connection to its history, biodiversity and culture is achieved, aiming to bridge the gap created by the deficiency in comprehension of a subject matter in its entirety, a common phenomenon observed in similar efforts of scientific information dissemination. The thesis begins with a detailed analysis of the available literature on the topics of scientific knowledge dissemination through the use of GIS products, as well as the importance of Geoheritage. It then focuses on the presentation of the study area's geology, biodiversity and cultural heritage, before proceeding to the detailed analysis of the Methodology followed to create the Story Map. The Methodology includes four individual phases, which are the literature review and the primary GIS data collection, the field excursions, the main GIS data curation and processing as well as the construction of the Story Map itself. Finally, a detailed presentation of the content of the Story Map, the first of its kind for this study area, concludes the thesis.

Key words: Information, Dissemination, Knowledge, Education, Public, Science, Data, Maps, Cartography, GIS, Story Maps, Geoheritage, Geology, Culture, History, Biodiversity, Penteli, Marathon, Field Trips.

1. From analogical to digital cartography: Benefits in modern societies information dissemination and education, with GIS and Web-GIS

The effective dissemination of scientific information to a wide audience is widely recognized as a crucial field of study within the realm of research and science. Disseminating scientific discoveries to a broad spectrum of individuals, including both specialists and those without scientific expertise, may serve as a very efficacious means of fostering a connection between the scientific community and the general public. This encompasses the elucidation of fundamental subjects that may have been established for many decades, as well as the explication of recent scientific discoveries. Within the realm of geosciences, maps serve as a crucial medium for effectively conveying scientific knowledge to the general public in a concise manner, alongside research publications, conferences, and general literature.

The field of cartography has seen significant improvements as a result of technical advancements and theoretical and experimental study. Consequently, the approaches have transitioned from being solely analog to being digital, dynamic, and interactive. As a result of the emergence of novel methodologies and advanced instruments for spatial depiction, users have expressed a heightened need for enhanced capabilities. Merely providing a basic, stationary, and two-dimensional cartographic portrayal of space has become insufficient for many. Indeed, traditional analog printed maps have lost their appeal among the majority of users, as an increasing variety of web maps, multimedia, and interactive maps have gained prominence. In order to depict the spatial dimension, it has become imperative to use dynamic settings that prioritize interaction. Digital cartography has become more prominent since it involves the conversion of manual techniques into automated procedures. It serves as a platform for exploring novel approaches to depicting geographical space, hence facilitating the creation of more dynamic and interactive maps (Cubas & Sampaio, 2015).

The traditional use of analog maps, which are printed on paper and supplemented with an accompanying explanatory legend, has been increasingly substituted by the use of digital, interactive online maps. The user is now able to engage with the map, include more data, and use it as a tool for visualizing desired material. According to Antoniou et al. (2018), the expeditious and effortless dissemination of digital, web-based maps is feasible on a global scale.

The advancement of new technology and the increased accessibility of geographic data in recent years have also led to significant advancements in Geographic Information Systems (GIS). A notable development in the field has been the transition towards web-based platforms, resulting

in enhanced accessibility and use of geographic information. The advent of GIS has also revolutionized the way users may generate and disseminate interactive maps and stories using web-based platforms. Platforms like as ArcGIS Online, Mapbox, and Carto provide a diverse range of tools and templates that facilitate the creation of online maps and visualizations. Additionally, these platforms often have collaborative capabilities and data sharing functionalities. The use of web-based GIS platforms has shown a consistent history of enhancing the accessibility and distribution of data. The visualization capabilities offered by these tools enable the examination of geographic data, while also expanding the range of choices accessible to users for the manipulation, analysis, and modeling of existing information (Dragićević, 2004). Consequently, the use of WebGIS is seeing a growing trend across many academic fields, with a number of projects having already used its features to effectively market and increase the appeal of tourism locations. Various potential applications can be identified in the literature. For instance, Antoniou et al. (2021) discuss the development of story-driven web maps that emphasize geolocation. Panagiotopoulou et al. (2018) explore the use of participatory WebGIS platforms to enhance historic town centers. Additionally, Mango et al. (2020) discuss the implementation of dynamic and interactive web-based maps for promoting tourist resources. Furthermore, the study conducted by Kiss et al. (2020) examined the spatial configurations and national approaches of countries towards addressing climate change, highlighting the potential of using geovisualization via freely available WebGIS tools. Recent advancements in virtual reality (VR) technology and its features have furtherly facilitated the development of interactive applications that allow users to be fully immersed in a specific location of interest (Pasquaré Mariotto et al., 2021). The research study conducted by Balla et al. (2020) examined the use of the open-source WebGIS system and Google Application Programming Interfaces (APIs) for the purpose of presenting geovisualization of spatial environmental information.

The rapid advancement of GIS has introduced novel instruments for conducting spatial analytics using intricate datasets including many variables. Maps have long been recognized as the conventional means of visually representing geographical entities or outcomes derived from spatial analyses. In recent years, there has been significant development in the field of Story Maps, making them accessible and applicable to individuals across all levels of experience. The significance of storytelling has seen a notable rise within web-based GIS platforms. As stated by Berendsen et al., (2018), the utilization of digital maps for storytelling serves as a significant method for conveying and conceptualizing the continuous aggregation of data. The aforementioned feature enhances the functionality of interactive maps by facilitating users'

comprehension of intricate spatial connections, hence contributing to an engaging user experience (Thöny et al., 2018). Moreover, extant research indicates that the use of storytelling has the potential to enhance the process of learning and improve the retention of information (Sundin et al., 2018). Additionally, storytelling has been recognized as a valuable instrument that may effectively supplement conventional modes of communication. Story Maps were developed as a means to provide a proficient method for the creation, elucidation, and presentation of stories pertaining to a certain location or subject matter, encompassing several facets. They may feature thematic maps that serve as more than just visual representations; they are essential tools for effective communication.

Hence a story map is an influential method for generating, elucidating, and delivering a story pertaining to any given topic. The identification of distinct facets of a given issue is of utmost importance. Story maps include more than just themed maps, since they serve as an essential means of communication. The provided visualizations are successful in conveying information, since they are robust and informative, using multimedia elements such as images and videos to enhance the story aspect. In a more precise manner, story maps refer to web-based applications that integrate multimedia data, 2D or 3D web maps, and story text with the aim of disseminating the resultant output and fostering engagement and involvement from the audience (Kerski, 2015). Similar to web apps, communication tools enable users to use many elements and data to create intricate stories. The interchange and dissemination of information on many subjects may be facilitated via the use of diverse applications that provide a range of interactive map-based functionalities. These applications are characterized by their dynamic nature and open-source framework. A story map, thus, functions as a tool for the use of "data storytelling" or "data-driven storytelling," in which it is utilized to reveal hidden insights obtained from data and proficiently convey them to consumers.

The use of story map data has seen significant growth, particularly within the realm of education (ESRI, n.d.). Baker (2015) emphasizes the effectiveness of using online GIS and mapping as an instructional tool to augment student learning. The use of a story map enhances the level of involvement, not only with the visual depiction of geographic information, but also with the accompanying written material. There are instances in the field of education when pupils use story maps as a means to investigate and comprehend their surroundings (Esri Community, n.d.). According to Graves (2015), individuals are more inclined to actively participate in a story that effectively captures their attention. Therefore, using a diverse range of textual elements, maps, graphs, video, and audio clips enhances the overall substance of the story. Story maps are a kind

of online application that facilitates the uploading and management of multimedia data. These applications often include the use of an existing map as a starting point, with the ultimate objective of enabling the sharing and active engagement of users (Kerski, 2015). Web apps serve as a means of communication, allowing users to include many functionalities and data to create intricate stories. Due to its open-source nature, this dynamic technology facilitates the sharing and exchange of information across many topics. The tool encompasses a diverse range of applications that provide various methods of engaging with cartographic representations (Kerski, 2016).

Furthermore, Story Maps have the potential to be used by individuals who are not proficient in GIS to disseminate scientific findings and enhance their accessibility and comprehensibility (Wright et al., 2014). The primary benefits lie in the enhanced interactivity relative to traditional maps, the active engagement of all users, and the capacity to simultaneously exhibit a diverse range of material.

Geovisualization and geovisual analytics have been used within scientific fields to construct geovisual narratives or story maps, which include maps, textual elements, pictures, and graphs (Janicki et al., 2016; Iturrioz et al., 2016). For example, the web-based program known as "Voyager" inside Google Earth has garnered a significant user base in a short period of time. This application offers a guided story experience, with new stories being generated and updated on a weekly basis (Williams, 2021). Geospatial applications facilitate the creation of story maps, serving as dynamic and communicative tools. In their work, Robinson (2017) introduces the concept of geovisual analytics as it pertains to the use of interactive visual interfaces for analytical reasoning using geographical information. An alternative methodology involves the development of interactive mapping tools for the purpose of exploring geographical data, identifying patterns, and making predictions about future consequences (Van Ho et al., 2011). The presented work showcases a geovisual story that establishes a connection between visual representations and accompanying textual information. This integration serves to provide further clarification and facilitate the identification of significant findings derived from geovisual research. In the field of geovisualization, it is widely recognized that incorporating a range of perspectives, such as alternative map views in conjunction with diagrams, graphs, photographs, and videos, can be an effective means of transforming data into information and, ultimately, knowledge (Van Ho et al., 2011; Berendsen et al., 2018). Another related example is an Ocean Story Map, a web-based application designed to showcase oceanic content and provide crucial information pertaining to the oceanic ecosystem designed by Wright, (2023). Finally, Story Maps

can also be used for marketing goals in many geographical applications such as land use and urban planning (Scott et al., 2016).

The use of Story Maps for promoting alternative forms of tourism for an area of interest is also important to be underlined. Antoniou et al. (2018) present a web-based application that has been developed with the objective of facilitating the dissemination of information to a wide array of users, including geologists, earth scientists, tourists, and other persons lacking specialized expertise. The program serves as a platform for exploring the Methana Peninsula, accessible through the following link: https://goo.gl/ok1j9F, selected as the focal point of this research due to its amalgamation of scientific and tourism appeal. The purpose of the application is to facilitate the distribution of scientific data, as well as provide accessible information to the broader public, such as details on hiking paths, churches, archaeological sites, and other related content.

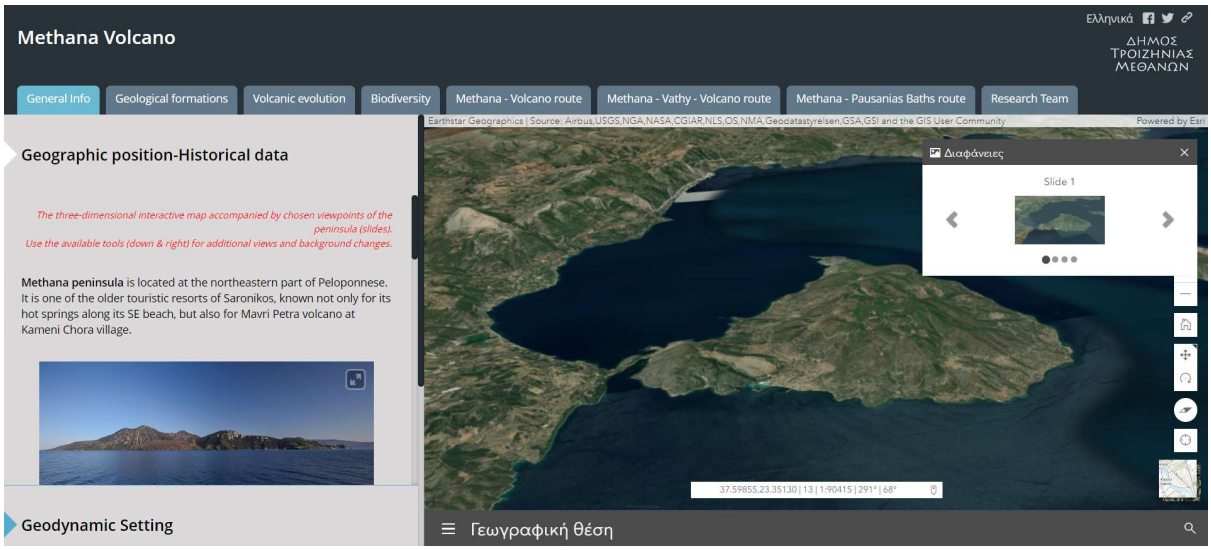

Fig.1) Screenshot of Methana Volcano, Greece. Story Map Home page (https://goo.gl/ok1j9F).

The Story Map provided a comprehensive analysis of the distinctive volcanic geomorphological characteristics and cultural landmarks found on the Methana Peninsula, located in the East Peloponnese region of Greece. These elements were meticulously documented, mapped, and visually shown via photography, to eventually provide an overview of the physical and historical attributes of the Peninsula, as well as its surroundings. Individuals have the capacity to discern and recognize historical edifices, notable landmarks, and significant geological formations. The Story Map was generated using ESRI Story Maps platform, a product of ESRI company which delivers both desktop and web-based GIS apps (Esri, 2023).

2. Geoheritage

Over the course of Earth's geological timeline, a multitude of natural processes have contributed to the production of diverse geological features, which have captivated the curiosity and intellectual endeavors of innumerable individuals seeking comprehension. Geodiversity refers to the comprehensive categorization of geology (rock, mineral, fossil), geomorphologic (landform, processes), and soil characteristics, which distinguishes processes and their resulting abiotic manifestations on the Earth's surface (Gray, 2004). The concept of geodiversity is intricately interconnected with cultural heritage, a correlation arising from the historical development and interaction of human civilizations with their respective natural settings. Furthermore, geomorphosites, which are a key element of geodiversity, have a significant impact on advancing our understanding of the Earth's history (Panizza, 2001) since they are considered part of a region's cultural legacy (Tefogoum et al., 2020). According to Reynard and Giusti (2018), a geomorphosite may be defined as a landform that has significant historical, cultural, aesthetic, and social value. The correlation between the cultural aspects of a specific region and its geomorphological context plays a significant role in the identification and appreciation of geoheritage (Hadi et al., 2015; Quesada-Román et al., 2020). The primary reason for this phenomenon may be attributed to the presence of a wide range of geological features, landscapes, and landforms, which provide the essential physical basis for various cultural activities. Therefore, these aforementioned elements have had a significant impact on the configuration of the physical environment in which groups have chosen to settle, create their built environment and cultivate their cultural traditions throughout the duration of human civilization.

An extensive comprehension of the geological structure of the region and its relevance has importance not just for scientists, but also for the general public. Frequently, the dissemination of scientific knowledge pertaining to geology, including areas such as biodiversity, cultural studies, and archaeological research, is characterized by a lack of coherence and organization. This phenomenon may result in a deficiency in comprehending the subject matter in its entirety, perhaps leading to the oversight of crucial information and connections across several research disciplines. For instance, scholarly investigations pertaining to the geology of a particular region may inadvertently overlook the potential influence of geological phenomena on its biodiversity. Similarly, cultural and archaeological inquiries may fail to include the geological background of the location into their analyses. The establishment of effective collaboration and integration among researchers and stakeholders is vital in order to develop a complete comprehension of the study region, hence facilitating the formulation of enhanced conservation and management plans.

Furthermore, this has the potential to enhance public consciousness of the significance and intrinsic worth of the region. Hence, it is essential to prioritize the development of innovative and effective approaches for conveying scientific research findings to the general public, as well as for disseminating knowledge pertaining to geological heritage, geological dangers, and geotourism (Németh, 2015; Pasquaré Mariotto et al., 2020). Current research has been primarily dedicated to the advancement of strategies aimed at enhancing the geological components of both natural and cultural heritage. These efforts primarily revolve on the recognition of the significance of incorporating geoheritage into conservation, education, and tourist initiatives (Freire-Lista et al., 2023).

The term 'geosite' describes a discrete part of the geosphere with important geological – geomorphological interest (Sturm, 1994), as a location featuring outstanding geodiversity (Komoo, 1997) and thus deserves protection and conservation for scientific, educational, cultural and aesthetic reasons or due to the representation of key phases of the broader area's geologic history regarding the creation, evolution and features of the geosphere (Zouros, 2009). According to the author, geosites usually represent significant geological structures, characteristic or scarce ore outcrops, rare mineralogical assemblages, important petrological outcrops, particular sedimentological structures, rare or unique fossils, strata types, characteristic tectonic structures, areas of currently evolving geomorphological and geological processes, rare geomorphological features and places of significant natural good. The total of an area's geosites comprise its geological heritage and narrate its geological history.

According to Gray (2004), the term 'geodiversity' encompasses the variety of geological (rocks, minerals, fossils), geomorphological (sites, natural processes) and soil characteristics and consists of natural formations, properties, associations and systems. Based on Stanley (2000), geodiversity is the link among humans, sites and culture, representing the variety of geological environments – along with the phenomena and processes that formed them – rocks, minerals, fossils and soils that offer the conditions for life on Earth.

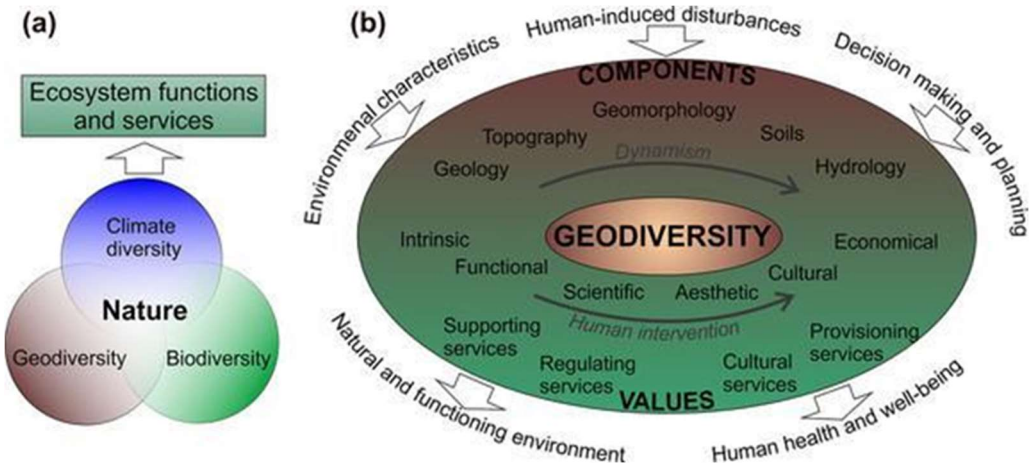

Fig.2) Geodiversity plays an inextricable role in nature and is important for the processes of an ecosystem (Gray et al. 2013). (b) The main components and values of geodiversity (Gray et al. 2013).

The realization of geodiversity's value along with its vulnerability to threats, has led to the emergence of specific methods aiming at its managing, protection and conservation. The total of methods applied for the protection and conservation of geodiversity – due to its inherent, ecological and functional values – comprises 'Geoconservation', according to the widespread term introduced by Sharples (1995).

The investigation of establishing geosites that possess distinctive geological characteristics, offering prospects for educational and recreational pursuits, together with the promotion of geotourism, has been examined as a means to enhance awareness and appreciation of geoheritage (Lima et al., 2013; Xu & Wu, 2022). Geotourism has the potential to enrich tourist experiences and cultivate a more profound comprehension and admiration of the Earth's past by emphasizing the geological significance of a particular location. In the last several decades, the notion of geotourism has gained traction and seen substantial expansion (Jia et al., 2022), contributing to both economic development and the preservation of natural and cultural assets (Quesada-Román et al., 2021). Geotourism may be defined as a kind of tourism that places emphasis on the natural environment and geological features of a particular region.

According to UNESCO (Henriques & Brilha, 2017), geotourism encompasses the promotion and support of tourism endeavors that center on the unique geological characteristics and landscapes of a specific area. The methods described in the study by Jia et al. (2022) serve to further the exploration and preservation of geological diversity, while also fostering a deeper understanding of earth sciences via educational programs and acknowledgements. Additionally, the importance of geoparks in the protection and promotion of geoheritage has been highlighted by Xu & Wu (2022). Geoparks serve as crucial venues for sustainable development, conservation, and education, while having the potential to facilitate collaborations among local people, scientists,

and government. Communication tactics, such as the use of signs, information boards, and interactive exhibitions, play a crucial role in the promotion of geoheritage (Quesada-Valverde & Quesada-Roman, 2023). Additionally, Kuleta (2018) conducted a study on the utilization of geodiversity assessment frameworks for the purpose of identifying and prioritizing locations that possess noteworthy geoheritage value. These frameworks use many factors, such as scientific significance, scarcity, and aesthetic value, to help the decision-making processes related to geoconservation and the advancement of heritage.

In the following sections representative case studies are presented, of how the promotion of geoheritage in combination with other values of an area can be accomplished, while also including the application of story mapping technologies.

2.1. Case study of Kos Island

Antoniou et al. (2023) describe the use of story mapping technology in the creation of a web-GIS collaboration platform, referred to as a "hub," for the island of Kos, Greece. The authors provide details on the construction of this platform, which aims to be interactive and user-friendly. The web-GIS hub may be visited at https://arcg.is/nvaum (accessed on 12 June 2023). In a more particular manner, the offered information encompasses a comprehensive overview of the historical, geological, environmental, and cultural legacy of the region. Subsequently, the technique used for the establishment of the hub is delineated. A comprehensive depiction of the distinct topics of interest pertaining to the Story Maps included in the hub is provided, along with corresponding images. The objective is to facilitate users of all backgrounds and levels of proficiency in investigating the natural and human-induced aspects of the environment in Kos. This exploration aims to uncover the distinctive geological past of the island, which is closely intertwined with its biodiversity and cultural evolution. Furthermore, the platform facilitates a diverse range of recreational pursuits, including hiking, cycling, and water sports, which are shown in both two-dimensional and three-dimensional formats. This approach enables the facilitation of an engaging and recreation-focused virtual excursion of the island, while concurrently establishing a fundamental framework for prospective geologists, tourists, enthusiasts of nature, and the general public to undertake exploration during their visit. Moreover, it offers the opportunity for local inhabitants to reacquaint themselves with their island from a novel and contemporary standpoint. Ultimately, the writers engage in a discussion on the potential applicability of the technique in analogous settings and significant domains

characterized by abundant cultural legacy. They also examine the merits and potential drawbacks of the strategy, afterwards providing their concluding comments and overall findings.

The story starts with a visual representation of the remnants of an ancient Christian Basilica located on the island of Kos, followed by a concise preamble elucidating the underlying objective of the Hub. Upon scrolling downwards, users will encounter textual content pertaining to the geographical information on Kos Island. Additionally, they will have the opportunity to engage with an ArcGIS web experience application, that offers an interactive two-dimensional web map that delineates the boundaries of Greek territory. Furthermore, the map incorporates imagery as a foundational layer, enabling users to explore the spatial characteristics of the area. Users have the ability to explore the online map and also have the option to pick bookmarks located on the right side of the interface in order to zoom straight into certain locations (Figure 3).

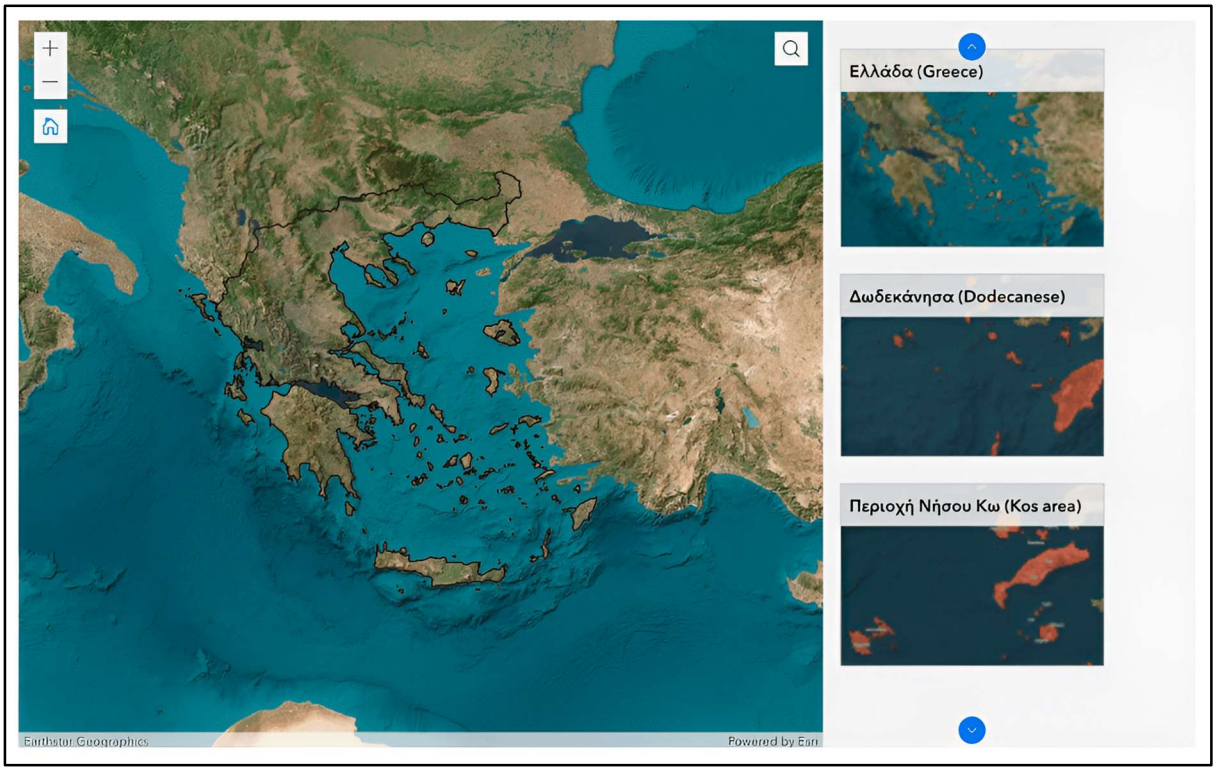

Fig.3) Screenshot of the Instant App to locate Kos Island in Greece. The main map depicts Greece's boundaries, while the right bookmarks zoom in on Greece, Dodecanese, and Kos. Source: Antoniou et al., 2023

In accordance with the story, a concise overview is provided of the island's physical characteristics, geological and tectonic composition, as well as its mineral resources. The topography of the island may be classified into four distinct portions, as seen in Figure 3.

Fig.4) An interactive 3D map of Kos Island's morphology. Source: Antoniou et al., 2023

The last section of the study is dedicated to a comprehensive gallery including all eight domains of knowledge, that comprise individual Story Maps (Figure 5).

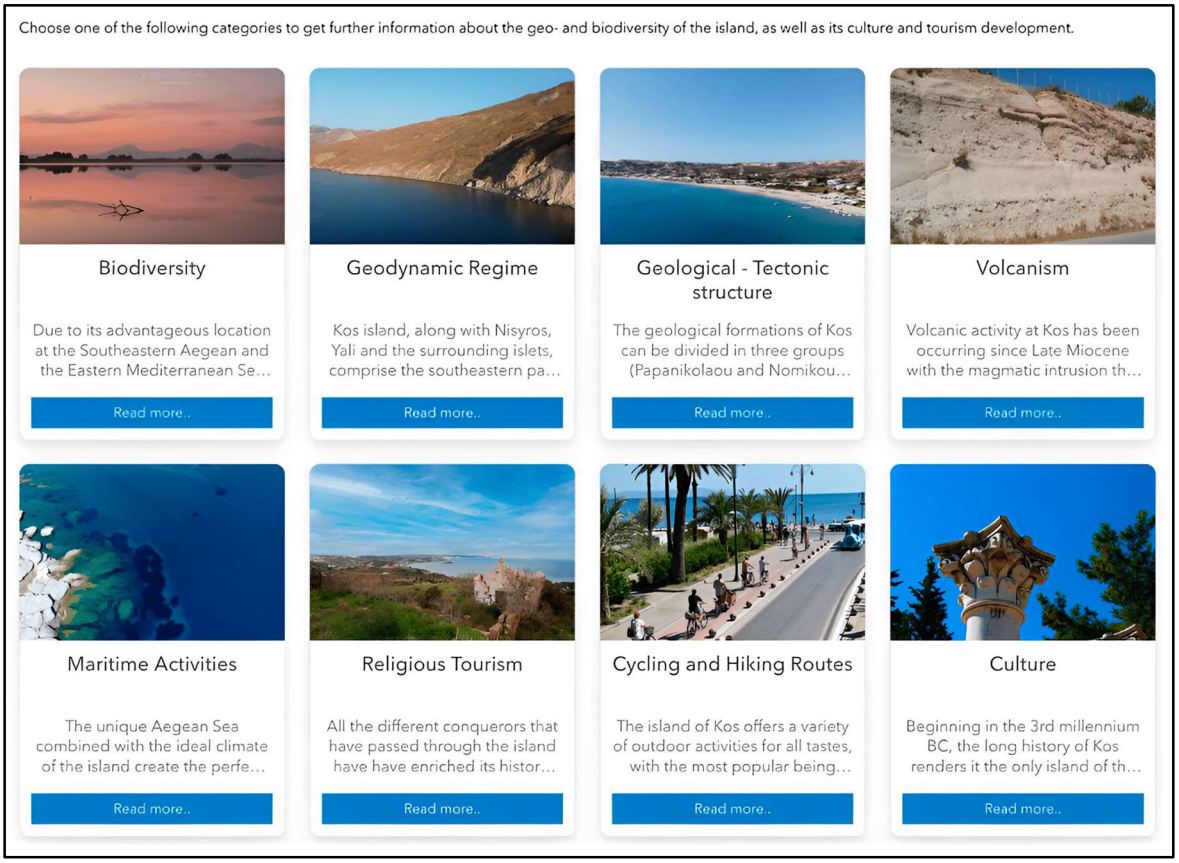

Fig. 5) A screenshot displays the eight categories and Story Maps that organize the data. Source: Antoniou et al., 2023

2.2. Case study of Santorini Island

The study conducted by Pasquaré Mariotto et al. (2021) had the objective of presenting nine virtual geosites (VGs) associated with the Santorini volcanic complex. These VGs exemplify a remarkable volcanotectonic setting, which emerged from several caldera collapses linked to significant explosive events (Druitt & Francaviglia, 1992). The researchers employed virtual reality (VR) applications and web-based geographic information system (GIS) technologies to accomplish this task. The objectives of this study were (i) to provide illustrations and descriptions of the selected VGs, (ii) to conduct a qualitative assessment of the selected VGs, and (iii) to demonstrate the utilization of a dedicated WebGIS platform for the global accessibility of VGs, thereby contributing to the promotion and appreciation of the Greek geoheritage.

In order to enhance the dissemination of all accessible models to the collaborating parties and the general public, it was necessary to use a specialized medium that facilitates the appropriate categorization and sharing of these models. Upon conducting a thorough examination of the various alternatives and taking into account the authors' considerable prior experience with ESRI products, it was determined that the most optimal selection would be the ArcGIS Hub platform (https://hub.arcgis.com/). ArcGIS Hub, a platform established by ESRI in 2020, facilitates the building of interactive websites that enable organizations to disseminate their geographical material. The team members possess the ability to personalize and improve the created website by using 2D and 3D maps, intelligent layouts, templates, and multimedia elements that can be adjusted to effectively present the accessible information. Additional material from other sources, as well as other apps that have been created using the ESRI platform, have the capability to be included. The virtual geosites hub, available at the URL https://arcg.is/1e4erK0, was developed using an educational account.

The narration starts with a visually captivating snapshot showcasing the panoramic view of Santorini, which seamlessly integrates both natural and manmade elements. This is then followed by a concise explanation elucidating the aim of the hub. Upon scrolling downwards, the user is presented with an interactive two-dimensional morphological web map that delineates the precise positioning of the chosen geosites (Figure 6).

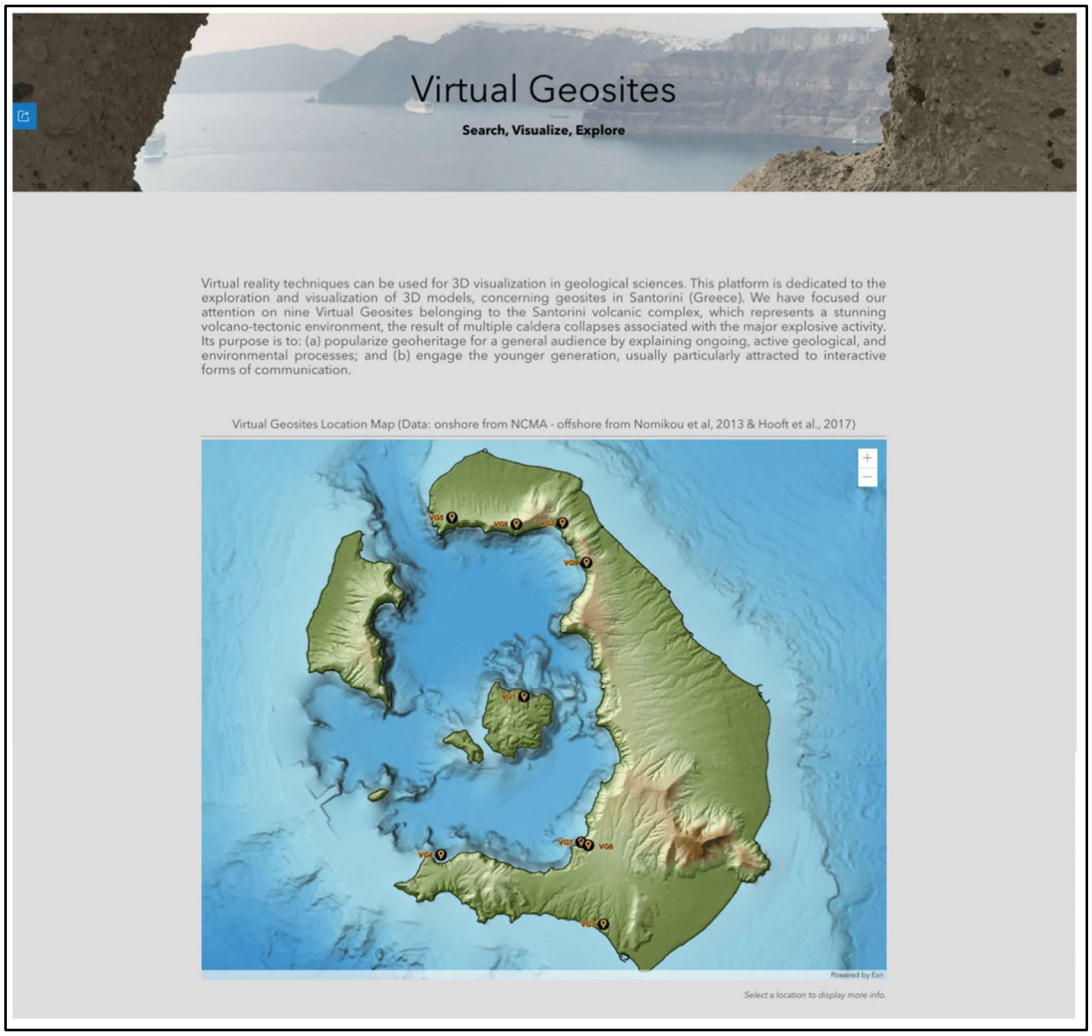

Fig.6) A screenshot of Santorini's virtual geosite hub.

The hub presents a concise summary of the volcanic history of the island, together with a simplified 3D geological map that has been adapted from the work of Druitt et al. (1999). Users have the ability to use the various tools provided on the map interface in order to adjust the zoom level, either by zooming in or out. Additionally, users may manipulate the map by right-clicking on any location, therefore altering the perspective and orientation of the scene, allowing for observation from numerous vantage points (Figure 6). The creation of both two-dimensional and three-dimensional online maps was facilitated using the ArcGIS Online platform, accessible at www.arcgis.com.

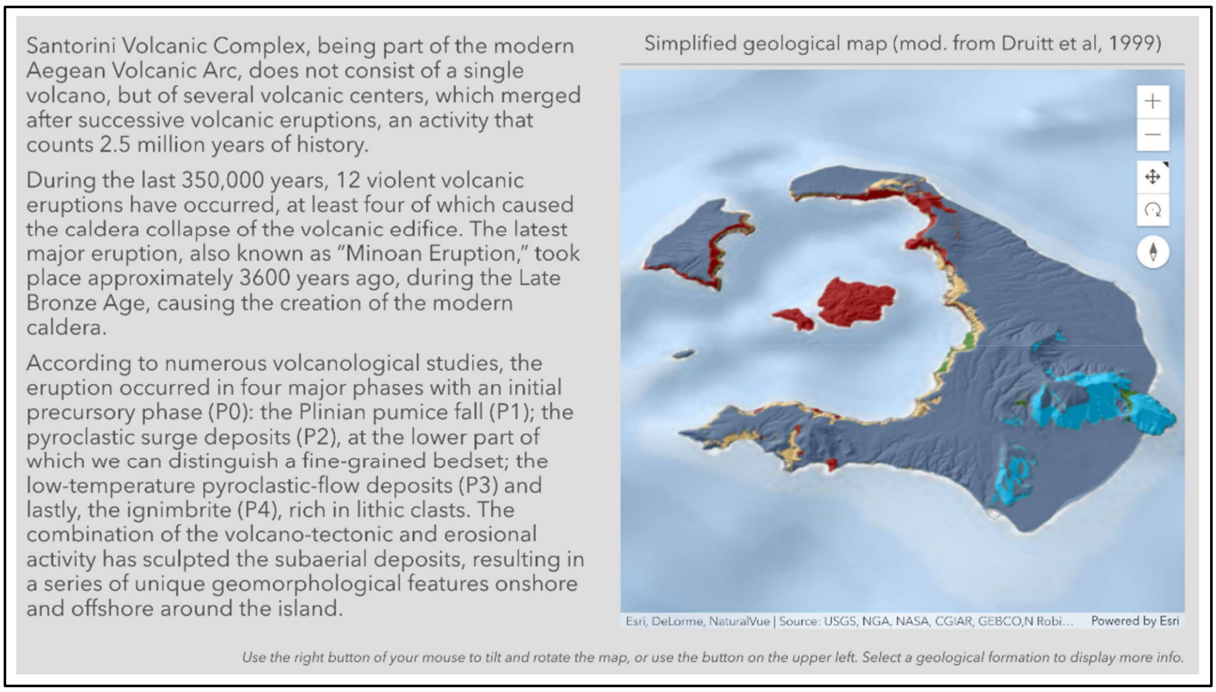

Fig.7) Santorini volcanic history, hub screenshot.

The concluding section of the study is devoted to a comprehensive gallery including all nine virtual geosites. Buttons provide users with the means to access a Story Map application pertaining to each virtual geosite. The rationale for using these apps to showcase and advocate for the suggested geosites was grounded on prior instances of similar applications, particularly those utilized by some authors involved in the current study (Antoniou et al., 2018).

2.3. Case study of Nisyros Geopark

As already mentioned, Geoparks can provide a means of unparalleled value when it comes to geoheritage and geoconservation. Nisyros Geopark, which aspires to be recognized as a UNESCO Global Geopark, is situated within the Dodecanese prefecture in the southeastern region of the Aegean Sea in Greece, part of an island complex positioned between Kos and Tilos islands. It includes Nisyros island, which is the most recent and currently active volcano within the South Aegean Volcanic Arc. Additionally, the area contains the nearby volcanic islets, of Strongyli, Pachia, and Pergousa, as well as the non-volcanic islet of Kandeliousa. Furthermore, the maritime expanse situated between these landmasses is also encompassed within this geographical scope (Figure 8). The combined land and marine area it encompasses amounts to 481 km^2.

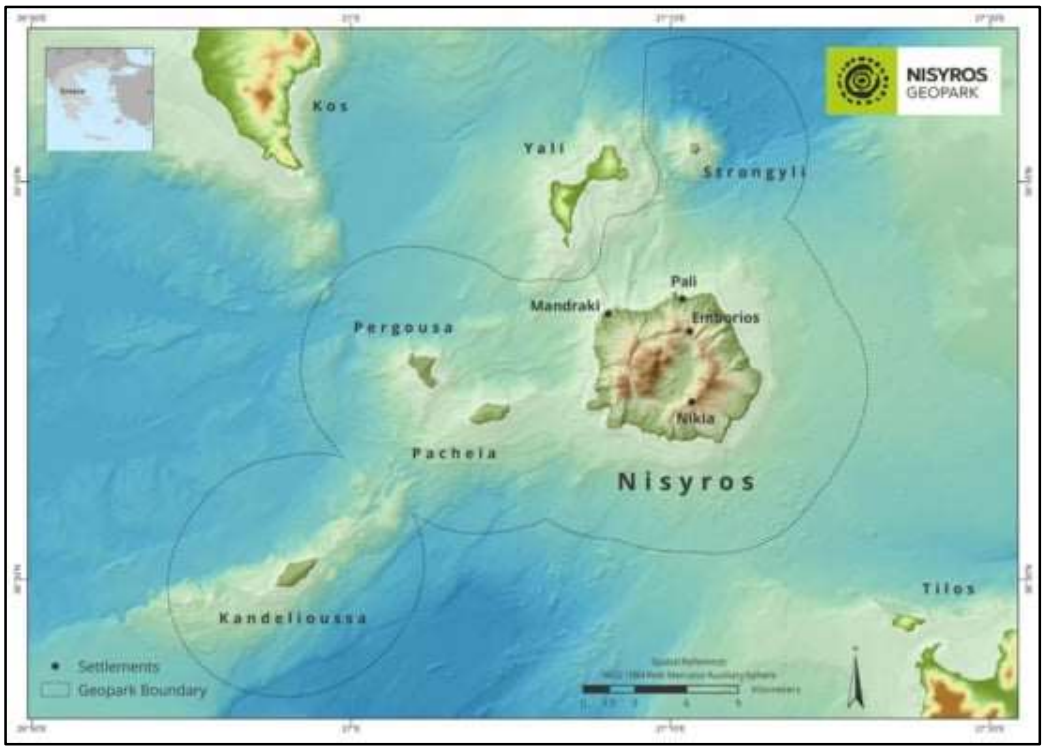

Fig.8) UNESCO Global Geopark candidate Nisyros, geotouristic map. Source: Nomikou et al., 2023

The volcanic arc under consideration consists of a sequence of active volcanoes from mainland Greece, such as Sousaki and Methana, to the southeastern area of the Aegean region. This arc also includes Milos, the Santorini – Christiana - Kolumbo Volcanic Field, and the Kos-Yali—Nisyros Volcanic Field (Nomikou et al., 2013). The location of the site is of particular significance since it is situated inside a geologically old volcanic region that had a pivotal role in the largest volcanic eruption in the Eastern Mediterranean Sea, referred to as the Kos Plateau Tuff, around 161,000 years ago (Pe-Piper et al., 2005). Nisyros is widely recognized as the most recently developed active volcanic formation in Greece, with a volcanic chronology that encompasses a very short duration of around 160,000 years. The volcanic activity discussed took place after the notable eruptive cycles of the Kos Plateau Tuff, as mentioned by Dietrich (2017).

The academic significance of the flora and fauna in Nisyros Geopark stems from the volcanic nature of the region and its advantageous geographical position along the migratory paths of Asian species into southern Europe and vice versa. The European network Natura 2000 encompasses two distinct geographical locations, which have been classified as areas GR4210032 and GR4210007. Additionally, there are three distinct regions that have been recognized as Wildlife Refuges (Nomikou et al., 2023)

The Nisyros Geopark extends its offerings beyond the mere presentation of a distinctive volcanic history and the aesthetic appeal of its natural environment. The island's unique cultural and historical heritage can be attributed to its strategic location at the intersection of western and oriental civilizations. This is further enhanced by its circular and mountainous volcanic morphology, which contributes to its relative inaccessibility. Consequently, the island serves as a sanctuary for the preservation of traditional values (Dietrich, 2017a). Additionally, it showcases the magnificence of art and culture, as seen in ancient and historic sites and structures. Evidence from prehistoric periods may be seen as remnants from the Cycladic and Minoan civilizations during the Early Neolithic era. As for historical documentation, it originates from the Hellenistic period and remains continuous during the Roman, Byzantine, Venetian, and Ottoman eras, extending into the present day (Liritzis & Volonakis, 2021). The territory has been enhanced by several historical eras, which have contributed ancient caves and spas, notable castles such as Palaiokastro, the renowned fortification of Nisyros (Figure 9), as well as churches and monasteries adorned with hagiographic murals, such as the Monastery of Panagia Spiliani. In light of this characteristic and taking into account its relatively modest dimensions, Nisyros Island distinguishes itself from other islands in the Dodecanese and Aegean regions, positioning it as a compelling contender for inclusion in UNESCO's Global Geoparks initiative.

Fig.9) Palaiokastro, the acropolis of early Greek town Nisyros, is the best-preserved Classical Period fortification. Source: Nomikou et al., 2023

The primary aim of the research undertaken by Nomikou et al. (2023) was to outline the early efforts made by the management body of the Nisyros aspiring UNESCO Global Geopark (aUGGp), in their goal to achieve the prestigious UNESCO Global Geopark title. This was accomplished through a combination of conventional and digital advancements, with a specific

focus on introducing the remarkable characteristics of the Geopark to the global geotourism and geoeducational community. The aforementioned activities included the planning, execution, and implementation of informational panels and signage at specified geosites, as well as the placement of indicators highlighting potential hazardous zones at the major geological landmarks on the main island of Nisyros. A novel and educational brochure pertaining to the hydrothermal region of Lakki was also produced, including an original and inventive folding style resembling a poster. Furthermore, a full handbook on the Nisyros Geopark was created, using clear and accessible language to describe all facets of the Geopark. Additionally, focus was directed towards two digital offerings, specifically the official website of the Nisyros Geopark and the initial complimentary mobile application created to offer information and enhance visitor engagement and geological interpretation of the Lakki region located within the volcanic caldera.

The official website of Nisyros Geopark, located at www.nisyrosgeopark.gr, is a contemporary and user-friendly digital platform that serves as a primary means of communication. It offers a comprehensive and visually appealing interface, enabling users to access essential information about the geopark's diverse features and facilitating their trip planning (Figure 10 and Figure 11). At now, the website is accessible in English, although efforts are being made to develop translations into Greek and other prominent European and Asian languages. These translations are either in process or being contemplated. The Home area serves as the first point of contact (landing page) for online visitors to the Nisyros Geopark, facilitating communication at the primary level. The website's layout is comprised of many key elements that include the header, which has links to subpages providing further material, the main body of the website that provides concise information on the Geopark and lastly, the bottom of the website which shows important information for users. Once Nisyros is officially recognized as a UNESCO Global Geopark (UGGp), the highest level of significance in terms of information architecture will be attributed to it. This level will primarily comprise dynamic content, such as regularly updated live feeds and actions of the Geopark, accessible through dedicated sub-areas that will host the Geopark's "Latest News," its ongoing activities (Events), and various announcements. These regions will provide abundant informative content arranged in a sequential manner that aligns with the Geopark's activities and advancements throughout time.

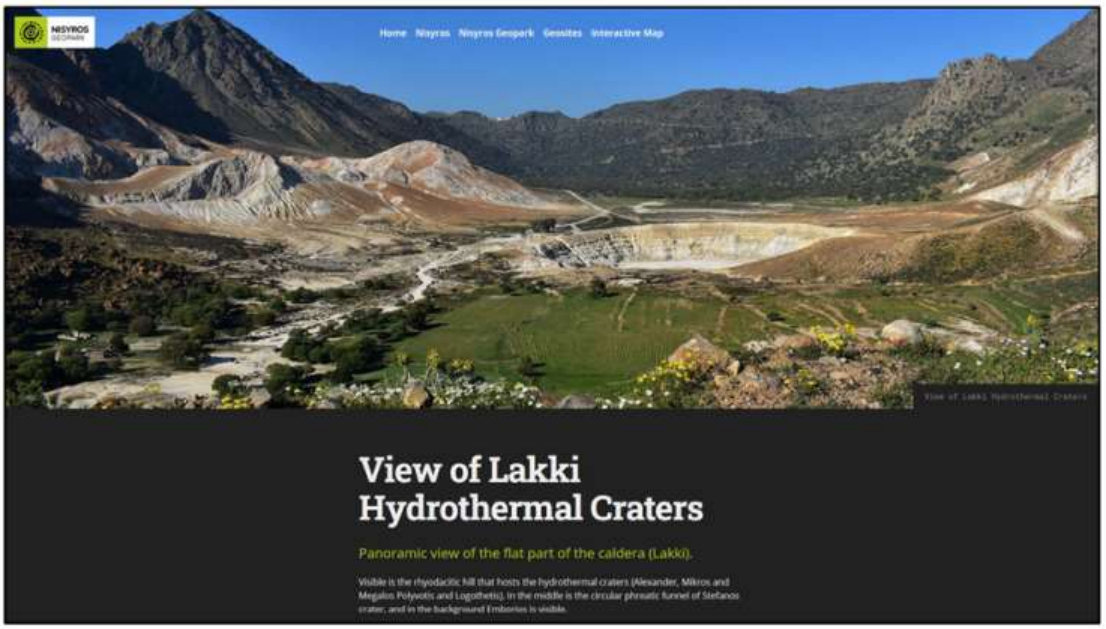

Fig. 10) Official Nisyros Geopark website's user-friendly design.

Fig.11) Nisyros Geopark website section opening page (Geosites).

The section labeled "Nisyros" offers a comprehensive and engaging encounter for tourists, providing valuable knowledge on many facets of the island of Nisyros via the following subsections: Mythology, History, Nisyrian People, Customs and Traditions, Nisyrian Villages, Museums, and Sights. The discourse begins by providing the mythical framework pertaining to the genesis of the territory, namely the Giantomachy, as expounded in the domain of 'Mythology'. Subsequently, a comprehensive account of the extensive historical trajectory of Nisyros is presented, replete with copious and informative content, as elucidated in the section labeled

'History'. The section titled "The Nisyrian People" presents significant insights into the contemporary history, folklore, customs, and traditions of the island. Its purpose is to emphasize the distinctive intellectual richness of Nisyros and the contributions made by noteworthy individuals from Nisyros. The section under "Customs and Traditions" provides informative material on the customs and traditions observed in Nisyros, including the island's notable architecture, folk culture, and many cultural events. The following three parts include concise explanations of the four main communities on the island, the several museums that may be explored, and other significant geological, ecological, and cultural features inside the Geopark.

The section entitled "Nisyros Geopark" offers an introductory overview of the Geopark, which exhibits a profound interconnection with the geocultural environment of the Nisyros island complex and its adjacent islands. The many components that fall under the scope of the subject being examined include the following subsections: Location, Islets Complex, Geomorphology, Volcanism, and Biodiversity. The section labeled "Location" provides a succinct description of the exact geographic positioning of Nisyros Geopark in Greece. In the meanwhile, the section labeled "Islets Complex" provides a concise summary of the physical and anthropogeographical characteristics of Nisyros and the many islands that make up the Geopark. The section pertaining to "Geomorphology" presents a thorough compilation of the physiographic and morphotectonic attributes that comprise the volcanic environment inside the Geopark. Within the designated segment titled "Volcanism," visitors have the opportunity to engage with the abundant geological history present in the region. The chapter titled "Biodiversity" offers valuable insights into the plant and animal life found inside the Geopark's island complex.

The "Geosites" portion of the Geopark showcases the 24 recognized geosites, including comprehensive scientific information along with visual materials for public access. The aforementioned part, titled "Interactive Map," is connected to the preceding section and showcases the ten planned geopaths of the geopark. This section largely highlights the interactive nature of the users' experience, assisted by an interactive map that showcases all the locations of significance pertaining to the geological heritage. The composition is comprised of three unique sub-sections, specifically: Geosites, Geopaths, and Travels & excursions. The designated portions known as 'Geosites' and 'Geopaths' provide visitors the opportunity to engage in the exploration of pedestrian pathways throughout the Geopark, with a particular emphasis on the island of Nisyros. These parts feature interactive maps that are designed to be user-friendly and easily accessible, including various multimedia elements like as text, images, videos, and sound. In the future, the website will enhance its content by including a part titled 'Travels and tours'.

This area will include interactive information pertaining to the many islets inside the Geopark. Consequently, visitors will be given the option to explore this isolated portion of the Geopark, which is now unreachable for direct visits.

2.4. Story Map for volcanic island of Nisyros

The primary aim of the research undertaken by Antoniou et al. (2021) was to showcase the use of Story Mapping technology in developing an interactive and user-friendly platform focused on the volcanic island of Nisyros, Greece. The platform aimed to offer users a comprehensive range of multimedia resources pertaining to the island's geography and biodiversity, as well as the significant volcano-tectonic events that have influenced its formation over the course of several millennia. Additionally, the platform sought to highlight the historical impact of various human civilizations on the island, ultimately leading to the establishment of its present-day cultural conditions. Furthermore, the website features comprehensive depictions of the existing hiking paths, complemented by interactive maps, points of interest, visual media such as photographs and videos. Consequently, it offers a pleasurable and recreational virtual experience of the island, while also furnishing a fundamental itinerary for prospective geologists, tourists, and nature enthusiasts to utilize during their physical exploration of the area.

The produced Story Map includes diverse data about the geological and physical characteristics of Nisyros, including its cultural legacy and biodiversity. Additionally, it provides information on the diverse walking trails that showcase these aforementioned elements. The Story Map can be accessed via the following link: https://tinyurl.com/ycq5buvy. The platform provides comprehensive textual descriptions pertaining to the aforementioned subjects, supplemented with two-dimensional webmaps and three-dimensional scenarios. Additionally, it incorporates multimedia elements such as photographs and hyperlinks. The created Story Map includes a range of data related to the geological and physical characteristics of Nisyros, including its cultural legacy and biodiversity, while the themed maps that appear in the platform were created using ArcGIS Pro. The determination of the precise criteria regarding the degree of interaction for each map, including the amount of zoom, the operation of pop-up elements, and the initial orientation of the map or scene, was accomplished by using both the online platform and the Story Map builder. Furthermore, to accurately represent the accessible information, many Story Maps templates were included into the main template.

The data was methodically organized into four main sections, which include (a) a thorough examination of the island, providing comprehensive information, (b) geological and

volcanological data concerning the formation, development, and current state of the volcanic field, (c) a detailed description of the network of hiking trails, and (d) an overview of the research team, consisting of the scientists who actively participated in this project.

Upon entering the interactive platform, users are presented with a selection between two language choices, namely Greek and English (Figure 12). Against the background, a concise video loop is shown, illustrating a progressive panoramic motion that captures the salient characteristics of the island's volcanic nucleus. The recorded visuals were obtained from the apex of a volcanic dome located inside the caldera. The objective of this video is twofold: to inspire users to delve deeper into the subject matter by showcasing the remarkable features from an aerial perspective, and to illustrate that, in a potential future visit to the island, they can effortlessly access scenic vantage points to admire the surrounding area independently, either by walking or utilizing alternative modes of transportation. This section of the platform was developed using the Story Map cascade template.

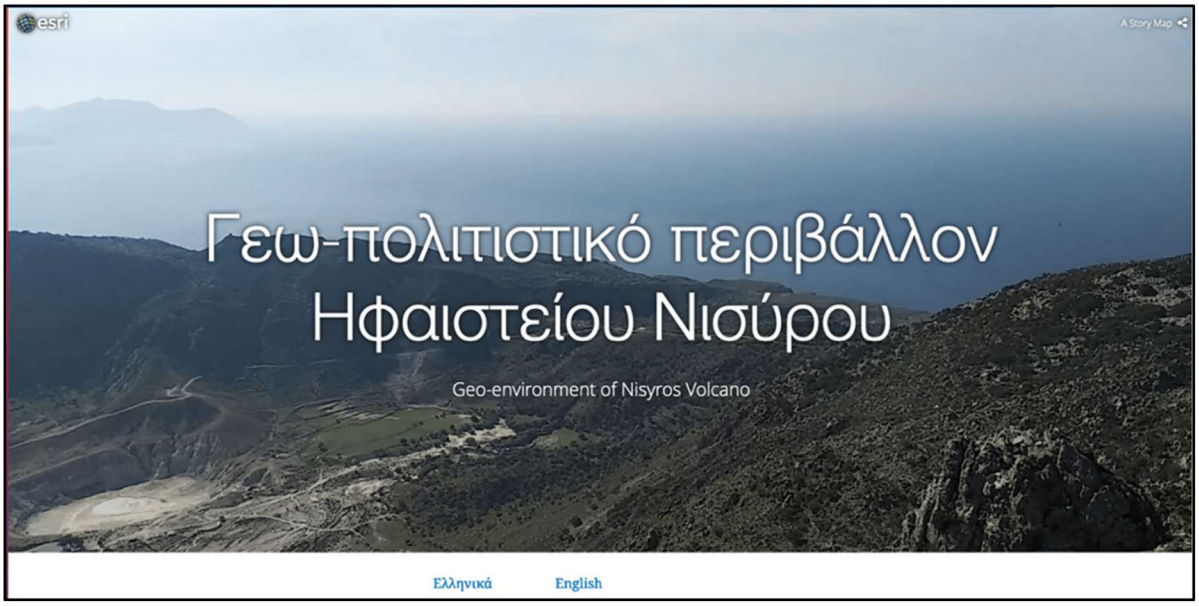

Fig.12) Screenshot of Story Map's main page with title and language choices. Source: https://tinyurl.com/ycq5buvy

The act of selecting a particular language triggers the opening of a distinct browser tab, which then directs the user to the main Story Map application. This process is repeated for each language option available. Upon first interaction with the interface, users are presented with a tabbed layout screen including four tabs positioned at the top, just below the Story Map's title (Figure 13). The four primary kinds of information pertaining to Nisyros island are represented, with the first category including general information and being characterized by its dynamic

nature. The following sections provide an overview of the material included within each respective category, as described above.

Fig.13) Screenshot of the app's main section when a language is chosen, with four major tabbed pages with vertical tabs for further information. The tab of general information is active. Source: https://tinyurl.com/ycq5buvy

2.5. Web-Based GIS for mapping and promoting areas of tourism value in Tanzania.

The work of Mango et al. 2020 focused on the design of an informative, narrative platform that involves interactive map content, for the management and promotion of a more sustainable form of tourism in Tanzania. Their different approach, however, includes the use of technology not only to address the public, but also to store valuable information for the sustaining of the industry. This is achieved by providing means for managing and promoting tourism resources.

The first step of their workflow included the establishment of a series of requirements for their model, including information providers and administers, users and means of accessing the information. All the available resources were contoured in one unified platform. What followed was the collection of spatially georeferenced data, to ensure spatial analysis on the final cartographic products. The data were carefully collected by considering the most usual needs of tourists, such as accommodation areas and activities nearby. They were then digitized and given attributes, while available multimedia content from external servers was added by providing paths. A geodatabase was used to store the available data, allow for further processing and handle the online maps to be produced. To create the online maps, the cloud computing platform of MangoMap was used, instead of a more automated, strictly web-GIS server. The platform allows

for cartography by using query services, while providing opportunities for data visualization including customizable symbols and colors, configurable pop-ups that appear when users hover above features as well as location and query tools. The coding environments of HTML, CSS and JavaScript were used.

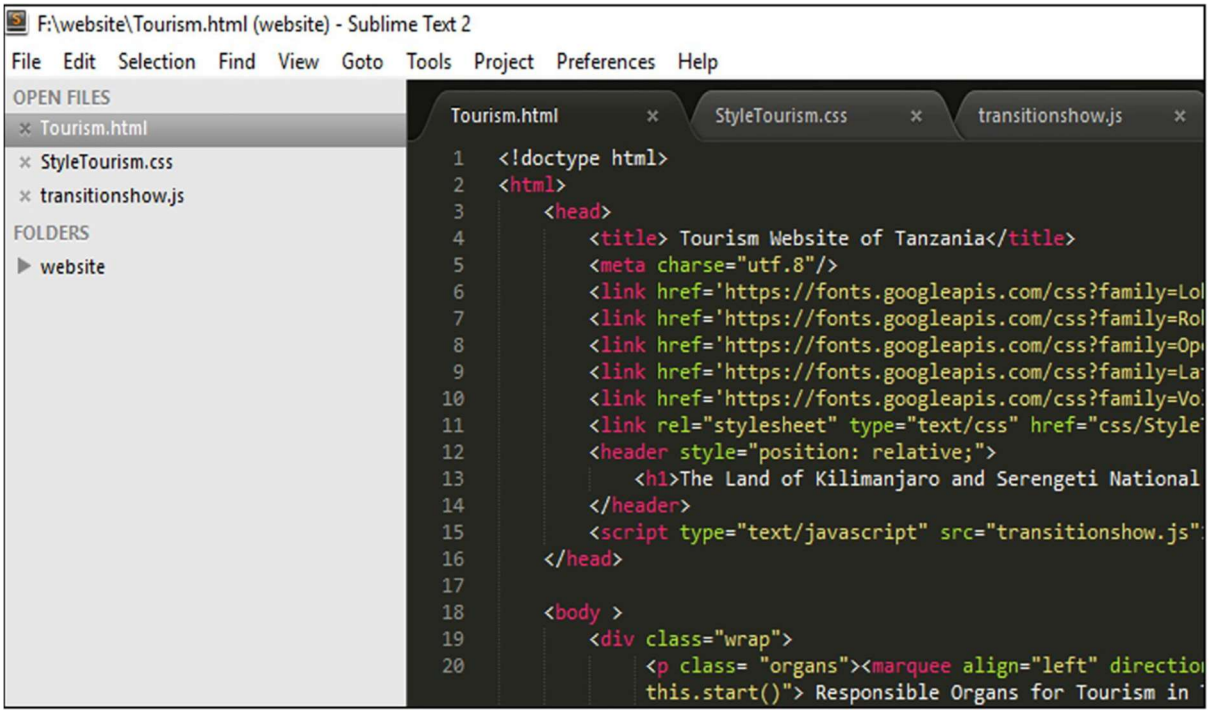

Fig.14) Queries for multimedia admission to the set of attributes of the features of the platform. Source: Mango et al. 2020.

The final product is an informative online platform that includes the interactive web maps along with accompanying information on their use, as well as access to updates by the promoted area's responsible management body. Users can use search queries based on multiple criteria, to access available and/or needed information.

It is important to mention that similar online mapping technology is used by mainstream GIS packages, like ArcGIS and QGIS. However, these tools do not require knowledge of coding, from the part of the developer of a similar platform. They also provide more flexibility regarding the available levels of interaction and the amount of data they handle. The authors of the case study example highlight the main limitations of their product, regarding the functionality of the server hosting of the platform, the retrieval of information being limited to the ones featured within the platform, the need of providing specific information for the retrieval of information by the users as well as the dependency on internet connection.

Fig.15) Example of the content of the interactive platform. Source: Mango et al. 2020.

3. Study Area of NE Attica

3.1. Geotectonic integration of Attica

The most important views regarding the geotectonic integration of the geological formations that make up Attica are given below in brief:

According to Jacobshagen (1979), in the region of Attica, the Pelagonian zone formations are distinguished, which he includes in the Central Hellenic Covers, and the outer units of the blueschists and the lower units of the Cyclades, which he includes in the intermediate crystalline masses. According to the same researcher, the area of Attica is in tension with large vertical movements due to low-angle normal faults (detachment faults) and large-scale shear stresses in the lithosphere, on older structures.

According to Mountrakis (1983), Attica is made up of formations that belong to the Attic-Cycladic and Lower Pelagonian units. The first occupies the eastern margin, while the second, pushed into the first, the western margin.

According to Papanikolaou (1986), Attica is made up of formations that are part of the unit of Eastern Greece (Pelagonian for others), which occupy its western part, and the units of Lavrio

and Attica that occupy the eastern part. These units are in a tectonic relationship with each other, with the underlying (outer) unit the one of Attica.

According to Migiros (1991), in the region of Attica there are: the Olympus - Almyropotamos - Attica unit, which corresponds to the Gavrovo - Tripoli unit, the Attic-Cycladic unit, which corresponds to the Pindos unit and the Sub - Pelagonian unit, which mainly expresses both with Maliaki Series and with Boeotian tectonic units, which appear only on the western margins of the area.

According to Katsikatsos (1992), Attica is composed of the formations of the Pelagonian zone (non- metamorphosed), pushed onto the outermost formations of the Neo-Hellenic tectonic cover and the autochthonous unit of Almyropotamos - Attica.

Lozios (1993), accepts the general framework, also included by Papanikolaou (2004), and other researchers (Durr, et al. 1978) for Attica, while in the region he studied he distinguished two units: a relatively indigenous unit, the Northeast Attica Unit, which is divided into the unit of Marathon - Ag. Marina and is part of the Olympos - Almyropotamos - Kerketeas unit and in the Penteli - Grammatiko unit as well as an allochthonous unit, the Agios Georgios Unit which probably corresponds to the Lavrio unit.

Papadeas (1991), differs greatly from the rest of the researchers. He considers that the whole of the metamorphosed rocks of Attica constitute a lateral transition to the unmetamorphosed Parnitha, and all of them come together by inundation in a pre-alpine background.

3.2 Lithostratigraphy

3.2.1 Alpine formations

As mentioned at the beginning of the chapter, the geological observations in the wider area of Attica start from the beginning of the 17th century. Before the mapping of Lepsius, a number of scientists of the time, gave the initial picture of the rocks that structure the Attica land, in a fragmentary way (Woods 1822, Kordellas 1883).

The period of initiation of the systematic study of Attica begins with the work of Lepsius (1893), who made an important contribution for the era. The lithostratigraphic structure he proposed for Attica was the basis for subsequent researchers, who for the most part accepted it. According to Lepsius, the units of Attica are broken down into the following formations:

- Precambrian: Varis Schists, Dolomites and Pirnaris Shales, Lower Marble, Kaisariani Shales, Upper Marble.
- Jurassic - Lower Cretaceous: Lower Calcareous layer of limestones and shales which he considers to be deposited unconformably on the previous ones.
- Cretaceous: Slates of Athens with limestone blocks, Upper limestones unconformably overlying previous formations.

In the first half of the 20th century, a significant number of Greek and foreign researchers were involved in the study of the region, based mainly on the lithostratigraphy of Lepsius, varying it partially and on a case-by-case basis (Negris 1919; Ktenas 1907; Trikkalinos 1954; Paraskevopoulos 1963).

Marinos and Petrascheck (1956), after a detailed study of the area and especially that of Lavrio, propose a matching of the formations of Lavreotiki with those proposed by Lepsius for Attica while the metasedimentary formations of Athens neither are identified, nor are they associated with the corresponding higher units of Lavreotiki. In general, they distinguish the formations of Lavreotiki into two groups:

- The autochthonous system. It includes successive layers of marbles, dolomites and slates in concordance with the ones corresponding to the Lepsius crystalline schist (Vari Schists– Upper Marble).
- The allochthonous cover. It includes mainly phyllites and quartzites with marble banks, which correspond to the Athens Schists and the Upper Limestone stage of Lepsius.

According to Papanikolaou (1986), the main units are:

- The Attica Unit, which is also the lowest tectonic unit, on which various other tectonic units, such as those of Eastern Greece, Lavrio and Almyropotamos, are thrust upon. It is metamorphosed and strongly deformed with initial folded structures in a NE – SW direction and younger ones in a NW – SE direction and consists of a large mass of marbles, often dolomitic and of mica, amphibolite schists with thin horizons of intermediate marbles. Within the shales, there are also mafic – ultramafic metamorphic rocks.
- The Lavrion Unit. Its section corresponds to the allochthonous section of Lavreotiki which gradually passes into the "allochthonous" section of Athens, less metamorphosed

than the first. It contains tectonic wedges with a wide variety of lithotypes that give it the characteristics of a tectonic melange. There is also a sand-to-pelitic metamorphosed mass (partly Cretaceous) containing blocks of different age and composition. On the upper layers of the unit, Late Cretaceous limestones are observed, both in Athens (Acropolis, Lycabettus, Tourkovounia), and in Lavrio (Berzekos hill). The most characteristic lithotypes in Lavrio are the sericite-chlorite schists, featuring meta-basalts and meta-gabbros with blueschist-type mineral assemblages. As far as the tectonic structure is concerned, transverse structures with a general direction of E-W dominate. In more recent publications (Papanikolaou et al., 2004) the Athens unit is divided into two lithological sub-units: (a) white to greyish and brownish non-bedded to thick-bedded neritic limestones, in parts dolomitized, featuring foraminifera and rudist fragments of Senonian age and (b) a complex system corresponding to the Athenian schists.

3.2.2. Post-Alpine formations

The post-alpine basins of Attica are a result of the rift neotectonics that acted and, in some places, still act in the region. The most important basins that appear near or in Attica are the following:

- Thebes Basin: It has a direction of E-W and is arranged parallel to the main rift structures. It is bordered by the mountains of Kithairon and Parnitha.
- Megara - Elefsina Basin: It is defined by fault structures of north and north-east direction. It is bordered by Geraneia Mountain, Mount Pateras, Mount Aegaleo and Salamis Island.
- Athens Basin: It is bounded by Mount Aigaleo, Parnitha, Penteli and Ymmitos. It follows fault structures of north and northeast direction.
- Spata basin: It is bounded by the mountains of Ymmitos, Penteli, Panio and is open to the east. The boundary fault structures have varied directions with the main ones being NW - NE and E – W.

The formation environment of the post-alpine deposits presents significant differences, which are mainly due to the rift evolution of the individual basins.

3.3. Geotectonic Evolution of Eastern Attica

From the preceding literature review, the position of Attica in the Hellenic Arc, is differently perceived depending on the researcher. The problem is complicated since almost all the rocks that appear in Attica are metamorphic and therefore fossils finding are rare. Also, the contact relationship of the formations is difficult in most cases to distinguish. In addition, there is great variation in the spatial distribution of compressive and tensile processes during the movement of the lithospheric plates.

The area of Eastern Attica constitutes the northwestern edge of the Attic-Cycladic zone (Trotet et al., 2001). This unit is tectonically located under the Pelagonian cover and is a complex of metamorphosed formations that can be divided into three sub-units:

- Upper unit that includes a sequence of unmetamorphosed sediments of Permian – Mesozoic age with phyllites, serpentinites, metagabbros and metabasites.
- Blueschist Unit, consisting of marbles, calcareous schists, metapelites, siliceous metabasites and meta-acidic rocks.
- Basal Unit that includes metasedimentary and igneous rocks with protoliths of Permian to Tertiary age.

Trying to approach the geotectonic evolution of the area studied, paleogeographically it is included between Olympus and Pelagonian units, constituting the northwestern part of the Attic-Cycladic unit together with the southern part of Evia. From the Triassic until today, the following geotectonic development is presented:

- In the period from Triassic to Upper Cretaceous the formation of the initial rocks of the units (protoliths) took place. Depending on the position and depth of the unit, lower shales, carbonate neritic formations and upper shales formed.
- During the Eocene, the subduction of the Cyclades (parallel to that of Pindos) and its HP/LT (High Pressure / Low Temperature) metamorphic event gradually started. The metamorphism started with HP conditions, with the formation of glaucophane and then the temperature increased above 300°C (Kessel, 1990) (330 – 380°C according to Baziotis (2008)). In this phase, the maximum compression episode ends.

- During the Lower Miocene, a paroxysmal phase of tension occurs where the metamorphic systems of the Cyclades are created, maintaining the previous high-pressure phase.
- During the Middle Miocene, the Central Aegean, like other parts of Greece, entered the tensile tension field, manifested by normal low- angle detachment faults and high-angle faults (Papanikolaou & Royden, 2007).
- In the Upper Miocene - Pliocene, the metamorphic formations of Eastern Attica began to exhume, due to the extension that occurred in the region. A normal detachment fault operated in the western part of Ymittos (Papanikolaou et al. 2004), moving over the pre-existing tectonic structures and delimiting the Spata basin. In the northern part of the basin, parallel to the massif of Penteli Mountain, there is a lateral normal fault that starts from the thrust zone of Parnitha and ends with a direction approximately E - W in the South Euboean gulf. In the southern part of the Spata basin, a large rupture zone also appears, with a WSW-ENE direction.
- In the final stage during the Pliocene-Quaternary, the modern neotectonic stress field was established, with active normal faulting mainly on the northwest of the Athenian Plain.

3.4. Geology of Mount Penteli – Marathon region

The description of the geology of Mount Penteli and Marathon was mainly adapted from Lozios et al. 2019, primarily due to the analysis of new petrological, morphological and microtectonic data derived from the authors' detailed geological mapping. Thus, the entire study area comprises of rocks that belong to two individual alpine tectonic units, the Northeast Attica Unit (NEAU) and the Agios Georgios Unit (AGU). All the rock formations of these units are metamorphic. Furthermore, the area is bound to the west by the post-alpine formations of the Agios Stefanos – Kapandriti neotectonic basin.

In accordance with the general lithostratigraphy of the Cycladic Blueshchist Unit (CBU – Lozios 1993), the NEAU consists of a basal meta-volcanosedimentary sequence of up to several hundreds of meters thick, that dominates at Mount Penteli and outcrops significantly at Marathon. The sequence consists of various metamorphic lithologies like schists, quartzite, metabasic blocks and acid metavolcanics. Within the sequence, some areas are dominated by meta-sediments (schists and quartzite) and some others by mafic and acid meta-volcanics. The

age of the magmatic protoliths, as determined by Pe-Piper and Piper (2002), indicate a mid-Triassic sequence within a rift-related geotectonic setting. Within the meta-volcanosedimentary sequence significant lenses of metagranitoid rocks can be found, with an estimated 255 to 246 Ma of age as determined by U-Pb SHRIMP zircon geochronology, featuring indications of a two-stage crystallization (Liati et al. 2013). Small bodies of ultramafic rocks (serpentinites) consisting mainly of serpentine and talc can also be found as lenses within the schists of the unit. At the upper layers of the meta-volcanosedimentary sequence, a thin but prominent blue grey metachert marble of a thickness of 1 – 30m can be found, representing the transition to the upper marble sequence. This strongly folded marble can serve as an indicator level to further distinguish the metamorphic and tectonic evolution of the units and provide exceptional examples of mid to large-scale folds that can be easily observed in the field. Following the transitioning blue-gray marble layer, a prominent, up to more than a kilometer thick white to blue, medium to thick-bedded neritic marble sequence can be found, thus comprising the upper layer of the NEAU. The marble is isoclinally folded in the macroscale and its various characteristics, like color, thickness and composition differ from place to place, due to the nature of the neritic platform. Although badly preserved, remnants of fossils indicate a Late Triassic to Late Cretaceous age for the protolith of the marble. The relative position of the above mentioned lithologies may vary, featuring both inversions and repetitions that are due to the severe folding of the unit.

Fig.16) Outcrop of folded marble formation at Penteli Mountain.

The AGU is only limited west of the Marathon reservoir and is generally harder to examine due to its many faults and its restricted layer thickness, relative to the NEAU. It mainly consists of three different formations, a basal sequence of blueschists, quartzite and rich in Na-amphibole metabasic rocks, an intermediate thin dark metachert marble at its upper layers and an overlying thick white-grey marble. The unit is separated by the NEAU by a several kilometers long tectonic contact which, apart from some limited exposures, is mostly buried under the post – alpine formations of the Agios Stefanos – Kapandriti basin. The contact is a normal fault dipping 45º-50º WNW, juxtaposing the marble sequence of the NEAU (footwall) against the AGU schists (hanging wall). Serpentinite lenses of similar composition of the already mentioned at the NEAU, can also be found within the schists of the AGU as well as intercalated between the two units, along the tectonic contact.

The remaining post-alpine formations, that dominate the Agios Stefanos – Kapandriti basin as well as the Marathon basin, consist mainly of alluvial deposits, scree and talus cones as well as a sedimentary sequence of Late Miocene to Late Pliocene deposits of conglomerates, sandstones, clays, marls and travertines. The depositional environments of these rocks reflect the neotectonic evolution of the basins and feature significant variability, of terrestrial, fluvial, lacustrine and marine origin.

3.5. Geographical, Biological and Climatological data of the Study Area

3.5.1. Municipalities

The study area comprises of the municipalities of Marathon and Penteli, as well as part of the municipality of Dionisos. The Municipality of Marathon is situated in the northeastern region of the Attica prefecture in Greece, with the distance between its location and downtown Athens being 42 kilometres. The administrative entities surrounding Marathon include the Community of Grammatiko, the Municipality of Kapandriti, the Community of Stamata, and the Municipality of Nea Makri. The Southern Euboic Gulf serves as the eastern boundary of the research area, including a 10-kilometer shoreline. According to Kallikratis Law, activated on January 1st 2011, the Municipalities of Nea Makri and Marathon, along with the Communities of Grammatiko and Varnavas, joined to form the new Municipality of Marathon, as it is today. The joint municipality has a total land area of 227 Km^2. It is part of the Prefecture of Attica.

The Municipality of Penteli is located approximately 17km NE of Athens and, according to Kallikratis Law, includes the towns of Penteli, Nea Penteli and Melissia, with a total area of 31.1 km^2. It comprises the urban end of the northeastern suburbs of Athens, featuring lush vegetation and including the surrounding hills of Patima, Koufos and Desi, as well as forest and quarrying areas. Penteli mountain, to the north of the municipality, took its name from the first settlement of Penteli in the area, while its older name was Vrilissos. Its greatest area used to belong to the Monastery of Penteli, around which the first settlements of the region started appearing, some of them traditional, that can be found to this day. Apart from the mountain, the Municipality offers a number of interesting historical and folkloric places for its habitants and visitors alike, such as the Doukissis Plakentias Tower, the Maisonette, the Plaisance hostel, the Tourelle tower, the Penteli Observatory and the Monastery of Penteli.

The Municipality of Dionisos is located north of Penteli Mountain, between the Penteli and Marathon ones. According to Kallikratis Law, it comprises of the towns of Agios Stefanos, Anoixi, Dionisos, Drosia, Krioneri, Rodopoli and Stamata, all former administrative units and individual municipalities, with a total area of 64.3 km^2. The study area does not include, however, the part of the former administrative unit of Krioneri.

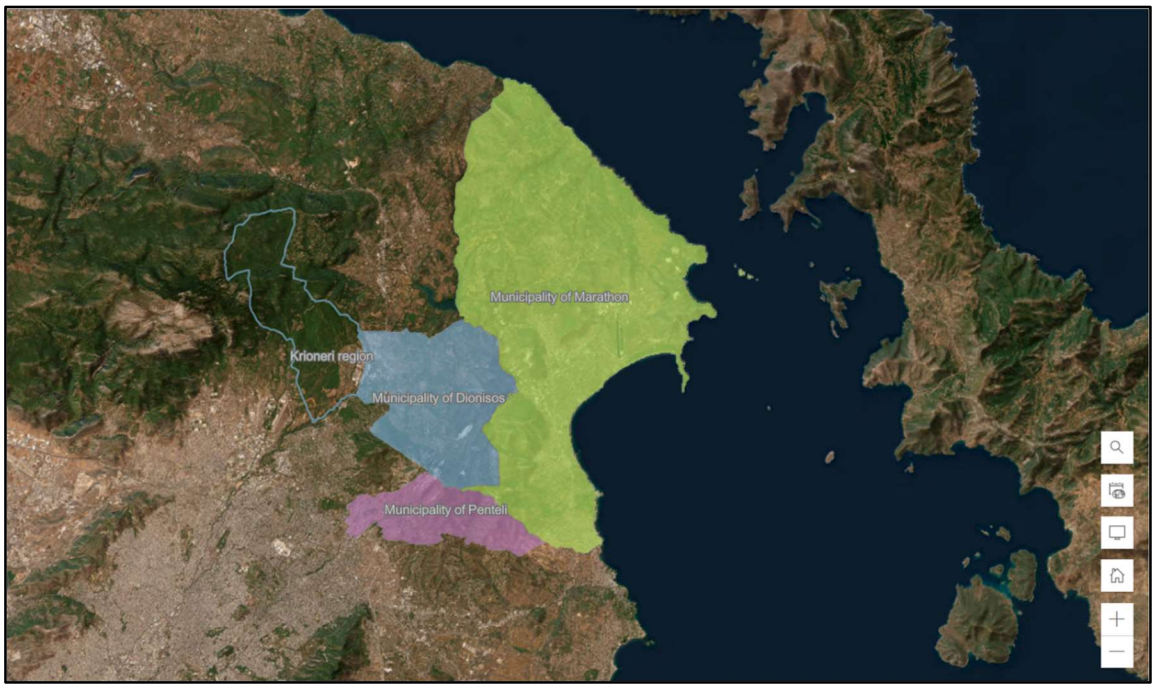

Fig.17) Municipalities that comprise the Study Area. The Municipality of Dionisos is not entirely presented, lacking the Kryoneri region.

According to the Hellenic Statistical Authority, the population of the Municipality of Marathon was recorded as 8,882 persons in the 2001 census. However, this number climbed to 33,423 residents in the 2011 census but declined to 31,331 in the 2021 census. The population of the municipality of Penteli was recorded as 4,829 in 2001 and climbed to 34,934 in 2011 and furtherly to 35,610 in 2021. The population of the Municipality of Dionisos was recorded as 4,987 in 2001 and climbed to 40,193 in 2011 and 42,376 in 2021. The prime reason for the rise in numbers between 2001 and 2011 is due to the unification of former administrative regions into the new municipalities, under the effect of Kallikratis Law. A portion of the rise in numbers between 2011 and 2021 may be ascribed to the phenomenon of secondary residences transitioning into primary dwellings, as well as the seeking of suburban areas' milder climate and living conditions. The Municipality of Marathon consists of eight districts, namely Marathon, Aghios Panteleimon, Ano Souli, Avra, Vothon, Vranas, Kato Souli, and Schinias. According to the 1961 census, the settlement of Marathon had the highest population count among all other settlements. Kato Souli has emerged as the second most densely populated village. Since 1971, Agios Panteleimon has had a notable surge in its population, positioning it as the second most densely populated area after the city of Marathon. Furthermore, it has been noted that a number of villages experienced abandonment, such as Mpeis Lofos in 1991. Conversely, whole new

settlements formed during this period, such Vranas, Avra, and Schinias. Generally, the population of Athens had a notable surge, particularly in the postwar era, resulting in the emergence of densely populated circumstances inside the Athens metropolitan region. Consequently, a significant portion of the population had a desire to acquire a secondary dwelling in the adjacent seaside and, to a lesser extent, wooded regions. From a specific juncture onward, several factors contributed to the establishment of permanent dwellings in the eastern region of Attica. These factors include the enhancement of transportation infrastructure, particularly in the recent decade, the development of a new expressway known as Attiki Odos, and the establishment of the Eleftherios Venizelos Airport in the late 1990s, situated within the Spata Municipality.

3.5.2. Climatic Characteristics - Biodiversity

The term 'Biodiversity' originates from the words biological diversity, defining the diversity among living organisms of all species, their land, marine and lacustrine ecosystems as well as the ecological complexes where they thrive (Grubb et al. 2019). In other words, biodiversity is the variety of life in all its aspects. It comprises of all types, levels and combinations of living being differentiations in nature. To the above, it is important to also consider an extra layer, that of the landscape diversity. Regardless of it being a non-living space, the landscape significantly participates in the formation of the types of flora and fauna that thrive within, as well as the formation and types of ecosystems that develop on different occurrences of regions. As a result, at a region with intense geophysical morphology and many successions of landscape and non-living elements (different exposures to the horizon points, presence of stationary or running water, different types of geologic bedrock etc), a significant variety of biodiversity of flora, fauna and microecosystems is expected to be hosted.

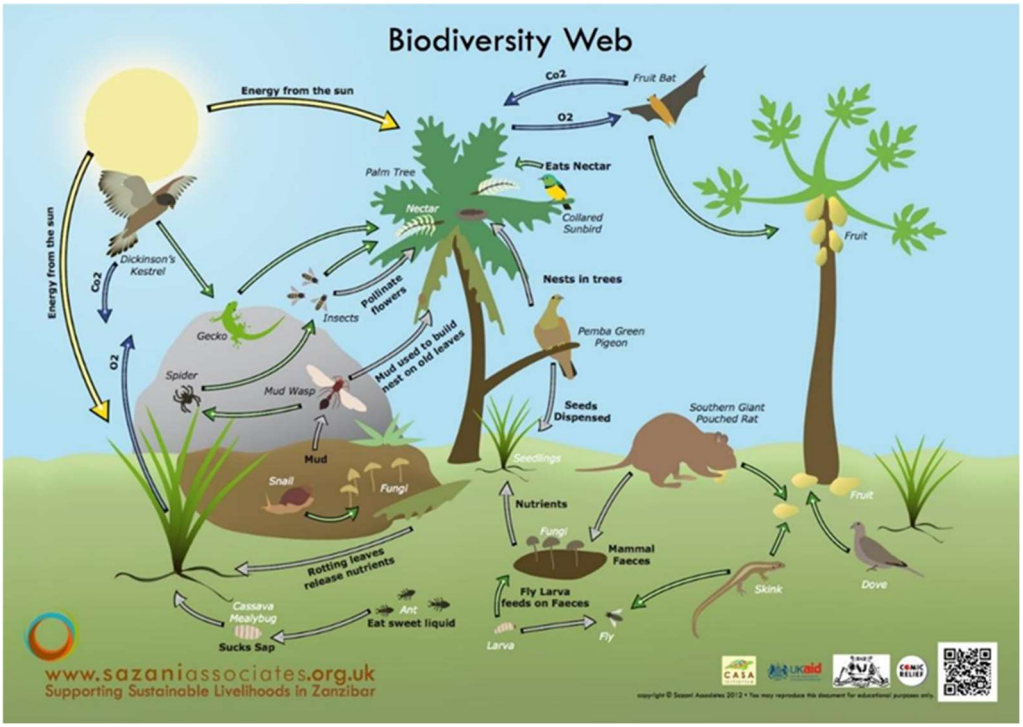

Fig.18) 'Eco Wheel' presenting the natural sources provided by biodiversity, featuring the factors of change. Source: www.sazaniassociates.org.uk

The network 'Natura 2000' is a European Ecological Network of regions, where physical types of habitats and habitats of species that are important at a European level are hosted. It comprises of two regional types:

- Special Protection Areas – SPAs for avifauna, as mentioned at Directive 79/409/EK «for the preservation of wild avifauna».
- Sites of Community Importance – SCIs as defined at Directive 92/43/EOK. For their definition, the types of habitats and species of Appendixes I and II of Directive 92/43/EOK and the criteria of Appendix III are taken into consideration.

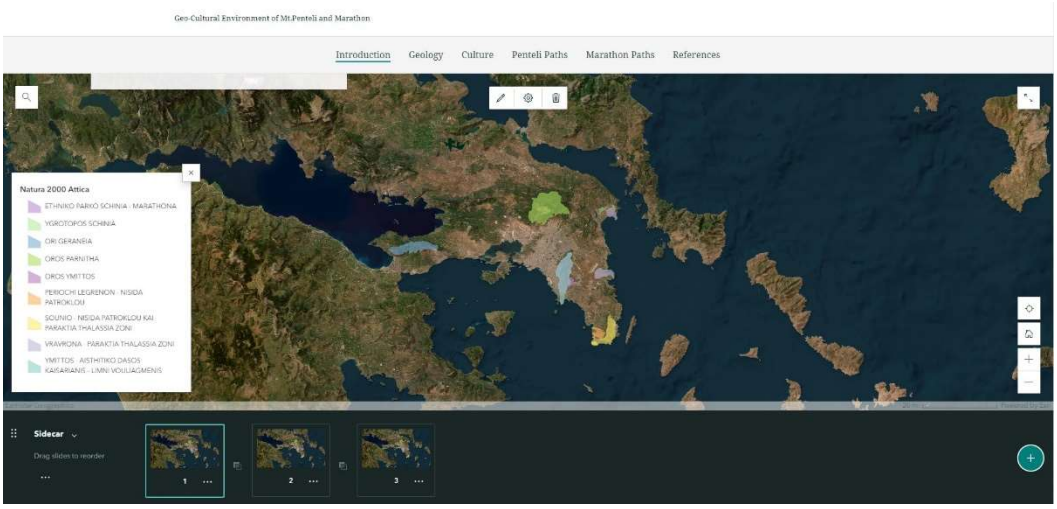

Fig.19) Natura 2000 Ecological Network sites in Attica prefecture, from the Story Map.

As far as biodiversity is concerned, there are two internationally designated Natura 2000 areas focused at the Schinias National Park and Marathon basin areas, with the site codes of GR3000003 'ETHNIKO PARKO SCHINIA-MARATHONA' and GR3000016 'YGROTOPOS SCHINIA', one designated area at a national level (Schinias National Park) and the Mount Penteli protection zones.

Fig.20) Natura 2000 designated areas at Marathon region.

With an area cover of 1332 hectares, out of which 25% is marine area, the National Park of Schinias – Marathon is one of the most important remaining habitats of Attica region, located only 40km northeast of Athens at Marathon plain. It is also one of the most significant coastal wetlands of eastern Greece, hosting an important number of migrating species during their stopovers at spring and fall, where they rest, refuel and seek shelter in the marshes. It is managed by the Organisation of Athens (ORSA), the Forest Service of Kapandriti and the

Management Body of Schinias National Park of Attica, in accordance with the ministerial decision 32473/7718/2001: 'Operation rules and management plan of Schinias Marathon national park'. The central part of the site is covered by the remaining part of the once extensive Marathon wetland, which has been suffering from drainage works (canalization) since 1923. The slightly brackish Drakonera spring, located at the foothills of Drakonera hill, today features a reduced discharge evident only during wet periods. A sandy coastal zone extends from east to west at the southern part and Kynossoura peninsula delineates the south-eastern part. A longitudinal zone near Makaria spring of a total surface of 450ha at the western part of the wetland had been until 2004 occupied by a small airport. In 2004 the Olympic Rowing Center was constructed at the area formerly occupied by the airport. A USA military communication base of a total surface of 100 ha had been operating for several years at the central part of the wetland. The Schinias coastal zone consists of sandy-gravelly dunes of Holocene age. Northwards, the swamp area is covered by silty-clayey, and locally sandy, alluvial deposits of the same age. Eastwards, the Mytika's and Drakonera's hills consist of the upper-cretaceous marbles of Agia Marina (corresponding to the upper marble of NEAU), which are locally covered by scree and talus cones. The area belongs to the broader geographical region of Attica, thus sharing its typical climatological conditions. The climate is Mediterranean, with prominent features the dry-hot summers and the mild-rainy winters. The atmosphere's average annual temperature ranges from 16.5˚C to 19˚C (Natura 2000 – Standard Data Form). The coldest month of the year is January, while the hottest months are July and August. Annual precipitation averages around 378mm, while humidity ranges between 59% - 64%. Cloudy days average around 50 annually, while sunny days around 130, giving a total of 2,920 sunlight hours each year. Prior to 1923 the discharge of both Makaria and Drakonera springs had been providing the wetland with slightly brackish water, which was subsequently conducted to the sea via lake Stomi, that formed near the eastern coast of the site. It is estimated that Makaria spring alone had been supplying the wetland with 6-7 millions of cubic meters of water every year. Runoffs from the upstream mountain catchment had been an additional source of water. To convert the swamp to agricultural land, a drainage channel was constructed in 1923 along the western border of the site. This channel was conducting the Makaria spring waters directly to the sea. Subsequently, a network of flood protection and drainage channels was constructed upstream the wetland, which also drove the flood waters directly into the sea. Secondary flood protection and drainage channels were embedded to that network during the 60's and the 70's in order to protect the military installations and the airport, which were meanwhile constructed inside the wetland area. As a result, the wetland's freshwater supply was restricted to the precipitation

received by the plain (which quantified for about 0,7 million of cubic meters of water annually), while at the same time it received significant quantities of sea water both subterraneously and through the superficial communication of Stomi lake. Consequently, the permanent salt lake of Stomi was converted to a seasonal pond and the wetland area shrunk significantly due to the dry conditions and the land reclamation that followed. The remaining wetland was flooded during the rainy season and dried up in the summer. It featured a variable salinity, with salty or brackish water generally dominating most of its parts and the fresh or slightly brackish element being restricted to a small area around Makaria spring, along a drainage ditch west of Drakonera hill and, to a lesser degree, along other drainage channels. The above-described hydrological status and changes in land use shaped the former natural habitat type status of the wetland and influenced the site's sandy coastal zone.

As mentioned above, in 2004 the Olympic Rowing Center was constructed at the area formerly occupied by the airport. Inside the Olympic Rowing Centre two artificial water bodies were constructed. The water from Makaria spring is directed, through hydraulic constructions, to the Olympic complex water bodies and then channeled to the central wetland. The following have also taken place: the removal of the airport's constructions and runway, removal of the idle military installation and area's soil mitigation, the abolishment of an extensive network of telecommunication antenna mounting structures, which were fragmenting the biotope and heavily disturbing the wild fauna. The construction of the Olympic complex and the permanent presence of two water bodies, channeling fresh/brackish water to the wetland has benefited the National Park's biodiversity.

At least thirty-five bird species were favored, including the strictly protected Aythya nyroca. Furthermore, it is observed that the surface area of reedbeds has noticeably increased. Halophytic vegetation occupies the central and most extensive part of the wetland, as a result of the heavy drainage activities and human pressure on the area during the past 80 years. Halophytic communities often form mosaics: salt meadows with Juncus (habitat type 1410) and salt scrubs are intermixed, giving way to glasswort swards (habitat type 1420) near Stomi lake, where the vegetation is established on a substrate of decomposing sea-grasses (mainly Posidonia oceanica). Juncus maritimus is the dominant species, while other characteristic species include Juncus heldreichianus, Limonium narbonense, Aster tripolium, Scirpoides holoshoenus, Scirpus littoralis, Bolboschoenus maritimus (=Scirpus maritimus), Puccinelia distans, Plantago crassifolia. The salt scrub is the main vegetation type, dominated by Sarcocornia perennis (at the lower sites) and Arthrocnemum macrostachyum (at the higher,

better aerated sites), while other species participating are Puccinelia festuciformis, P. distans, Limoniun narbonense, L. virgatum, L. bellidifolium, Centaurium spicatum, Suaeda vera, Salsola soda, Atriplex portucaloides. Annual halophilous pioneer communities (habitat type 1310) with Cressa cretica develop along dry channel beds and sometimes in patches with increased salinity that remain inundated longer. Other Saginetea species, such as Spergularia salina, Parapholis incurve, P. filiformis, Salsola soda, appear among the salt scrub but rarely form representative communities (Natura 2000 – Standard Data Form).

Reedbeds with Phragmites australis and Typha angustifolia (Corine 53.1) occupy chiefly parts of the central and north-western part of the wetland, with evidence that they are expanding. Tamarisk galleries (habitat type 92D0) develop at channel banks and at embankments throughout the wetland and notably at the main channel of Makaria spring with Tamarix tetrandra (mainly at the eastern part) and Tamarix hampeana (mainly at the western part). These two habitats form mosaics at the north-western part of the site. Freshwater aquatic habitats develop at Makaria spring and along its drainage channel. At stagnant waters at the small pond created at Makaria spring, Magnopatamion vegetation with Potamogeton nodosus (habitat type 3150) occurs. Along the channel, at slow flowing points, there are floating communities of Apion nodiflori (habitat type 3260) with a benthic mat of Chara (habitat type 3140 is included in 3260). Close to the estuary the flow is not permanent and there develop Potamogeton pectinatus and Nasturtium officinale communities (habitat 3290). Typical communities of the habitat “Mediterranean temporary ponds” (habitat type 3170) have not been identified in the wetland. A single small patch of dwarf pioneer annuals characterized by Crassula sp. And Herniaria hirsute has been located at a road bank (SW part of the site) on sandy, temporarily waterlogged substrate. Also, small communities with Juncus bufonius, Poa annua, Plantago coronopus develop at small temporary ponds among the juniper matorral at the lower parts of Drakonera. These communities, with the participation of Isoeto-NanoJuncetea species, could be assigned as habitat vegetation (such as Juncus articulatus, Mentha pulegium, Serapias lingua, Centaurium pulchellum, Lotus angustissimus) have been reported from the site. The site’s coastal sandy part maintains successive zones of ammophilous habitats.

At a zone of 50 meters from the sea there is only naked sand with loose driftline communities of Cakile maritime, Matthiola tricuspidata, Salsola kali (habitat type 1210), followed by ridges of low embryonic dunes (habitat type 2110) with Elytrigia juncea (=Elymus farctus), Eryngium maritimum, Medicago marina. Pseudorlaya pumila, Lotus halophilus, Allium staticiforme, Rhagadiolus stellatus, Silene colarara also participate in the ammophilous communities. To the

western part, closer to the mouth of Makaria channel and in front of the Park's inhabited zone, the structure of the dunes is even more degraded. There develop ammophilous communities with Cyperus capitatus and Sporobolus pungens and a low dune front with Centaurea spinosa. Behind this zone and all along the coast there are low, stabilized dunes, forested with Pinus pinea at the western part and Pinus halepensis at the eastern part (the two pines intermix towards the center). The understory is composed of maquis species, mainly Pistacia lentiscus and also Quercus coccifera, Juniperus phoenicea, Myrtus communis, Rhamnus alaternus, Rubia peregrine, Ruscus aculeatus, Smilax aspera, Asparagus acutifolius and by phryganic species such as Helichrysum stoechas, Phagnalon graecum, Anthyllis hermaniae, Cistus incanus, C. salvifolius, Coridothymus capitatus. The herb layer includes species such as Cyclamen hederifolium, C. graecum, Ophrys lutea, Serapias lingua. A zone at the northern part of the Pinus pinea forest is covered by low to medium height matorral dominated by Pistacia lentiscus (habitat type 2260). Malcolmietalia annual grasslands (habitat type 2230) with dominance of Silene colorata, Anthemis tomentosa, Medicago littoralis, develop mainly at extended patches on mostly flat, stabilized sand of the rear dune at the western part of the site. In the more disturbed zone towards the wetland synanthropic grassland of Stellarietea mediae develops to the expense of the typical dune grassland. Isolated Juniperus oxycedrus ssp. Macrocarpa individuals and small stands of Pinus pinea grow at these places. It should be noted that the dune therophytic grasslands of Malcolmietalia (2230) of the site, belonging to the synclass of Thero-Brachypodietea, were previously assigned as habitat type 6220, which is of similar floristic composition.

However, since these communities are part of the dune system, there are better described as habitat type 2230. In a narrow zone between the embryonic dunes and the forest there are small stands of Juniperus oxycedrus ssp. Macrocarpa (habitat type 2250) with Pistacia lentiscus. Pistacia lentiscus formations in sand dunes comprise the habitat type 2260. These formations most probably constitute remnants of previously well-developed post dunal communities of the type found elsewhere in the Aegean.

The Kynosoura peninsula is covered across its greatest part by maquis, medium to high, at places scattered but generally quite thick. Juniperus phoenicea (habitat type 5210) is dominant in most of the stands while other shrubs participating are Pistacia lentiscus, P. terebinthus, Ceratonia siliqua, Olea europaea ssp. Oleaster, Ephedra foemina, Quercus coccifera, Rhamnus alaternus, Calicotome villosa, Prunus webbii, Prasium majus. In the herb layer and at openings a multitude of therophytes, grasses and geophytes develop, including the endemics Fritillaria

obliqua and Scorzonera crocifolia, as well as some orchids. Phryganas Satureja Juliana, S. nervosa, S. graeca, Euphorbia acanthothamnos, H. stoechas, Phagnalon graecum, Coridothymus capitatus, Teucrium capitatum, T. divaricatum develop in the understory and at openings of the maquis mainly at the western part. At open rocky places with boulders, at the crest of the promontory and at some slopes Euphorbia dendroides dominates the scrub, growing along with Anagyris foetida, Phlomis fruticosa, Ephedra foemina. At the same sites small chasmophytic communities with Asplenium cetarach, Cheilanthes acrostica, Cosentinia vellea, Umbilicus rupestris develop at rock crevices. The scrub descents the steep slopes over the sea. Juniper matoral of similar composition but generally thinner and lower (due to recent fire and grazing) covers Drakonera hill as well. Chasmophytic vegetation of good representativity develops at a small rock face at the hillcrest (Natura 2000 – Standard Data Form).

Therophytic grassland patches (Thero-Brachypodietea, habitat type 6220) grow at openings of the scrub but at the flat areas of the foothills Stellarietea and Artemisetea species take over. Schinias wetland has traditionally been an important waterfowl and waterbird migration station. Visitors include Plegadis falcinellus, Botaurus stellaris, several Ardeidae, Rallidae, Ciconiidae, Anatidae, Tringa, Calidris species, as well as numerous birds of prey (mainly Falconidae).

Site's significance has been upgraded after the pre-mentioned interventions to the hydrological regime. Wintering avifauna among others includes the protected Acrocephalus melanopogon. Although small in numbers, the presence of several species of birds of prey at the surrounding hills is significant. These species, which prey on the wetland plain, among others include Circaetus gallicus, Buteo rufinus, Falco peregrinus, Bubo bubo, as well as the more common Buteo buteo, Falco tinunculus, Tyto alba, Otus scops. At the maquis vegetation covering the hillsides protected species typical of this habitat type breed, such as Sylvia hortensis and Sylvia rueppelli. Along the channel's and the ponds' banks one can find the reptiles Emys orbicularis, Mauremys 44apsica, Testudo hermanni, Testudo marginata, Elaphe situla, as well as the endemic fish Pelasgus marathonicus. Other important fauna and flora species are Hipparchia aristaeus and Anax imperator, which are protected by the Greek Law (Presidential Decree 67/1981). Also, Anacamptis pyramidalis, Cyclamen hederifolium, Orchis laxiflora, Serapias lingua and Serapias parviflora (Natura 2000 – Standard Data Form).

The site of Schinias National Park retains an important ecological quality despite its proximity to the city of Athens. In fact, its importance and priority for conservation is heightened by this proximity. The site's ecological value is mainly based on the following features:

1) An abundance of habitat types, which alternate in a relatively small area. The forest of Pinus pinea, though currently at a declining conservation status, is quite representative and moreover one of the few in Greece and unique in Central Greece due to its coastal environment. The sand dune system, despite its degraded structure, is composed of a variety of communities (only the remnant of a previously well-developed system) and is the only one surviving in Attica region, featuring species already extinct from everywhere else in the wider area. The coastal wetland is the largest and most important in Attica region with typical halophytic communities. The tamarisk galleries constitute an ideal forest at places where soil salinity prevents the development of other trees and comprises a refuge for birds and other fauna species. The remaining stands are spectacular at places (these too have disappeared from other sites in Attica region). The freshwater aquatic habitats have just adequate representativity and low floristic diversity but with favorable conservation prospects. The J. phoenicea matoral is well conserved and hosts a multitude of species that make Kynosoura a natural botanical garden.

2) The flora is rich in common species and includes some endemic, rare and protected plants.

3) Fauna presence is rich, despite the severe degradation and continuous heavy human pressure. The site has a high potential of becoming an important bird migration station as it lies on the Eastern Europe-Balkan Peninsula-Africa central migration axis and comprises one of the very few freshwater stations in the Attika region (and the Eastern Greece in general). One of the facts for the inclusion of the site in the national IBA (Important Bird Areas) catalogue. It is estimated that the area's ecological potential is much greater than what its currently degraded status implies and that it will manifest as soon as the wetland's original hydrology is restored. However, improvement has been noticed since the construction of the Olympic complex. The area's role as a breeding and migration site for many aquatic birds could be further upgraded.

4) Cultural, educational and social aspects of the area. The area holds some very strong historical associations (Marathon battle – 490 BC) and lies near to important archaeological sites (Marathon tomb, Rhamnous). Furthermore, it is ideal for educational and research purposes in the fields of biology and nature conservation. Finally, it is one of the most important sea recreation areas for the inhabitants of Athens and one of the few in the area that still retain their aesthetic value and the classical beauty of the Attica landscape. The Presidential Decree

for the designation of the site as a National Park and the Ministerial Decision set its Management Plan and Operation Rules. However, a lot of effort still needs to be made for their adequate implementation, so that human pressure on the biotope minimizes and the area can serve as a model Integration – pole for the concepts of ecology, environmental education, culture, sustainable development and mild recreation activities (Natura 2000 – Standard Data Form).

The official sub-areas of the Schinias National Park, according to the national designation, are the following:

A1: Wetland Area.

A2: Drakonera Hill and Kynosoura Peninsula.

A3: Koukounaria and Pine tree forest.

A4: Makaria Spring.

A5: Marine Area.

B1: Olympic Center of Canoeing.

B2: Recreation, Sports and Residence Area.

B3: Beach of Marathon Bay Area.

C (Γ): Supervised Agricultural Area.

According to the Presidential Decree 26/8/1988, ΦΕΚ 755/Δ/1988, 21/10/1988, there are 7 defined zones of protection of Mount Penteli, regarding its land use and accessibility. It is the only official designation for the mountain. The following zones have been designated:

Zone A: Recreation, Sports and Agriculture use.

Zone B: Agriculture use.

Zone C (Γ): Residence Area and Agriculture use.

Zone D (Δ): Recreation Area.

Zone E: Quarrying Area.

Zone F (ΣΤ): Area of environmental education and recreation.

Zone G (Ζ): Recreation, Sports and Cultural Events area.

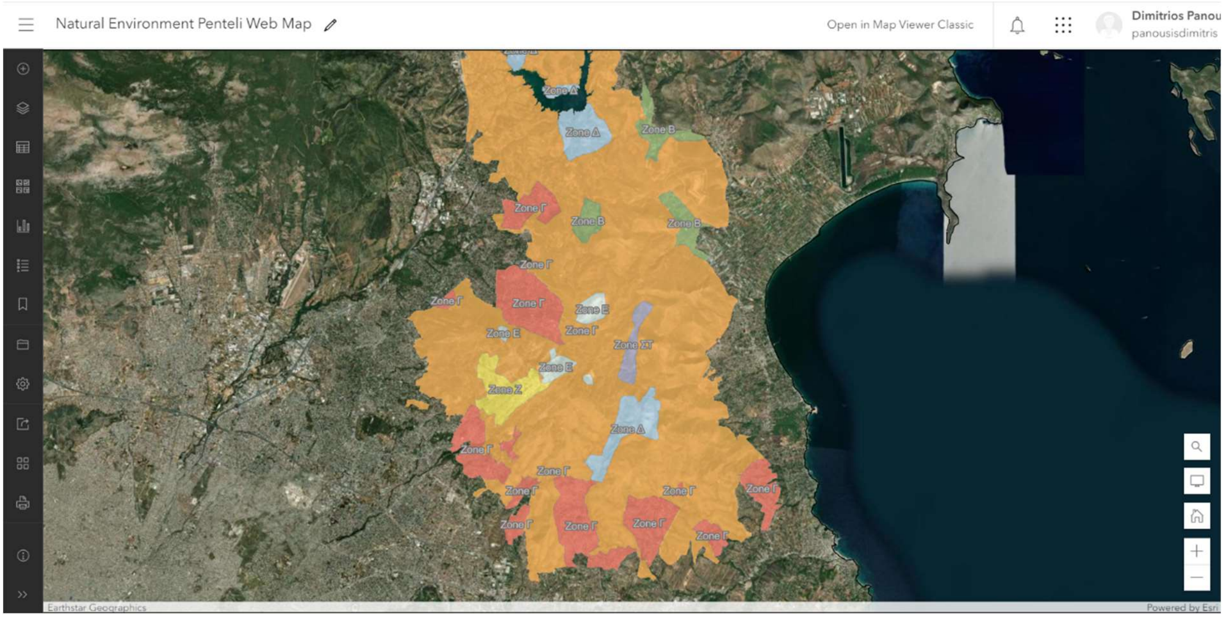

Fig.22) The protective zones of Penteli Mountain as featured in a Story Map's web map.

3.6. Culture - History

The Marathon region is associated with some of the most important phases of human history in the Mediterranean and Southern Europe in general. It was here when, a number of morphological, hydrological and sociological circumstances determined the flourishing of human societies and civilizations as early as the Early Helladic period (3200 – 2650 BC). Several well preserved and conserved archaeological areas provide the basic map for visitors to unfold the area's significance, relive the series of events that determined history and explore findings of unparalleled importance.

At Tsepi location, on the path to the Marathon Archaeological Museum, is the Early Helladic cemetery, one of the most ancient features of human habitation in the area, accessible to visitors. It was first investigated by Spyros Marinatos in the 1970s and by the Greek Archaeological Society, under Professor M.Pantelidou, in recent years. It is a large, well-organized cemetery that consists of tombs defined by rectangular or trapezoid stone enclosures, arranged in rows. The inner-chamber walls are constructed in dry-stone masonry or vested by schist slabs. Each grave has antae flanking the entrance and a small 'dromos' (road) leading to its interior. The deceased were placed inside in a contracted position and were brushed aside with every new inhumation. The burials were accompanied by terracotta vases, figurines and

stone and bone tools. Numerous such vases were recently discovered within an excavated pit, probably deposited there during a funerary ritual. Both the graves and the pit contained locally produced pottery of various types of Cycladic Style (small amphorae, large basins, cups, jars, tall-footed fruit bowls), thus indicating the close ties and influence between Attica and the Cyclades (Source: www.efaanat.gr).

Fig.23) View of the interior of the protective area at the Tsepi Early Helladic cemetery.

At Vranas location and next to the main building of the Marathon Archaeological Museum, a cemetery of tumuli (burial mounds – tombs) was created in the Middle Bronze Age (2000 – 1600 BC). During these times the dead were usually buried in or near the settlement. The tumuli at Vranas comprise an infrequent case where the place of the dead is separated to that of the living, although the settlement associated to the tombs has not been found yet. The nearest known settlement is at the coastal site Plassi, about 4km to the east of the location of the tombs. Each tumulus, considered to belong to families wealthy enough to build them, comprised of several graves where men, women and children had been laid, thus offering evidence on the social organization, the beliefs of the people for the afterlife and the connection of the living to the dead. Four tumuli were excavated by the professor Spyridon Marinatos in 1970, but there are also another three existing. Tumuli I and II, the biggest and most well-preserved (diameter of 16m) and tumulus III (diameter of 7m) are protected by a modern shelter, while the fourth

one (tumulus IV) about 40m to the east, is covered with earth. They present common features in construction, like the circular or elliptical precinct built with flat stones, the surface coverage with river stones, the cist graves simple of compound of 2 or 3 compartments when lying in the center.

At the time, the number of burial gifts even for the prominent dead was restricted to only 2-4 locally produced or imported clay pots. An even older cemetery, similar to the one at Tsepi, is also thought to exist at deeper layers beneath the tombs. Tumuli II, III and IV were also used in the Late Bronze Age by the Mycenaeans, by generally maintaining traditional practices (Committee of Archaeological Artifacts of Eastern Attica).

Fig.24) The two most prominent Tumuli in the Middle Bronze Age cemetery at Vranas.

In the locality of Mikro Elos (Small Marsh) of Brexiza, Marathon, also referred to as Nissi area (island), excavations first started by in 1792 by the French Consul in Athens, L.S. Fauvel, revealed an extensive complex of the sanctuary of Egyptian gods and the luxurious bathhouse (balneum), as well as a large ellipsoidal cistern further to the south. The cult of the Egyptian gods was gradually adopted by the Greeks since the 4th century BC and constantly gained ground. The complex, now accessible to visitors, was founded by Herodes Atticus around 160AD. The great orator, sophist and benefactor hailed from Marathon and resided at this area, with the complex possibly been established within his estate. According to the Herodes' biographer Philostratos, it was referred to as the sanctuary of Canopus. In founding it, Herodes

imitated Emperor Hadrian who had built a Serapeion on an artificial islet at Tivoli, close to Rome, modeled on the Serapeion of the Canopus town on the Nile Delta. The sanctuary comprises the large rectangular area of the sanctuary proper to the west and of a forecourt to the east, being enclosed by a wall with four entrances, one on each side. They imitate Egyptian pylons, framed by two rectangular towers, between which marble steps and a threshold are preserved. Each entrance is flanked inside and out by pairs of colossal statues on pedestals, one male representing the Pharaoh type statue and the other three female representing the goddess Isis in different types, as inherited by the mixing of Greek, Roman and Egyptian cultures. The original statues are located at the Marathon Archaeological Museum, while replicas are presented on site. Paved causeways led from the four pylons to the center of the sanctuary, where a stepped construction dominates set upon a rectangular terrace surrounded by a passageway. On the outside of the passage the paved causeways terminate in four steps and an elevated platform, each one of which is flanked by a room. In two of these rooms there have been found a statue of Isis, and Egyptianizing Sphinx, enormous lamps with relief busts of Sarapis and Isis as well as marble falcons representing the god Horus. The stepped construction appears to be the focus of the worship in the sanctuary. According to an inscription, the sanctuary may have been dedicated to the god Sarapis, the hellenized version of the Egyptian god Osiris. Isis, being the spouse of the last, had a dominant role, while their son Horus was also worshipped. The nature of Isis was in tune with Greek beliefs, resulting in her identification with Greek deities.

The building of the balneum (bathhouse) Is also part of the complex built by Herodes Atticus in Brexiza area. Such baths comprised of a changing room (apodyturium) and three bathing rooms – for the cold (frigidarium), the tepid (tepidarium) and the warm bath (caldarium). Around them expand additional halls, creating a composite building. The center of the Brexiza complex holds an elliptical marble-lined pool intended for warm baths. Around it, eighteen chambers were built to serve for the perspiration of bathers, hot baths, tepid and cold baths. The heating system for the hot baths and the perspiration started from the furnaces in which fire burnt. The warm air reached spaces beneath the floor, called hypocausts, and from there it rose through vertical pipes built into the walls, to eventually heat the rooms. Visitors could start the bathing process from the changing room. Then, they could exercise in the palestra or a similar hall, if available. Following the physical exercise, they usually started bathing in the tepid bath and proceeded to the chamber of the hot bath (caldarium). In more composite

bathhouses the bathers could use the sweating room (sudatorium). Finally, after visiting again the tepid chamber they completed their bath in the cold room (frigidarium).

Fig.25) Sanctuary of the Egyptian Gods at Brexiza location, Nea Makri.

In Marathon valley and in late summer of 490 BC, 10000 Athenians and 1000 men from the small city of Plataea in Boeotia, an ally of Athens, under the leadership of Miltiades, fought and defeated the army of the Persian Empire. Today, an earth mound or tumulus, 10m in height and 50m in diameter, cover on the spot where the clash reached its climax, the layer of ash and burnt bones from the funeral pyres that then filled the plain, and the remains of the banquets for the 192 Athenians dead in this historic battle. Stelai inscribed with the casualties' names were erected on the summit of the tumulus. The victory of the Athenians remained for centuries the most glorious event in the annals of the city's history and the Marathon warrior was the immortal model of the freedom fighter. Funerary games and torch races were organized in honor of the fallen, and the Tumulus remained into Roman times a place of pilgrimage for Athenian youths. The 'Soros' (mound), lost in the plain, was discovered and excavated by Valerios Stais in 1890/1891 after an unsuccessful attempt by Heinrich Schliemann in 1884. The vases from the pyre which covered the entire surface and from the pit in which offerings were deposited are exhibited in the Marathon Archaeological Museum and the National Archaeological Museum in Athens.

Fig.26) View of the Tomb of Marathon Warriors, within the archaeological site.

Some years after the historic battle of Marathon in 490 BC, the Athenians erected a Trophy to commemorate their victory over the Persians. The trophies of the Persian Wars, unlike the ones of the battles among Greek city-states, were of monumental character. The trophy, as the traveler Pausanias (2nd century AD) relates, was built of white marble. Parts of this original trophy were incorporated in the medieval tower very close to the church of the Virgin Mary (Panagia Mesosporitissa). A stone inscribed 'Tropaion' (Trophy), identified near the tower in the past, confirms the location of the monument near the spot of the final destruction of the Persians in the edge of the Large Mash. The Trophy is in the form of an unfluted column shaft, 10m in height, with an Ionic capital. On its upper surface it bears a hollow to support a statue, probably that of the goddess Nike, of which only one small fragment survives. According to the style of the capital and the sculpture, the monument is dated in the age of the general Kimon, son of Miltiades, in about 470/460 BC. Today, the surviving parts of the trophy are exhibited in the Marathon Archaeological Museum. On this evidence, it was reconstructed of marble in the location it was probably originally set up.

Fig.27) The Trophy of the Battle of Marathon replica, erected close to its real inferred location.

Located inside the municipality of Marathon, specifically situated between Grammatiko and Kato Souli, is the historic town of Ramnous (Figures 28,29). Despite its close proximity to Athens, located around 60 kilometers away and reachable within an hour by vehicle, this particular archaeological site remains rather obscure, despite its significant value as determined by experts in the field of archaeology (Zygouraki, 2021).

The ruins of the ancient municipality of Ramnounta are situated in a strategically significant position unparalleled in ancient times. Furthermore, the natural environment around these ruins remains unaltered to this day, contributing to the preservation of this historical landmark. The region has shown uninterrupted human habitation since the Neolithic era (Zygouraki, 2021).

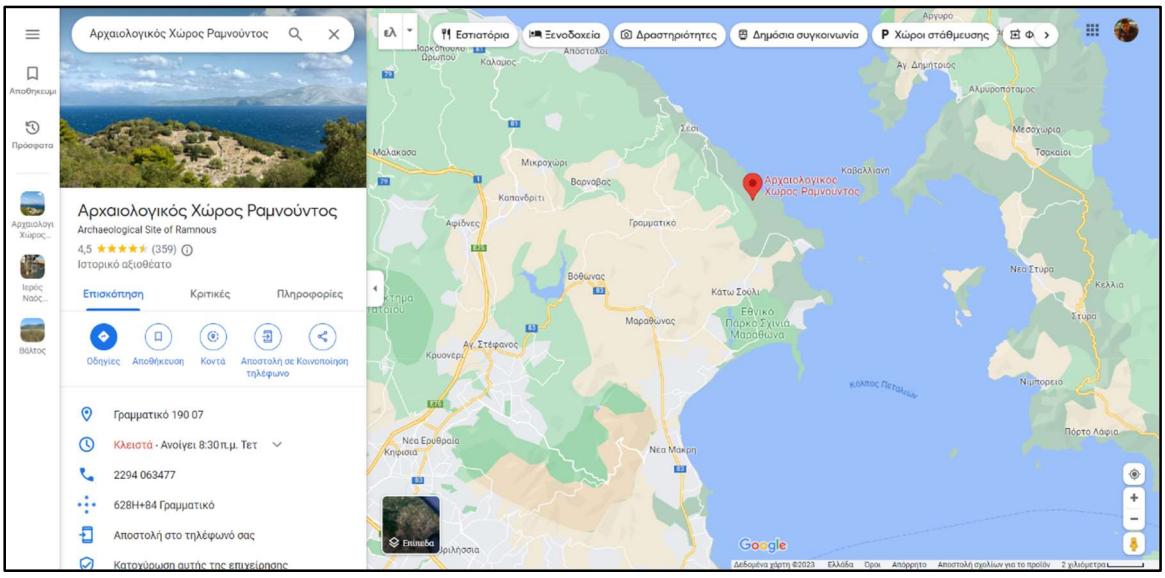

Fig.28) Location of archaeological site of Ancient Ramnounta.

Ramnounta is a well-preserved ancient municipality of Attica that was associated with the Eantida tribe. The ancient village was fortified with walls and included many structures, including public buildings, shrines, and residential dwellings.

Fig.29) View of Ramnous fortress from the ancient road descending toward the fortress.

4. Creating a Story Map for the promotion of points and paths of geological, cultural and religious interest

According to the available literature, the study area of Mount Penteli and Marathon includes the following categories of geodiversity:

- Interesting geological outcrops (metamorphic marbles, folds)
- Tectonic structures (faults, folds and fracture structures)
- Representative geomorphological locations (caves, creeks, karst)
- Geodynamic process-related sites (tectonic grabens and horsts)
- Geo-mythological, geo-historical and geo-archaeological sites
- Ancient sites of ore and mineral extraction.

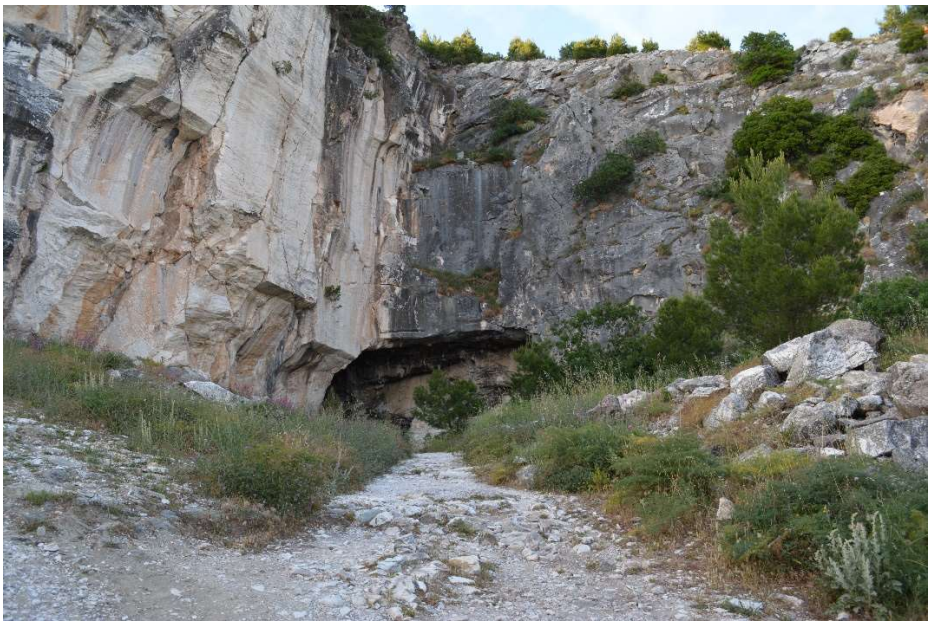

Fig.30) Daveli's cave at Mount Penteli is a prime example of the area's geodiversity, being an interesting marble outcrop that combines a representative geomorphological environment, a site of geo-historic importance and an ancient site of extraction.

4.1 Purpose of thesis – Objective – Goals

The purpose of this thesis is to record, map and photograph specific points of interest of the Mount Penteli – Marathon area, regarding its geological significance, its cultural – historic identity and its biodiversity. Furthermore, different paths of interest are also proposed to promote the above-mentioned points and their characteristics and provide a basic visit plan for anyone wanting to discover the study area in more detail.

The goals of the thesis were met by applying suitable, modern technics and research tools to promote the special geological characteristics of the area, that have both influenced and determined the course of history for Greece, thus making it a place of significant geoheritage value, suitable for alternative means of tourism, like geotourism. Already existing walking trails, asphalt and dirt road paths that facilitate access to the proposed points of interest combined with cultural-historical values of the Penteli – Marathon area are then presented through the creation of a publicly accessible narrative platform (Story Map).

To achieve the aforementioned goals, a workflow with specific steps was planned and followed, briefly consisting of the following phases:

The first phase consists of gathering representative literature material for the study area, including its geology – geoenvironment (rock formations, tectonic structures, morphology etc), its culture and history (settlements, archaeological sites, religious places etc) as well as its biodiversity (mainly from the available protection zones datasets). During this phase, the main points of interest as well as the proposed paths of interest for both the Penteli and Marathon sub-regions were mapped, providing the initial primary GIS data.

The second phase was to visit the study area itself, by scheduling specific field trips for the collection of data. The field trips included hiking some of the proposed trails of interest of Mount Penteli and Marathon region, assessing the available geological points of interest in regard to their complexity and structure so that they can be easily understood by the public, determining the proposal of additional points of interest based on hiking and other activities already taking place in the areas as well as curating data form the first phase, such as offset paths or/and offset points. Available shapefiles from external sources were also collected and assessed for the following construction of the platform.

The third phase included the curation of all available data in a GIS environment. For the purposes of the project, ArcGIS Pro along with ArcGIS Online were used. The available data were organized in a database and then mapped in the GIS software, with their attributes set.

During this stage, the individual web maps and web scenes of the story map were also created, following the eventual curation of the data, within the ArcGIS Online environment.

The fourth and final phase included the construction of the narrative platform itself. Following an extensive literature overview of already done Story Maps, the platform's contents and structure were determined, the descriptive text, available multimedia like photos and videos were added and the final product was created.

4.2 First phase of implementation

During the first phase of the project and following the literature review, an illustration of the main points of interest and paths was conducted by using Google Earth Pro and ArcGIS Pro software.

Literature Review

From all the available data gathered through literature review (see final chapter 'References'), the domains of interest that the assignment focused on include the area's geology, biodiversity and culture/history. The selected literature references were analyzed and the available information was presented in the theoretical part of the assignment (see chapters 1,2 and 3). At this stage too, GIS data from external sources (https://geodata.gov.gr/) were also collected to assist the better presentation of the area through the final product. For more details, see chapter 4.4.

Illustration of points and paths of interest through Google Earth and ArcGIS Pro

The geological sites of Interest, adapted from Lozios et al. 2019, were initially located with high accuracy by inserting the available coordinates and plotting them as points on Google Earth Pro. Then, the created .kmz file of the points was converted to a GIS layer and then inserted to ArcGIS Pro. From the literature review, a number of additional points regarding places of cultural, historical, folkloric and natural interest were also added as separate layers for Penteli and Marathon, to distinguish them from the geologic ones. The points were given

their descriptive attributes, while important geospatial attributes, like their coordinates, were recalculated within the ArcGIS Pro environment. The point shapefiles were then uploaded as feature classes within ArcGIS Online, to create the basic mock maps for the next phase of the field trips.

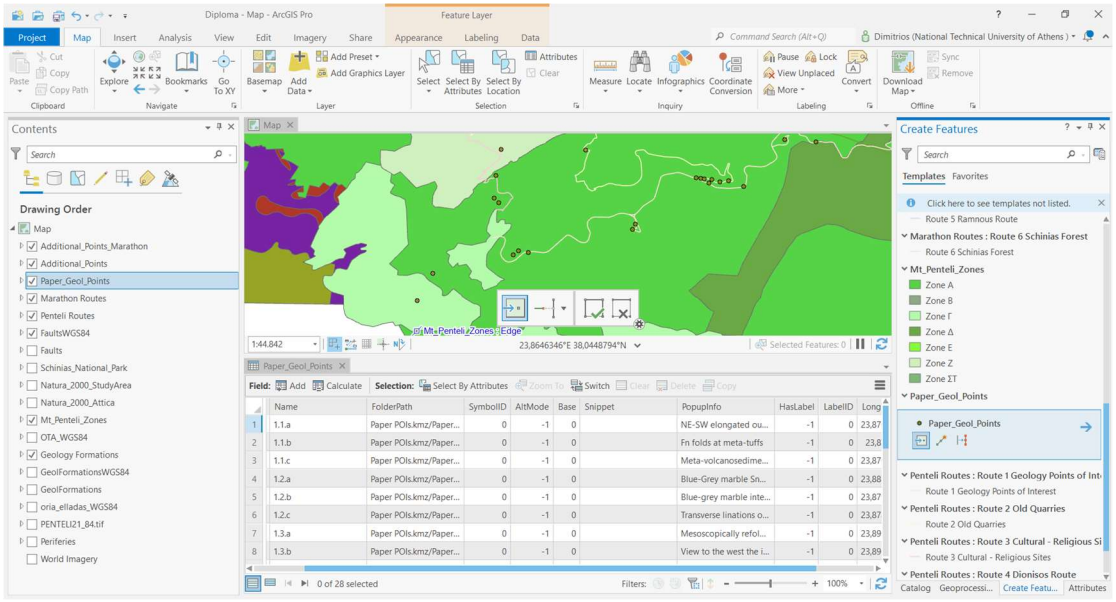

Fig.31) Placing the points of interest within the GIS software.

The paths of interest for Mount Penteli and Marathon region were initially digitized in the environment of Google Earth Pro, due to the high spatial resolution of its satellite imagery and also due to the general high visibility of the paths, as a result of sparse vegetation. The paths were compiled by joining different walking trails, driving ways and short trips based on Lozios et al. 2019 as well as a number of online websites that host articles written by experienced nature enthusiasts and professionals on the region. Some of them are circular, meaning that both their start and end points match, hence visitors can end up exactly where they started from, while others connect different points of interest based on their thematic. For example, path number 2 for Penteli Mountain, named ‘Old Quarries’, passes through the remnants of old marble extraction sites for its most significant length, while path 3 ‘Cultural and Religious Sites’ connects areas of historical and religious importance, such as Lithagogias street, Daveli’s Cave and the Monastery of Saint Panteleimon. For the digitization of paths that were not visible at the satellite imagery, a basemap from ‘Anavasi’ cartographic company, specialized in producing high accuracy hiking maps for different areas across Greece, was purchased and used. More details regarding the process of digitization and curation of GIS data can be found in the following chapter 4.4. Following the field trips, the paths were finalized and then digitized with high precision in ArcGIS Pro, with basic attributes such as their length been

calculated. The finalized shapefiles were then uploaded as feature classes in ArcGIS Online, had their symbology properly adjusted and then fitted within the final Story Map platform.

Some of the websites that were used to determine the paths of interest for the study area are the following:

https://www.topoguide.gr/mountains/attiki/advs_pendeli/pendeli_hiking.php

https://penteli.gov.gr/%CE%B1%CE%B8%CE%BB%CE%B7%CF%84%CE%B9%CF%83%CE%BC%CF%8C%CF%82-%CF%80%CE%B5%CE%B6%CE%BF%CF%80%CE%BF%CF%81%CE%AF%CE%B1-hiking/

https://www.monopatiapolitismou.gr/?p=139

https://www.topoguide.gr/mountains/attiki/advs_mikri_attiki/hiking_on_attiki_marathonas.php

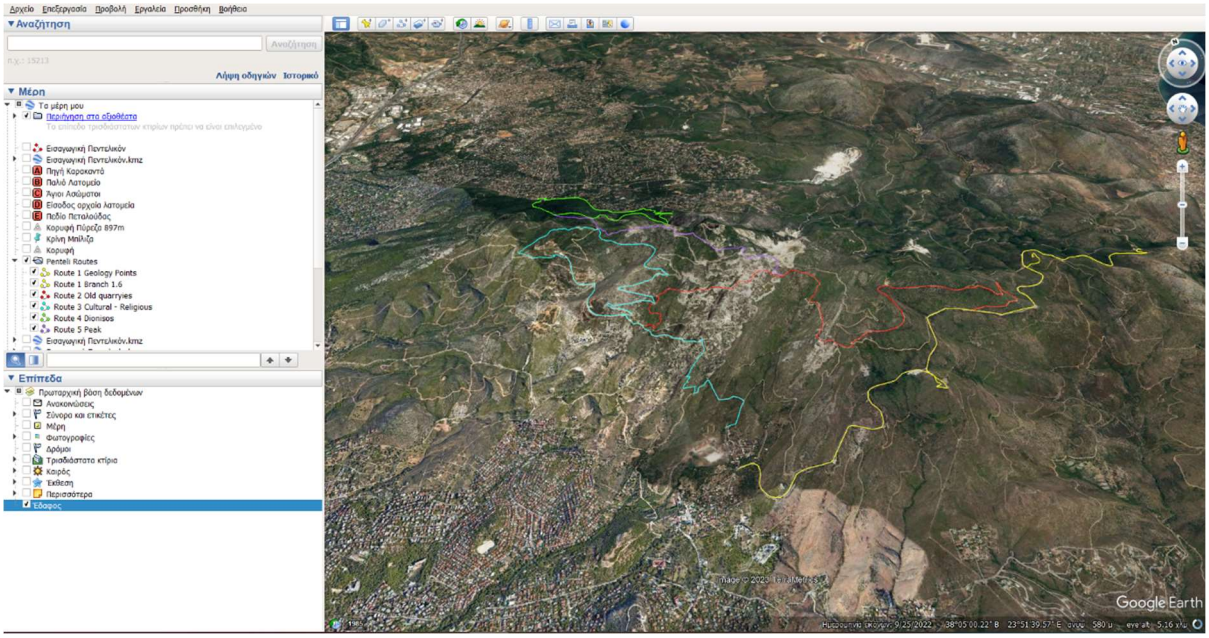

Fig.32) Mapping the proposed paths of interest of Penteli Mountain at Google Earth Pro.

4.3 Second phase of implementation

This phase included a number of dedicated visits to the study area, in the two sub-regions: first, the excursions to Mount Penteli and then, the excursions to Marathon. The field trips were among the most important phases of the project and played a key role in evaluating the primary data (proper location and descriptions of the points and paths), collecting additional data for the different points of interest, gathering additional literature for the Story Map's narrative text and, most prominently, collecting multimedia (photos, videos, aerial - drone footage) of the area. During the trips, many portions of the proposed paths of interest were also evaluated regarding their accessibility, level of difficulty and significance. ESRI Field Maps mobile application was used to access the online mock maps prepared during the previous phase, that included the primary data (points and paths of interest). This contributed to exactly locating the points and paths and provided an easy way of correcting the data, when necessary. The excursions took place in late spring of 2023 (for Mount Penteli) and early autumn of 2023 (for Marathon). These time frames were proven ideal as optimal meteorological conditions and human activities prevailed in the region. A total of 7 daily excursions took place, yielding more than 10 GB of multimedia and text data, to support the project. All photos were shot using a Nikon D5200 DSLR camera, with a 18-55mm Nikkor optical lens, in standard JPEG format of 300 dpi horizontal and vertical analysis, 6000x4000 in dimensions and less than 10MB in size. The drone photos were shot using a DJI Mini 2 with its default camera, in standard JPEG format of 72 dpi horizontal and vertical analysis, 4000x2250 in dimensions and less than 10MB size.

Mount Penteli excursions

A total of 4 daily excursions took place at Mount Penteli in the late spring – early summer of 2023, which involved geological inspection, trail inspection, multimedia data collection and the determining of additional points of interest and the final courses of the proposed paths.

Excursion 1 – The geological points of interest – 28/05/2023

The first excursion at Mount Penteli involved all the proposed geological points of interest, as suggested by Lozios et al. 2019. It was practically the execution of the first path the above authors proposed in the Journal of the Virtual Explorer, regarding the points where the geology of the mountain, especially the microtectonic textures of the rocks, was more prominent. The path begins at the end of Palaia Penteli suburb and follows the course of Dionisos Avenue all the way till the Nea Makri junction, at the eastern part of the mountain. For the purposes of this project, the first three points of interest (adapted from Lozios et al. 2019) – 1.1.a to 1.1.c – were not included in the main path, being in a relatively separate area on the southern flanks of the mountain, inaccessible by car or trail in order to be examined up close. Thus, the path was designated as Penteli Path 1 – Geology Points of Interest in this project, starting where the main urban network stops. All the remaining stops at the points of interest were executed and representative photographic material was collected. The majority of the land this path passes through suffered from the May 2022 Mount Penteli wildfire, however signs of soil and vegetation recovery are already observable. In many cases, the remaining road-side vegetation occults some of the rock facades and this may result in their eventual partial or even complete concealment.

Fig.33) View of a metabasite block at Penteli Mountain, represented by point 1.4.a3.

For the purposes of the Story Map, the descriptions of many of the geological points of interest were significantly simplified due to the complex nature of the area's geological history and the hard-to-understand microtectonic descriptions that only experienced and specialized audiences would follow. Instead, simplified descriptions were adopted, regarding the general nature of the rocks and focusing on their color, age and brief history.

Fig.34) Mesoscopically refolded epidote-chlorite shists and acid meta-volcanics, point 1.3.a1.

Points 1.6 (granitoid wall) and 1.8 (crenulation cleavage in schists) were found to be hardly accessible, due to dangerous turns of the normally busy avenue.

Excursion 2 – Saint Panteleimon Monastery – Davelis Cave – 1/06/2023

The second excursion started from the Monastery of Saint Panteleimon, accessible by asphalt road both from Kifisia and Nea Penteli districts and included in the Penteli Path 3 – Cultural and Religious Sites. Representative photo material was gathered from the interior area of the monastery, as well as the surrounding meta-volcanosedimentary rock formations.

Fig.35) View of the Saint Panteleimon Monastery of Penteli.

Leaving the monastery, the excursion continued by entering the dirt road leading to Davelis Cave and parking the car. Characteristic photos of the marble formations and the remnants of ancient quarrying areas, that nowadays are used as climbing pits, were collected. At the entrance of Davelis Cave, Agios Nikolaos and Agios Spyridon byzantine chapels are located, while photos were also collected from the cave's interior as well as from the beginning of Lithagogias Street, the ancient path from where processed marble columns for the Parthenon were delivered to Athens.

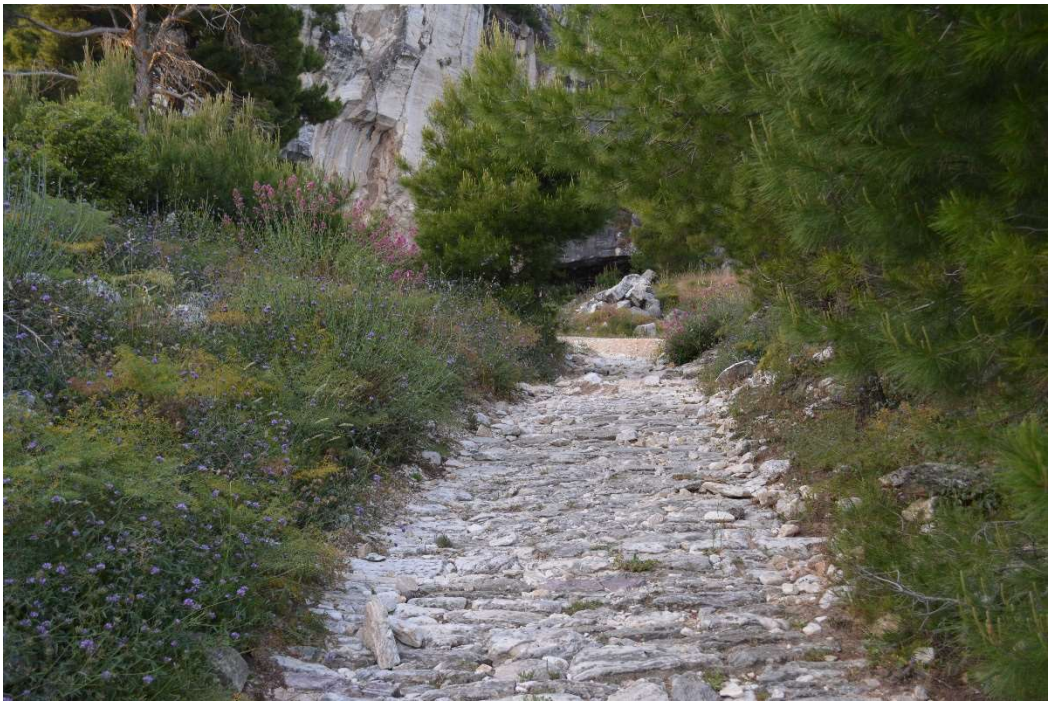

Fig.36) View of the Lithagogias Steet at Mount Penteli.

The excursion ended by joining the starting portion of Penteli Path 2 – Old quarries, a trail that leads up to the Agios Ioannis Latomon chapel. The uphill trail is in excellent condition, carved on metasedimentary schists of the basal formation of NEAU. It offers exceptional views toward the top of the mountain (Pergari – 1109m). At the intersection with the asphalt road (and Path 3), the downhill direction was followed, featuring impressive marble roadcuts, back to the car.

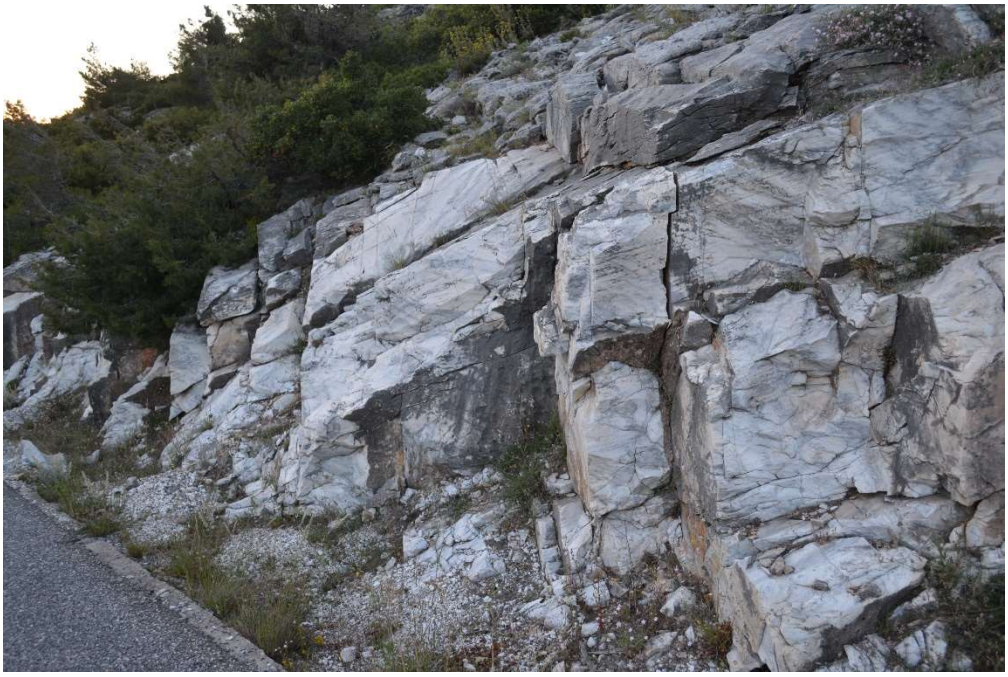

Fig.37) Marble outcrop near the main driving artery of Penteli Mountain.

Excursion 3 – Quarrying Path – 3/06/2023

The excursion followed a significant portion of the Penteli Path 2 – Old Quarries, starting from Agios Ioannis Latomon chapel. The majority of the path was dirt road, in condition good enough to be traversed by a small vehicle. It offers spectacular views toward the Athenian plane and the city, along with the surrounding mountains. It passes by old mounds of gravels and rocks, leftovers from 20th century marble extraction works, as well as old quarrying stone dwellings and dilapidated remnants.

Fig.38) Building ruins associated with old quarrying activity at Penteli Moutnain.

However, there are no directions and visitors should rely on a map that shows the basic intersections or a gnss system with basic basemap imagery (like Google Maps or this project's Story Map). The conditions of this part of the path can also become especially unfavorable during warm days of spring, summer and autumn, as vegetation is very limited and the marble dirt path highly reflects sunlight, adding to the heat.

Fig.39) Low vegetation and excessive heat await visitors and hikers on sunny summer days at Penteli Mountai. View of the Penteli Path 2, close to an old pile of quarrying debris.

The path continues with a high-slope trail leading down to Agioi Asomatoi chapel and the small mountainous refuge. The trail, despite the slope, is easily discernible and wide, featuring impressive muscovite-garnet schist formations along the way. Some of its portions can be dug out during rainfall however, thus requiring special attention by hikers.

The area in and around Agioi Asomatoi is clean, while a spring provides water that is not suggested to be drinkable. The refuge is always open, providing a basic, although not the best, spot to relax and refresh. The area can sometimes be used for outdoor mountain night parties, and dwelling there during the night is generally not suggested.

Fig.40) Agioi Asomatoi monastery and refuge.

Excursion 4 – Dionysos Path – 10/06/2023

The final excursion at Penteli Mountain took place at the northern flanks, starting from the district of Drosia, following the entirety of the Penteli Path 4 – Dionisos Path. It is the only path that passes through the last remaining dense pine forest of the mountain, thus being one of the most famous for hikers. The trail begins at the end of a road and enters the forest.

Fig.41) Close to the starting point of Penteli Path 4 at Dionisos.

It is clean, easily discernible but requires a relatively basic experience with hiking on high slope trails, as well as hiking shoes. It passes by the three chapels of Profitis Ilias, Agios Nikitas and Agios Loukas and is generally well marked. At Agios Nikitas chapel area, at the time of visit, the directional panels had been thrown down.

Without directions, it can be difficult to follow suit with the trail, although a good offline map with location services activated is enough. The trail widens up and lead to the ‘Aloula’ area, where an open-air museum of quarrying art is displayed, at excellent condition. Impressive views toward the Marathon plain are also offered.

Fig.42) View from the museum of quarrying art at Aloula location, Penteli Mountain.

From the museum of quarrying art, it can be difficult to follow suit, so a map is strongly suggested. It is also the only part of the path that is not so well conserved, having vegetation hiding some parts of the trail, but not entirely by the time of visit. Visitors should also pay attention to wildlife, especially snakes that fine refuge in water pits along the way.

Fig.43) Turtle resting next to the trail's marble steps, close to Solinario Spring.

The trail ends close to Solinario spring, that can be accessed by hiking the stone steps. It then joins the old dirt road that served the quarries, when active. The road is in good condition and descends back down to Dionisos urban network, passing through lush pine tree vegetation.

Representative photos of many sections of the path were collected, including key areas where the trail can be lost, to assist visitors in following right on course.

Marathon Excursions

A total of 3 daily excursions took place at Marathon region in early autumn of 2023, which involved geological inspection, trail inspection, multimedia data collection and the determining of additional points of interest and the final courses of the proposed paths.

Excursion 1 – Marathon Dam – Varnava Creek – Varnava Beach – 23/09/2023

The first excursion in the Marathon region began at one of the most emblematic engineering constructions of modern Greece, the Marathon Dam. It is the starting point of the proposed Marathon Path 1 ‘Marathon Dam to Varnava Creek’, which involves asphalt and dirt road sections connecting many of the area’s points of interest. Representative photographic material was collected from the area of the dam, as well as aerial footage showcasing the artificial lake and the structure of the dam.

Fig.44) View of the Marathon artificial reservoir and the water tower, from the dam.

The excursion continued northwards to the settlement of Vothonas, and the recreation area where Agia Paraskevi chapel and a local stone theater are. The place is a well-known pic nic area for locals and travelers alike, and it is the starting point of the dirt road section of Marathon Path 1, while the dominant rock formations are post-sedimentary rocks of the meta-volcanosedimentary sequence of NEAU.

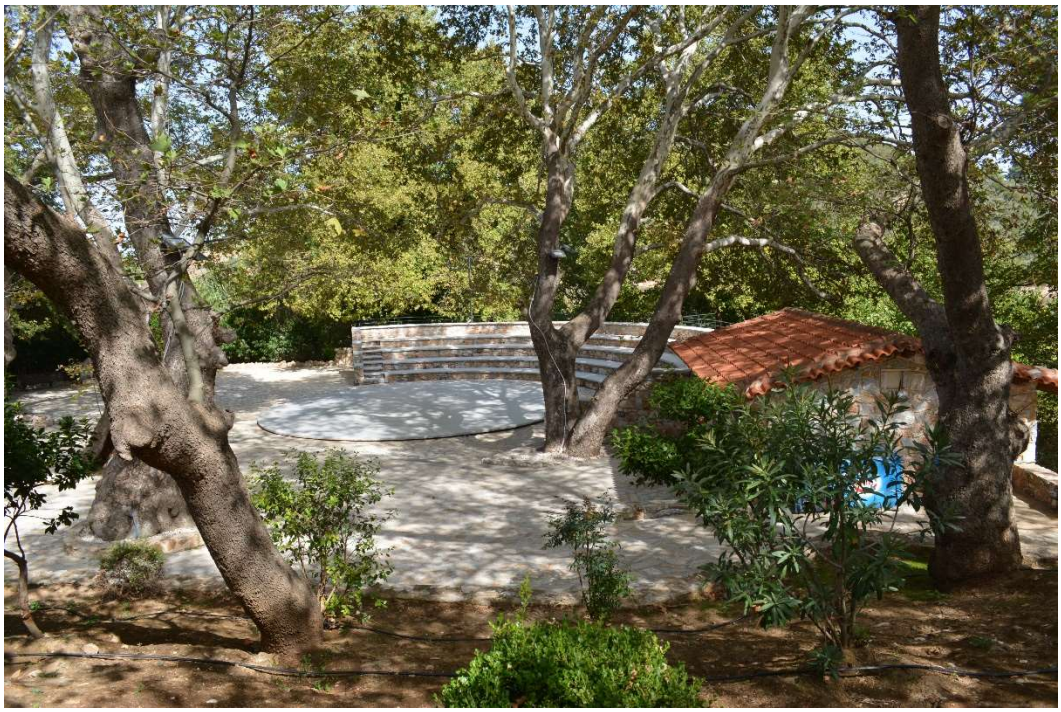

Fig.45) Traditional Stone theater at Vothonas, at the starting point of Marathon Path 1.

Following the gathering of material at the chapel and the pic nic area, the dirt road was hiked all the way to the geological point of interest 2.2.b (Lozios et al. 2019). The road is clear, but shadow spaces are limited due to the intense multiple wildfires that have hit the region for the past decade. The geologic points of interest 2.2.a and 2.2.b however are not easily discernible, requiring well-experienced hikers to access their off-road location as well as experienced observers. Nevertheless, it was decided to leave the points on map and instead offer simplified explanations of the general geology of the surrounding area, and the tectonic contact between NEAU and AGU.

After hiking the path back to the recreation area, the broader Varnava region was visited, starting from the varnava creek. It is another pic nic area, more organized, providing both recreation and launch options. It offers lush vegetation, while visitors are allowed to hike the nearby short trails through the creek, next to the stream. At summer months, as during the time of the excursion, the stream was empty.

Fig.46) Pic Nic area at the Varnava Creek.

The excursion was concluded by following the entire Marathon Path 3 ‘Varnava Creek to Varnava Beach’, an ideal short road trip connecting Varnava settlement to the homonymous beach. It passes through some of the most impressive outcrops of the meta-volcanosedimentary sequence of NEAU, as in points 2.6 and 2.7.a and b, while offering stunning views toward the Southern Euboic Gulf. Access to the points 2.7.a and 2.7.b needs attention, as they are roadcuts

at relatively dangerous spots. At the path's end, Varnava beach is an ideal bathing destination for locals, featuring a thin-pebbled coastline and offering many options for recreation and food.

Fig.47) View of the Southern Euboic Gulf at the Varnava Beach.

Excursion 2 – Ramnous – Schinias – Oinoi – 24/09/2023

This excursion was the longest that took place in the study area, covering most of the remaining points of interest and involving not only multimedia but also general literature data. It started at Ramnous archaeological area, which was fully accessible. The ancient town was fully explored and many representative photos were collected. The archaeological area was found to be well conserved, supervised, clean and the assisting information material that was provided at the entrance sufficient. However, there was only one detailed informational panel, close to the Temple of Nemesis. As a result, visitors who would like to learn more details about the fortress, its building and their individual use need to seek the information online, if available.

Fig.48) View of the eastern gate to the Ramnous fortress.

Following the excursion at Ramnous and on the way toward Schinias National Park along the proposed Marathon Path 5, the two geologic points of interest 2.3 and 2.4 were visited. The points offer panoramas on tectonic faults and a closeup inspection is hard, both due to dense vegetation and the complexity of the structures. As a result, it was decided to include the points but only offer a brief description on the morphology presented in the field.

At Schinias National Park, a significant portion of the Marathon Path 6 ‘Schinias Forest’ was explored. This path was composed by combining the already existing trail network that was created, promoted and conserved under the auspices of ‘Paths of Culture’ project, organized by the Hellenic Company of Environment and Culture. Due to the dense pine (Koukounaria) forest that the path passes through, it was necessary to carefully identify the parts of the trails that have been covered by pine needles and soil and curate the data on ESRI Field Maps accordingly. Trail signage can be found all across the path and forest, however it needs to be better conserved.

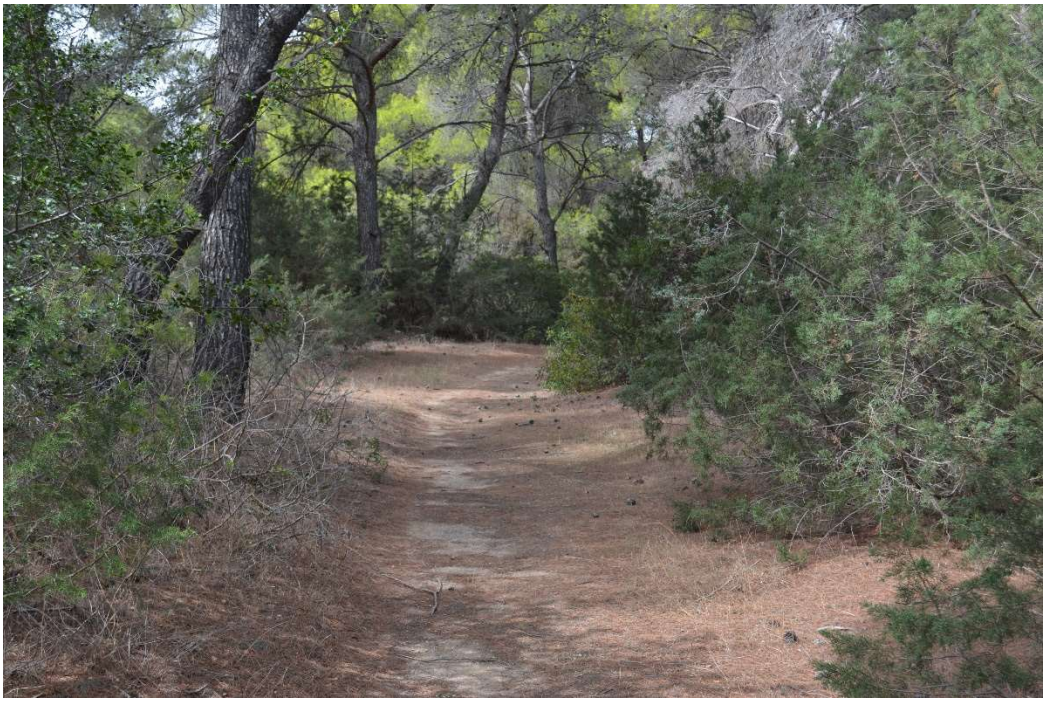

Fig.49) Trail view at the Schinias National Park Koukounaria coastal forest.

Leaving Schinias National Park, the Marathon Path 4 ‘Schinias to Marathon Tomb’ was entirely explored. The path consists of primarily asphalt road, it is easy to follow and connects the National Park with points of interest like the Trophy of the Battle of Marathon and the Marathon Tomb. A significant portion of the path was adapted from ‘Paths of Culture’ path 3, hence relative signage can be observed along the way. However, the path also contains a branch leading to the Marathon Archaeological Museum and the Early Helladic Cemetery.

The path was followed and inspected all the way to the Marathon Tomb of Warriors archaeological area. The site is one of the best conserved of the Marathon region, having significant visibility and sufficient informative material, both as leaflets and as informative panels. A carefully designed trail encircles the tumulus, allowing for a complete exploration, while access to the tumulus itself is prohibited. Apart from photos, a significant amount of information and additional literature was collected for the area’s history, including details on the tumulus already presented.

Fig.50) The archaeological area of the Marathon Tomb features impressive informational material, like this 3D reconstruction of the broader region.

The excursion concluded at the Oinoi medieval tower, located at the beginning of Marathon Path 2 ‘Marathon and Oinoi Gorge’. The path was also partially adapted from the ‘Paths of Culture’ path 2, excluding its northernmost branch due to bad conservation. The tower is easily accessible by a small dirt road at the end of the asphalt section of the path.

Fig.51) The medieval tower at Oinoi.

Excursion 3 – Agioi Apostoloi – Museums – 25/09/2023

The final excursion at the Marathon region included visits to the official Marathon Race starting point, the Early Helladic Cemetery at Tsepi, the Marathon Archaeological Museum and the Sanctuary of Egyptian Gods. Representative photo and literature data was gathered during the visit.

Fig.52) (Above Left) Agioi Apostoloi Byzantine chapel and the surrounding rest area. (Above Right) The official starting point of the Marathon Endurance Race. (Below Left) The original sphynx statue of the Sanctuary of Egyptian Gods, exposed at the Marathon Archaeological Museum. (Below Right) The entrance of the Plataieis Tomb.

4.4 Third phase of implementation

After the successful completion of the field trips and the gathering of additional literature data (incorporated at the Study Area chapter), the locations of the points and paths of interest were re-assessed and specific adjustments were made, to achieve the best possible precisions. Some of these changes were already made through the Field Maps mobile application but others, that required more time – like the trails, were made later through the GIS. All GIS data were set to the WGS ’84 coordinate system.

With the finalization of the primary data and the eventual determination of the paths, a detailed digitization of the latter followed through the ArcGIS Pro environment. Access to ArcGIS Pro was made possible through the provided student academic credentials by the National Technical University of Athens. For the digitization, the satellite imagery basemap was used, providing high quality, up to date earth images for the study area. It was noticed that the highest zoom level available, however, replaces the basemap with an older version of satellite imagery data, characterized by reduced spatial resolution and a small offset. As a result, the paths were digitized in the highest available zoom level of the original basemap imagery before that shift. For path 4 of Penteli (Dionisos Path), the basemap of Anavasi was used due to restricted satellite visibility of the trail because of dense vegetation. A total of 5 paths for Penteli and 6 paths for Marathon were digitized.

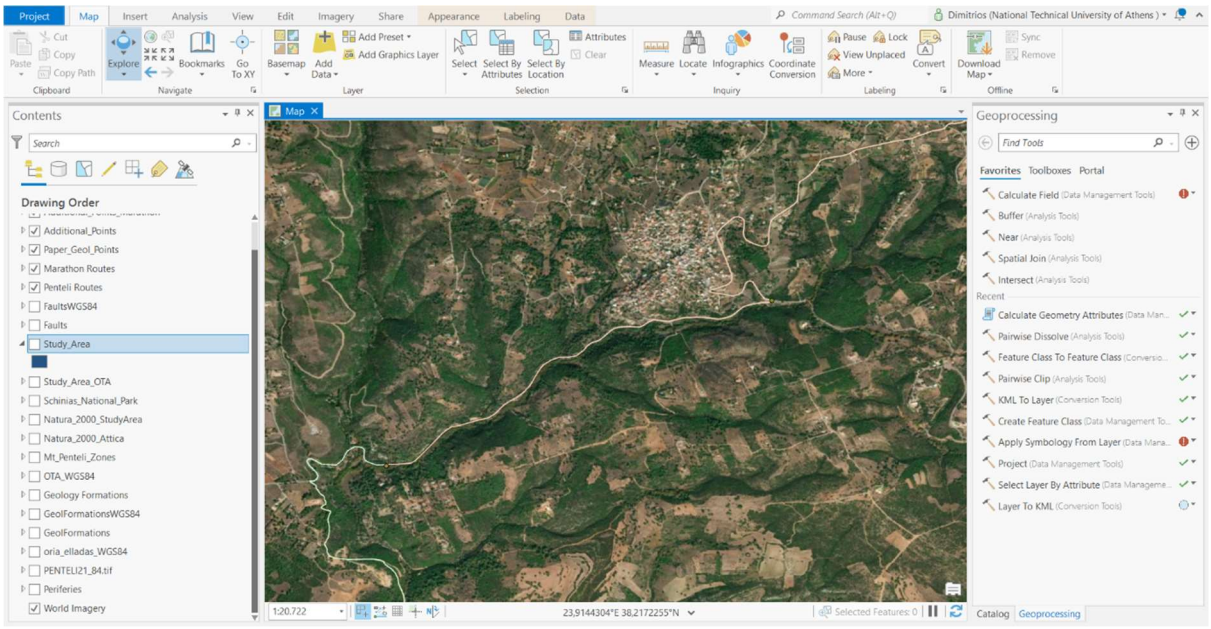

Fig.53) Digitizing in detail using the Satellite Imagery basemap in ArcGIS Pro.

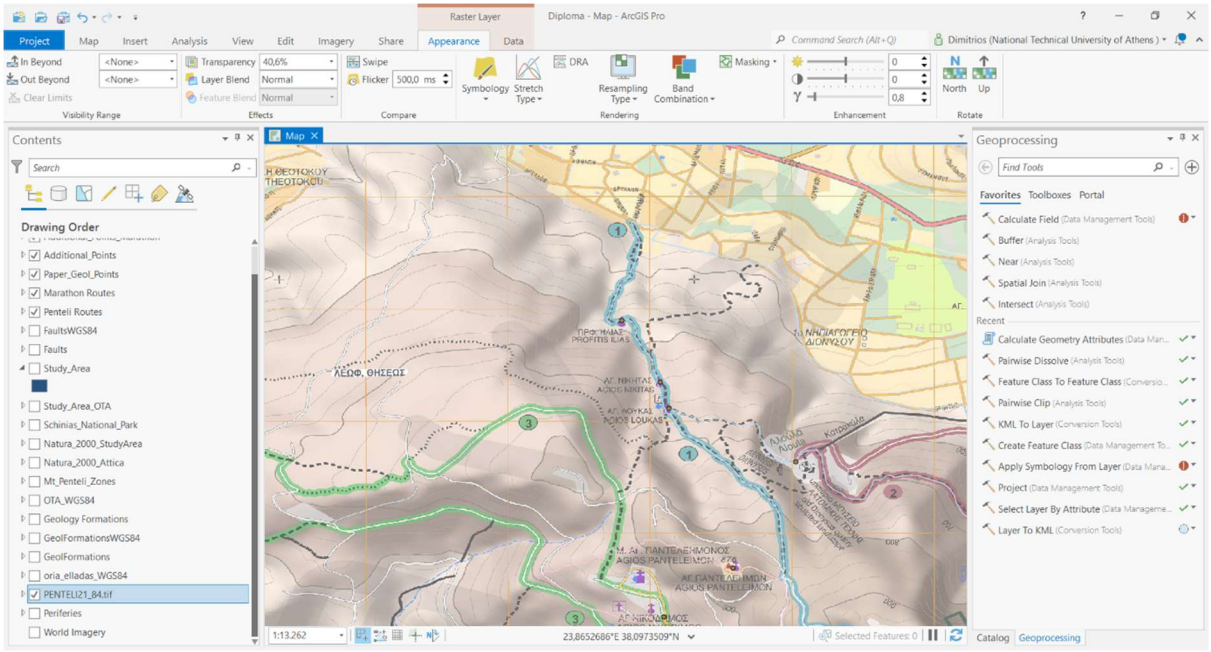

Fig.54) Digitizing using the Anavasi Map ‘Mount Penteli’ digital basemap. Path 4 – Dionisos Path, corresponds to the combination of sections of paths 1 and 2 of Anavasi.

The final paths and points of interest were eventually organized as group layers, for the better management of the accumulating data within the ArcGIS Pro project. Here, it is crucial to underline an important limitation that was faced in this phase of data curation, regarding the functionality of ArcGIS Pro. The software, due to limitations of the computer used for the conduction of the assignment, was unable to allow for configuration of the symbology of the layers in the single symbol format, which kept resulting in its termination (crashing). It was possible to configure a set of symbols based on unique values, without however the ability to individually configure each one of them. Hence, it was eventually decided to configure proper symbology later, within the ArcGIS Online environment.

As already mentioned, the proposed paths of interest involve different types of paths. As a result, it was found necessary that a symbological distinction among these different types would be helpful for users of the platform, as it would allow for better preparation of a possible visit to the area, thus enhancing the cartographic value of the featured interactive maps. Three types of paths were hence recognized, asphalt road, dirt road and trail. The distinction between a dirt road and a trail is based solely on the latter’s definition, according to national legislation. The term ‘trail’ is attributed to the narrow, vehicle-free road, that is used for trespassing of pedestrians and animals (Ministerial Decision 151344/165/2017 in ΦΕΚ 206/B/30-1-2017 «Determination of technical aspects of tracing, signage, opening and conservation of trekking – hiking trails»). Its basic difference from a vehicle road is that it is characterized by a smaller

and variable width, possible significant variance in slope and the existence – or not- of steps. More specifically, climbing – walking/trekking trails are paths used for outdoor activities such as hiking, climbing, access to natural environments, points of interest (POIs) (natural or cultural) or generally for the purpose of introducing humans to nature, history and culture of an area. They also contribute to communication and transport among mountainous and hardly accessible regions, traditional settlements and otherwise inaccessible low-altitude areas. All kinds of motor-driven means of transportation are not allowed on trails.

Fig.55) Examples of walking – trekking paths at a) Methana peninsula, b) Santorini Island and c) Methana Peninsula.

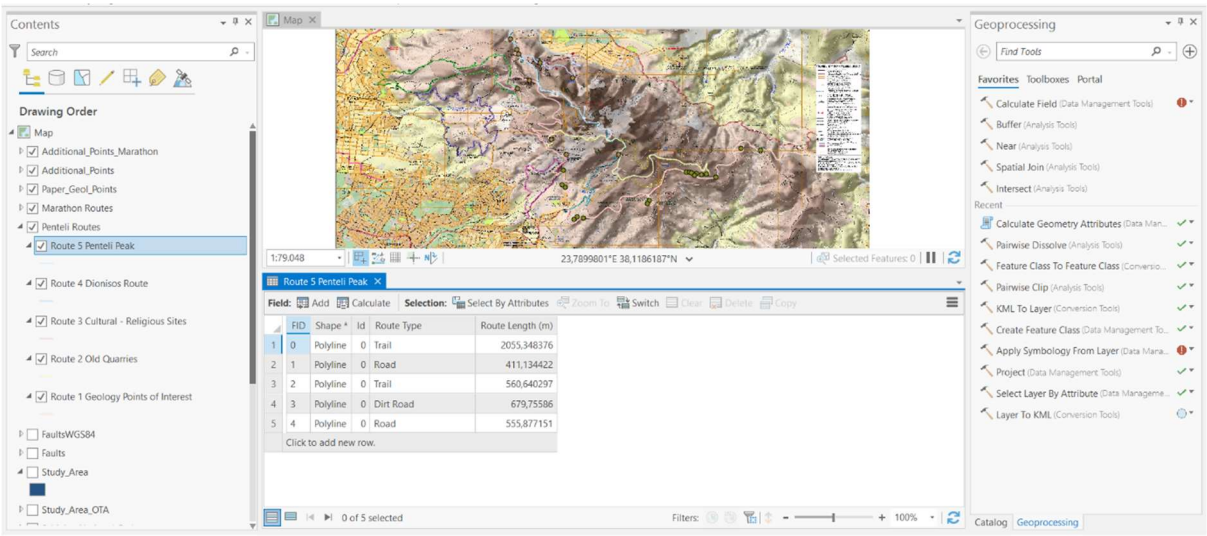

Fig.56) Types of paths within a dedicated attribute field, that was later used for the determination of symbology.

After finishing with the paths of interest, the curation process of the data from external sources stage began. All these data were collected from the Greek national open-data provider, the platform of Geodata.gov. The platform offers data related to municipal boundaries, natural and cultural sites, road and railway networks as well as city plans for municipalities. For the purposes of the assignment, the data used were the following:

- Natura 2000 protection zones of Greece.

- Protection zones of Mount Penteli (national legislation).
- Protection zones of Schinias National Park, according to national legislation.
- Former administrative units, before the applying of Kallikratis Law (to compose the Study Area polygon)

The available shapefiles were assessed in terms of coordinate system, data plenitude, spatial resolution and accuracy. It was found that the projection on the map was accurate, hence the only curation needed for most of the shapefiles was to select the proper coordinate system. Some descriptive attributes were also added in English. The main part of the curation process involved the Schinias National Park shapefile, as it lacked protective zone A5, the marine area. This zone was manually digitized and added to the shapefile, with the aim of the equivalent Natura 2000 polygon, that significantly matches the area covered by the nationally recognized park and includes the zone.

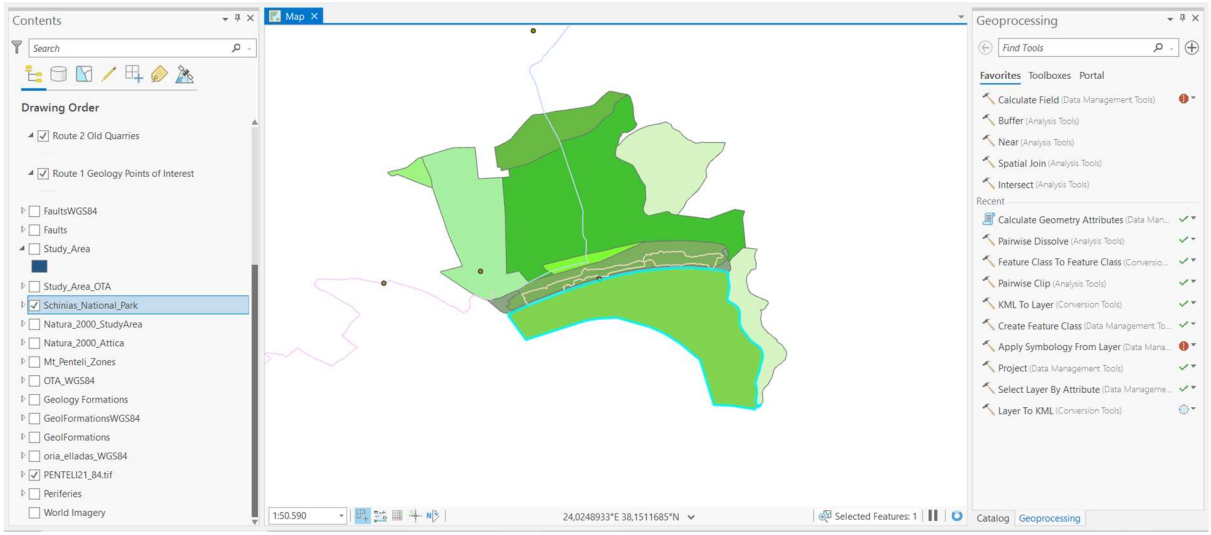

Fig.57) From the recognized zones of Schinias National Park area, the marine one (A5) – here selected – was manually digitized and added to the shapefile, thus curating its data plenitude.

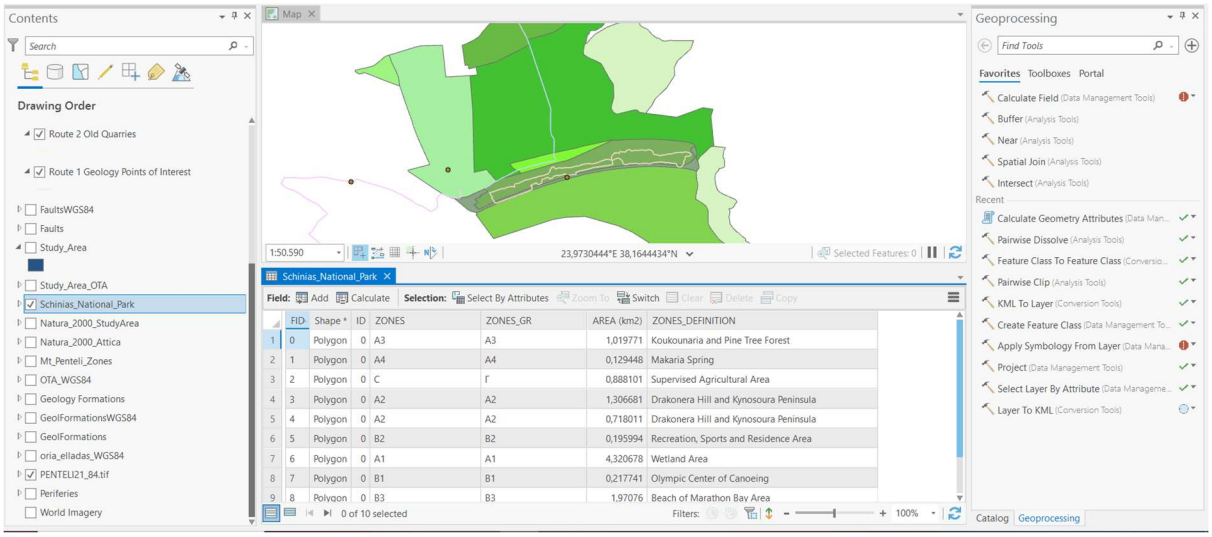

Fig.58) Adding English descriptive definitions in the attributes of Geodata shapefiles.

The available geological data were mostly gathered by Lozios et al. 2019, as well as more recent geological mapping works in the area. Due to the complexity of geological formation distribution in the area, it was decided to simplify the map and present only the available alpine and post alpine geotectonic units, with their most important features, instead of including all the additional sub-units and lithologies. The process was executed by using the pairwise dissolve tool of ArcGIS Pro, after grouping the geological formations based on the geotectonic unit they belong to. Simple yet efficient descriptions on the geological units were also provided in the attributes and are accessed as pop-ups in the final platform.

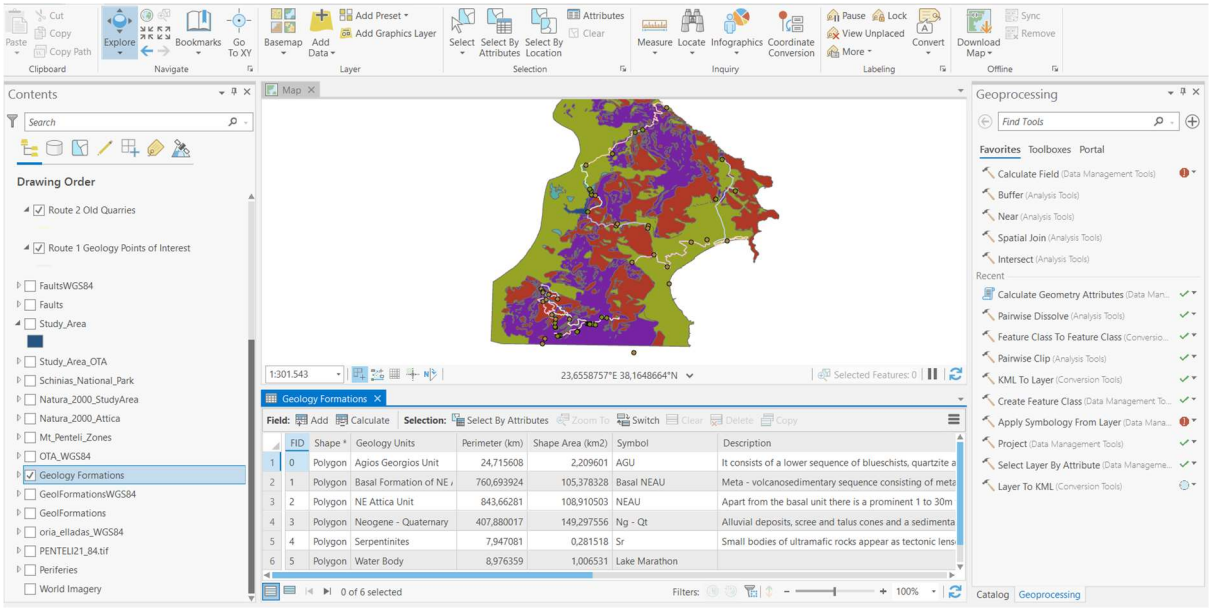

Fig.59) The simplified version of the area's geologic map, along with short descriptions of the formations that comprise the geological units. The descriptions will be accessed as pop-ups in the final platform.

The final work on the data within the ArcGIS Pro environment involved the creation of the Study Area polygon, that will show in the initial stages of the Story Map platform. The study area includes the entire Municipalities of Penteli and Marathon, as they occurred from the applying of Kallikratis Law in 2011, as well as parts of the Municipality of Dionisos, lacking the former administrative unit of Krioneri. As a result, it was decided not to use an already completed dataset of the modern municipality boundaries, but the older administrative units, so that they could be dissolved into the area truly covered by the proposed points and paths of interest.

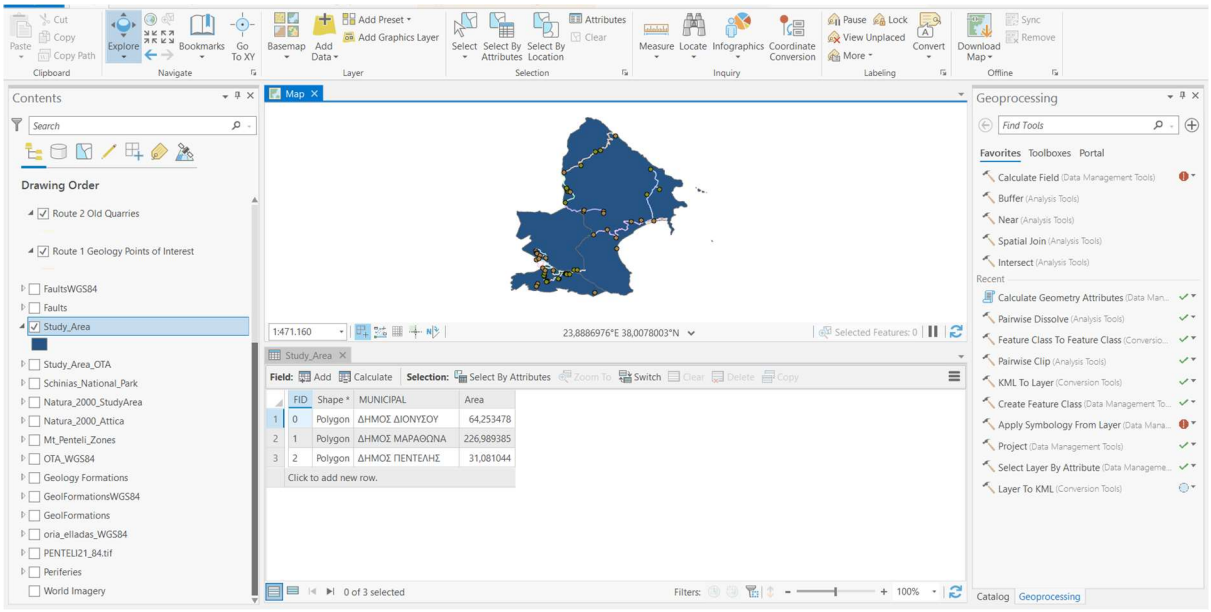

Fig.60) The polygon of the study area in ArcGIS Pro. As mentioned, the symbology was configured later within the ArcGIS Online environment.

All the curated and final versions of the shapefiles that occurred from the above descriptions, were then compressed in .zip files and uploaded as feature classes in the ArcGIS Online environment. Access to ArcGIS Online was again provided through the academic student credentials of National Technical University of Athens. All the uploaded feature classes were set to private sharing level and an additional share to a group, for discussions with the supervisors.

The first step of processing the data within ArcGIS Online involved the configuration of symbology, not allowed in ArcGIS Pro. Two different colors were used for the point feature classes, a green for the geological points of interest and a pink-purple for the additional points of interest, that include sites of cultural, archaeological, religious and folkloric interest.

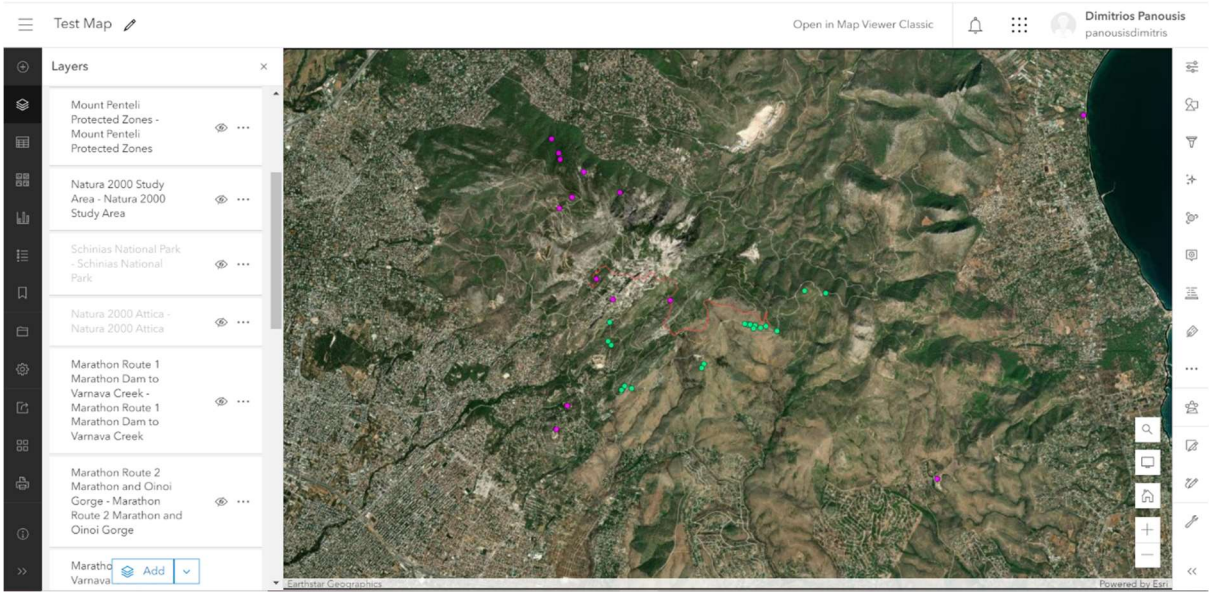

Fig.61) Two different colors for the points of interest, green for the geological and pink-purple for the additional.

Furthermore, the symbology of the paths of interest was set. Here, each path was decided to be depicted by a different color, while each different section – path type of the path was attributed a different linear symbol: Classic line for asphalt road sections, dashed line for dirt road sections and dotted line for trails.

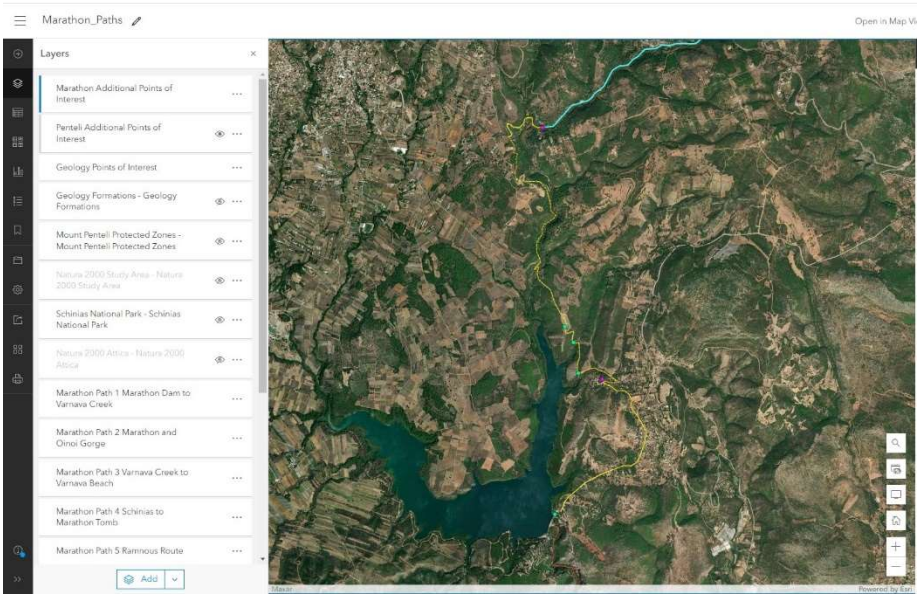

Fig.62) Different types of symbology for the paths of interest.

Finally, the symbology of the polygon layers was configured. To allow for a proper user experience when viewing the maps that were produced based on the above data, zoom levels were set on the appearance and labeling of the map features.

After completing the configuration of the symbology, all the interactive 2D and 3D web maps to be used in the Story Map were created. A total of 15 online maps were produced, regarding the area's protective zones, the geology and the paths and points of interest. A series of other maps were also added to the Story Map, configured right within the story builder, and will be discussed in the following chapter.

The first two maps focus on the biodiversity – the protective areas. They include the Natura 2000 zones of Attica and the study area, as well as the protected areas under national legislation, with a satellite imagery basemap. The zoom levels were set so that users start by viewing the Natura 2000 zones. As the zoom level increases, the Natura 2000 zones vanish and the more specific ones for the region appear. This allows for an interesting interactive motion effect by combining the zoom levels later within the platform. The protected area maps are Web Maps, meaning they can be explored in two dimensions.

The geologic map as well as the path maps are all Web Scenes, meaning that they allow for 3D exploration. The geologic map uses a terrain basemap while the rest use a satellite imagery. Users can select different features that appear on the web maps and web scenes to reveal the available information in the form of pop-ups. They also have the ability to search different locations, read the legend and activate the location feature so that they can explore while knowing their exact location.

4.5 Fourth phase of implementation

This final phase involves the creation of the Story Map platform itself. Story Maps have been designed both for groups of experts and the wide public that, lacking specific knowledge or skills, can however take advantage of spatial analysis results by making the most of GIS tools applications. This led to their establishment as one of the most effective, easy to use informative and educational tool that has gradually become widespread to this day.

Through the interactive 3D applications included in the platform, users can navigate spatial information in an informative manner. As vision is considered one of the dominant senses for humans, when it comes to providing information, many prefer getting informed through images. Information can be organized alphabetically, timely (with restrictions), by category or by hierarchy. However, when it comes to spatially organizing information (a system that organizes information based on their spatial location), a significant advantage is presented regarding the ability of its illustration. It also allows for a useful and dynamic way of gathering information, which allows full interaction with users.

As a result, the reason that all available spatial information regarding the study area was presented through a Story Map, is mainly due to several related advantages. Primarily, this form of maps is more appealing to users regarding their cartography and design, than a traditional, static map. Furthermore, the platform is very easy to use and navigate, while multimedia (photos, videos, drone footage) facilitate the public dissemination of information. The interactivity and the 3D models provided by the platform guarantee users' improved education on the presented topic, as the available pop-ups that appear in every map focus on providing more details on the selected topic of interest. Through the presence of narrative text, that appears on the screen alongside the maps and/or multimedia, users get covered by a wide variety of information and topic analysis. Another basic advantage of using this platform is that the illustrated elements automatically adapt to the analogies of the user's screen, hence making them ideal for viewing in laptops, smartphones and tablets.

There are many online platforms that allow for interactive storytelling experiences, such as Odyssey by CARTODB (https://github.com/CartoDB/cartodb), TimeMapper (https://timemapper.okfnlabs.org/), Google Earth Outreach (https://google.com/earth/outreach/) and StoryMapJ (https://storymap.knightlab.com/). Each of these platforms offer different methods of organizing and visualizing the available information and may require third-party applications or even coding to perform certain tasks (Antoniou et al. 2023). To promote the individual characteristics of the study area in the current assignment, the ArcGIS StoryMaps approach is used, that allows for narrative maps, combining text with spatial information and multimedia without the necessity of external programs and knowledge of programming. As an ESRI service, it also matches with the rest GIS environments used throughout the assignment, while the author is experienced with developing ESRI Story Maps. A series of open source configured apps is also provided along with the story mapping builder, that are ready for immediate use. Additionally, the builder offers many options for accessibility regarding users with limited vision and/or mobility.

The layout of the Story Map was determined after reviewing other similar works, such as those included in the winners list of ESRI's annual storytelling competitions, as well as by taking into consideration the amount of available data and the best possible way to present them. It was finally decided to present the available information through 6 individual tabs, being Introduction, Geology, Culture, Penteli Paths, Marathon Paths and References. The Story Map can be found here: https://storymaps.arcgis.com/stories/20a6173756044d51994553e9ffe86260

The Story Map begins with the title of *'Geo-Cultural Environment of Mt.Penteli and Marathon'*, followed by the sub-title of *'Exploring landscapes that defy the expected'*. To the background, a high-resolution panoramic photo of the Marathon artificial reservoir welcomes users to the environment that the Story Map explores.

Fig.63) Landing page of the Story Map.

Users can explore its full content by continuously scrolling down or by immediately selecting the desired tab, connecting them to the related available information. Before the Introduction, a short paragraph describing the content and purpose of the Story Map, as well as the context it was created in, can be found.

The Introduction section informs users about the Study Area of northeastern Attica. It was decided to add a similar starting form for every individual tab, by initiating with a quote about its content and then presenting an image gallery of representative photos associated with the tab. In this way, users will be more attracted to the content that follows up. Thus, the opening quote of *'An area of unique geological, biological and cultural heritage just a stone's throw away from the bustling city'* can be found, followed by photos of the variety of landscapes and experiences the area has to offer.

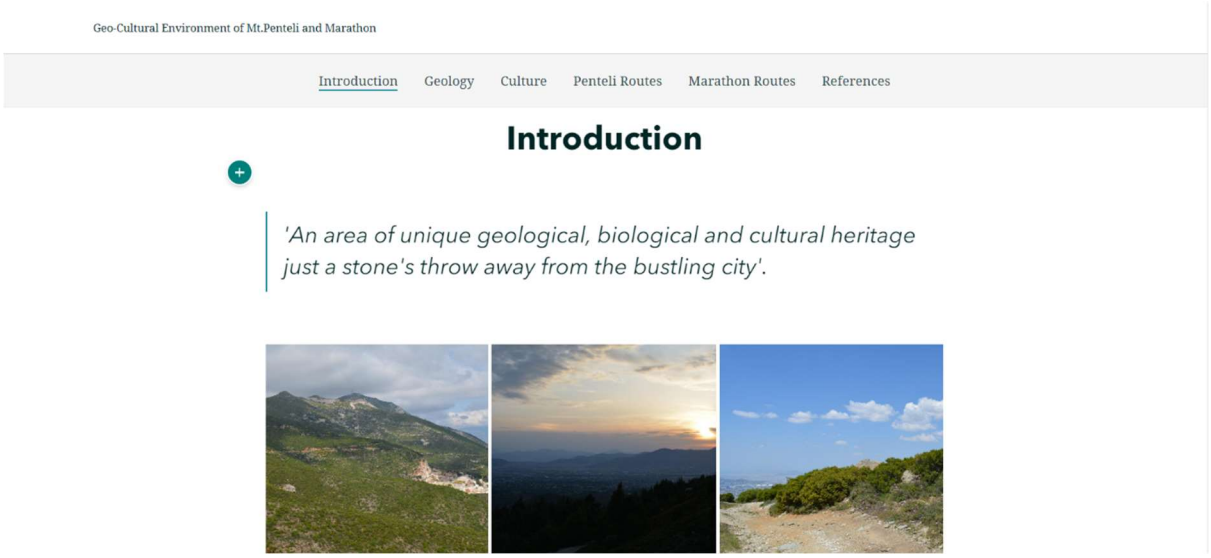

Fig.64) The start of the Introduction tab.

A short paragraph describing the basic geographical characteristics of the area is then followed by an interactive web map presenting its location, highlighting the three polygons that correspond to the Municipalities it is comprised of. Users can move and rotate the map with the available tools to the right, as well as set the desired zoom levels. The map can be centered by clicking the house icon, while the current location of the user can be activated. Users can select a polygon to reveal the informational pop-up, or show the legend, by clicking the related icon to the bottom left of the map.

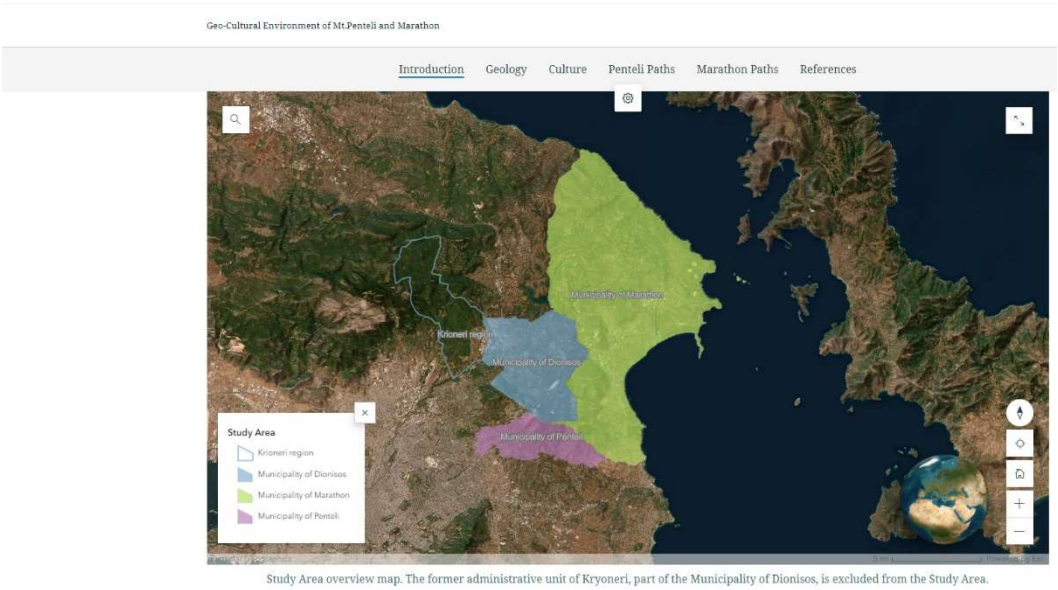

Fig.65) The web map showing the location of the study area and its three involved municipalities.

Narrative text then describes the basic characteristics of the municipalities of Penteli, Marathon and Dionisos. The provided information focuses on the location of each municipality, along with brief details on its historical, cultural and folkloric values. To underpin the narrative, express maps presenting the location of interesting areas and settlements of each municipality were crafted and placed to the side of the text. Users can enlarge and interact with the map by moving and rotating it. Hovering above each presented point, the name is revealed, while clicking on it shows additional information.

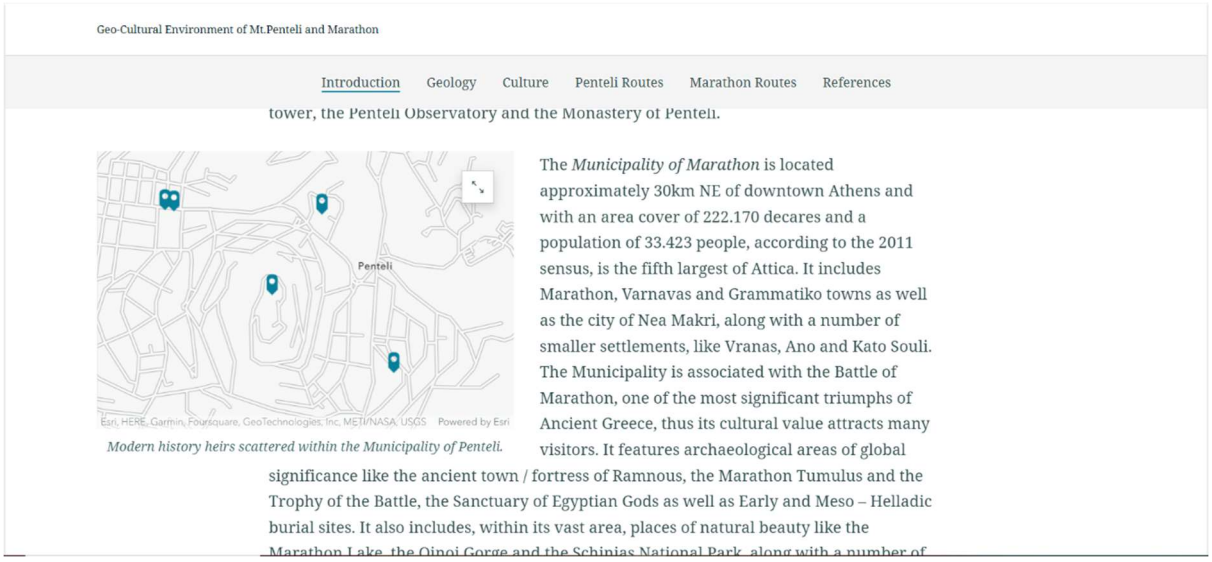

Fig.66) Narrative text explaining basic features of the municipalities and express maps showing locations of interest.

Continuing to scroll through the Introduction tab, a sub-section focusing on the area's protective zones is located. Scarce information and lack of sufficient multimedia content prevented the author from developing a dedicated tab for the Biodiversity of the area, so the available information regarding the protected areas under international and national legislation are presented within the Introduction tab. Narrative text is accompanied by interactive web maps showing the location of these protected areas, both for Marathon and Penteli Mountain regions. However, the web maps are dynamically presented through a sidecar, a method of information visualization that involves an interactive (or static) background and a scrollable text, organized in slides. Each slide can be set to include a specific background and narrative text with all available options of assisting multimedia content. Here, the same web map is used as the background of three slides of the sidecar, with different however zoom levels and placements. Each slide is accompanied by a brief text describing the map. As users shift from slide to slide, the web map automatically shifts to the pre-determined placement and zoom level, creating an interesting motion effect. Of course, users can still fully interact with the

map, select features and reveal the available information through the pop-ups and the legend, as well as find their location.

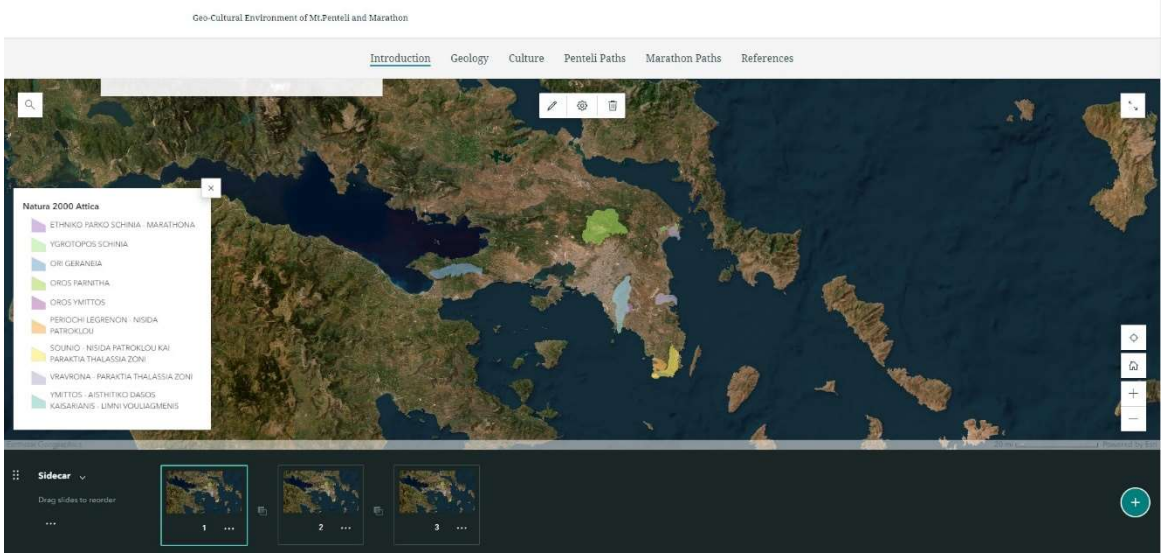

Fig.67) Sidecar presenting the protected areas under international legislation for Attica prefecture.

The 'Geology' tab focuses on the presentation of the geological structure of the study area. It starts with the quote of *'The geological heritage of a region provides the basis for its biodiversity and carves its cultural identity'*, followed by an image gallery of representative photos of the geological heritage of Marathon and Penteli. Then, the distinction between alpine and post-alpine formations is followed by an interactive web scene (a 3D map) of the simplified geologic map of the area. Users can move, rotate and zoom the map, identify the geological formations through the pop-ups and the legend, search areas and find their current location.

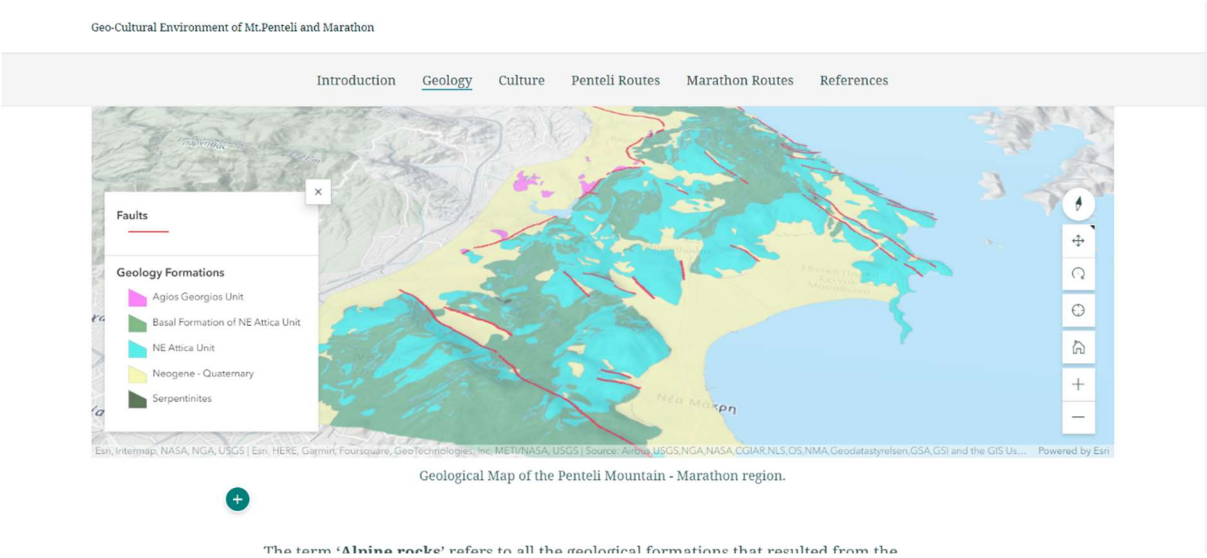

Fig.68) The interactive 3D geologic map of the study area.

Narrative text then proceeds to describe the terms of Alpine and metamorphic rocks that are found across the area. To assist the descriptions, a short educational YouTube video was embedded regarding the explanation of metamorphic rocks.

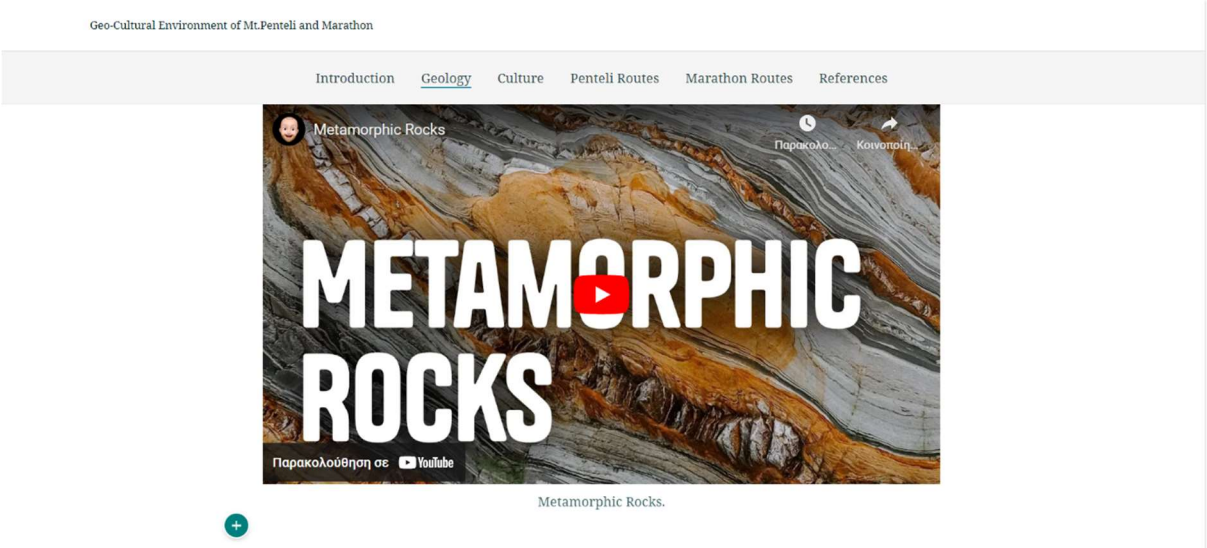

Fig.69) A short educational video was embedded to assist user's in understanding the presented terminology.

A sidecar then presents each individual geologic unit of the area, featuring a representative photo of each geologic formation in the background along with narrative text describing the unit, as

well as additional photos to enhance the information dissemination. Users can select and enlarge both the background and the narrative text photos.

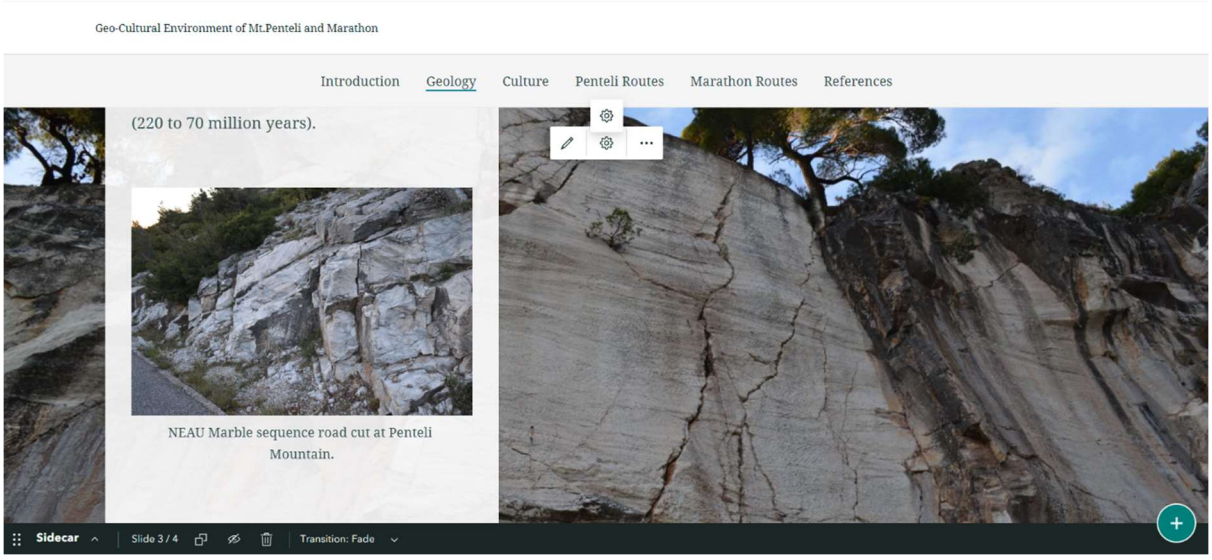

Fig.70) Sidecar presenting the geological formations of each unit.

The 'Culture' tab focuses on the presentation of the area's most valuable historical, archaeological and cultural features. It starts with the quote of *'A region featuring unparalleled historical values, imprinted on its archaeological and cultural heritage'*, followed by an image gallery showcasing photos of the rich history of the area, waiting to be explored.

Followed by a short introductive text, a sidecar explores the sites of interest by featuring a background interactive express map showing their location, and narrative text accompanied by representative high-resolution photographic material.

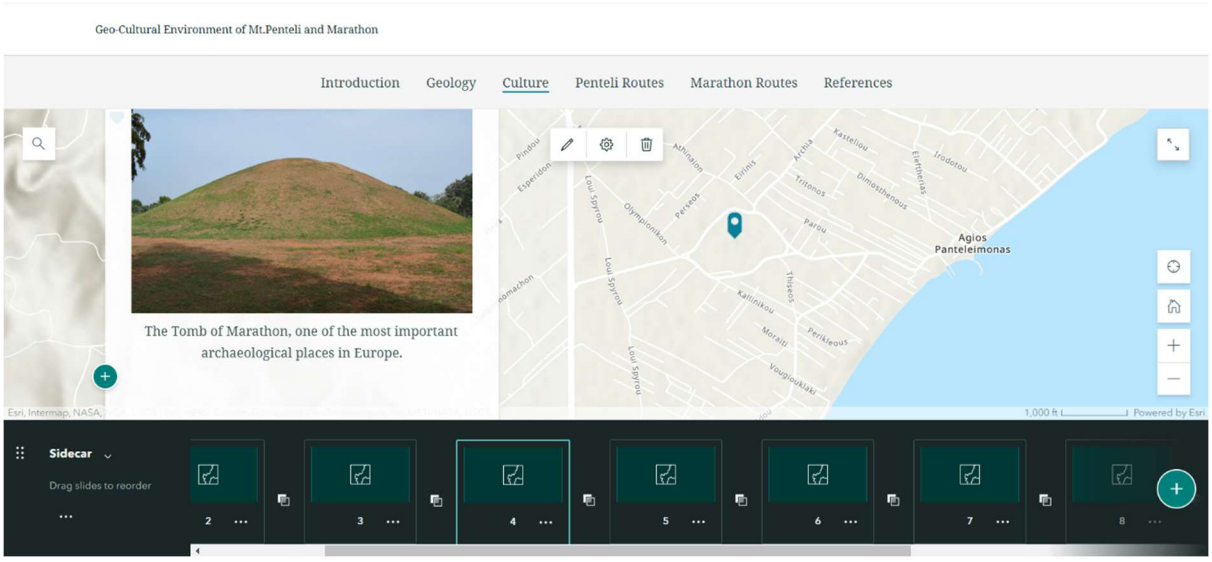

Fig.71) Sidecar describing the most important historical and cultural features of the area.

The following two tabs focus on the points and paths of interest for Penteli and Marathon respectively. They both follow a similar layout, starting with a quote, then followed by an image gallery, then by a web map featuring all the paths of the region and then by a descriptive sidecar. Each path is presented individually on each of the sidecar's slides, using a web scene in the background and narrative text with multimedia on the left side of the screen, describing the main features of each path. What differentiates this presentation, however, from the rest of the Story Map, is the availability of map action buttons throughout the narrative. These buttons allow users to automatically focus the map on each described area, to get a closer look on the points of interest. The maps allow users to fully interact, the same way as previously described.

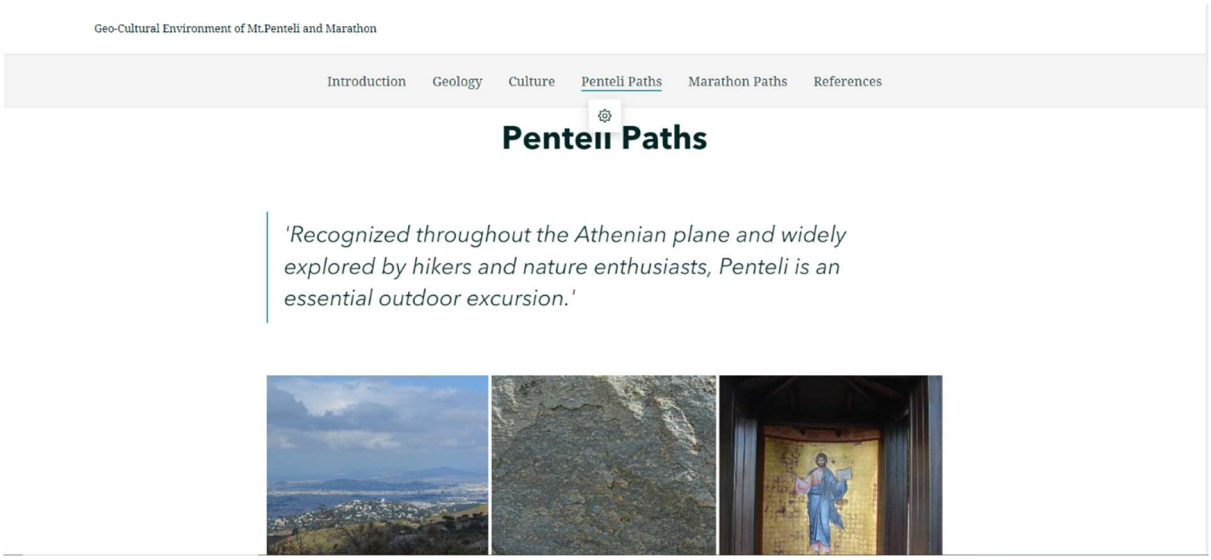

Fig.72) The start of the Penteli Paths tab.

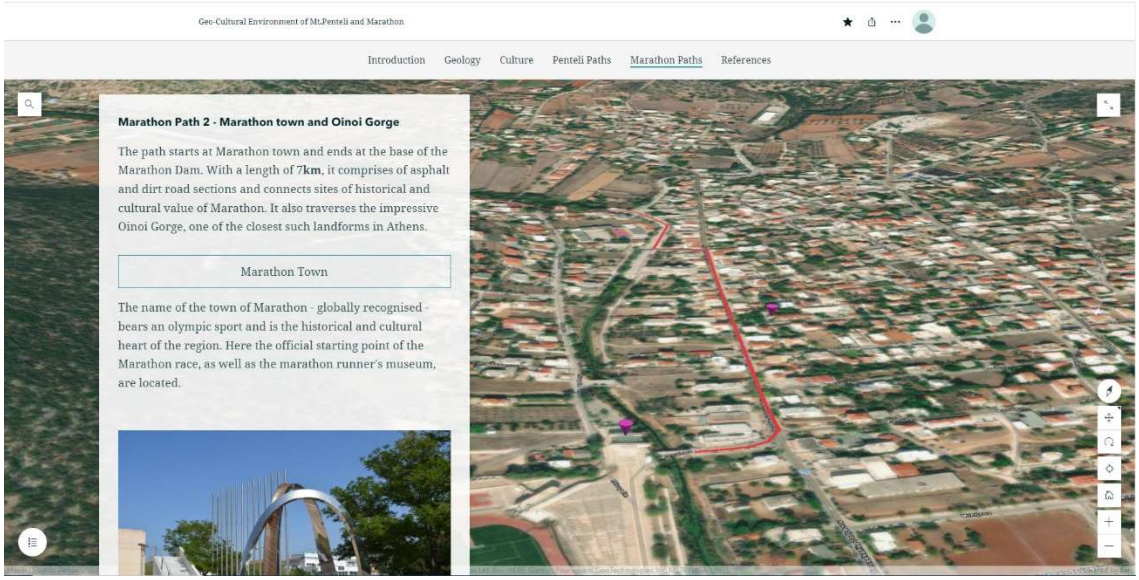

Fig.73) Narrative text includes map actions allowing for automated focusing of the web scene.

The reason for the presentation of the initial web maps featuring all the proposed paths for Penteli and Marathon respectively, is to allow users a live-tracking experience of their location, whenever they use the Story Map in the field. Tracking of the location is also possible within the web scenes of the sidecar, however it may be considered as more useful to track the course on a 2D map.

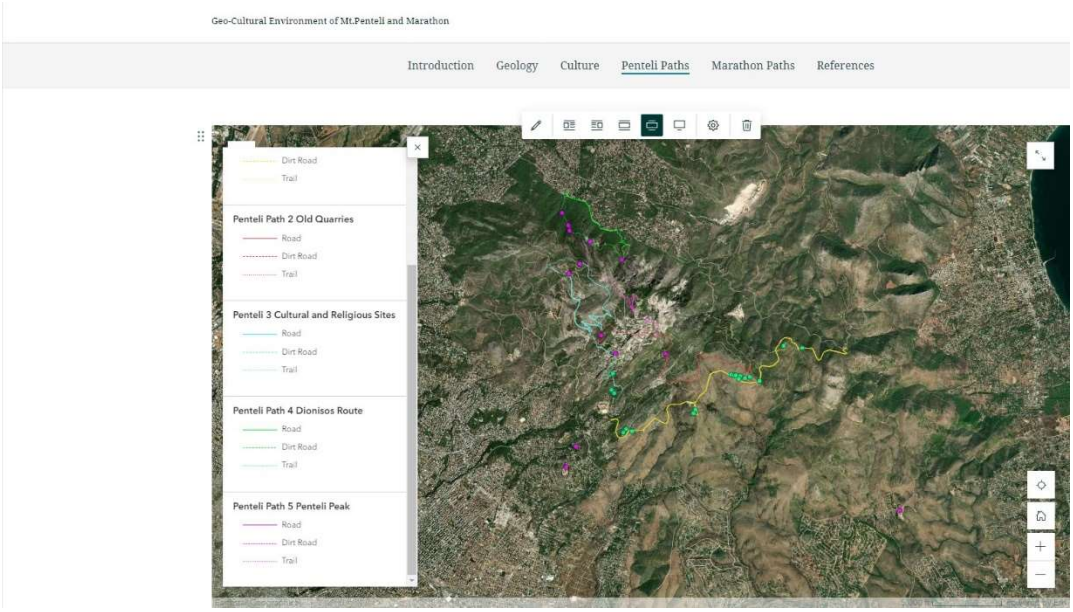

Fig.74) The general web map featuring all the paths of interest for Penteli Mountain.

The final tab of the Story Map presents the available sources of all information presented in the previous ones. The references are organized into the scientific literature section, which contains the main papers mainly focusing on the geology of the area, and the websites section.

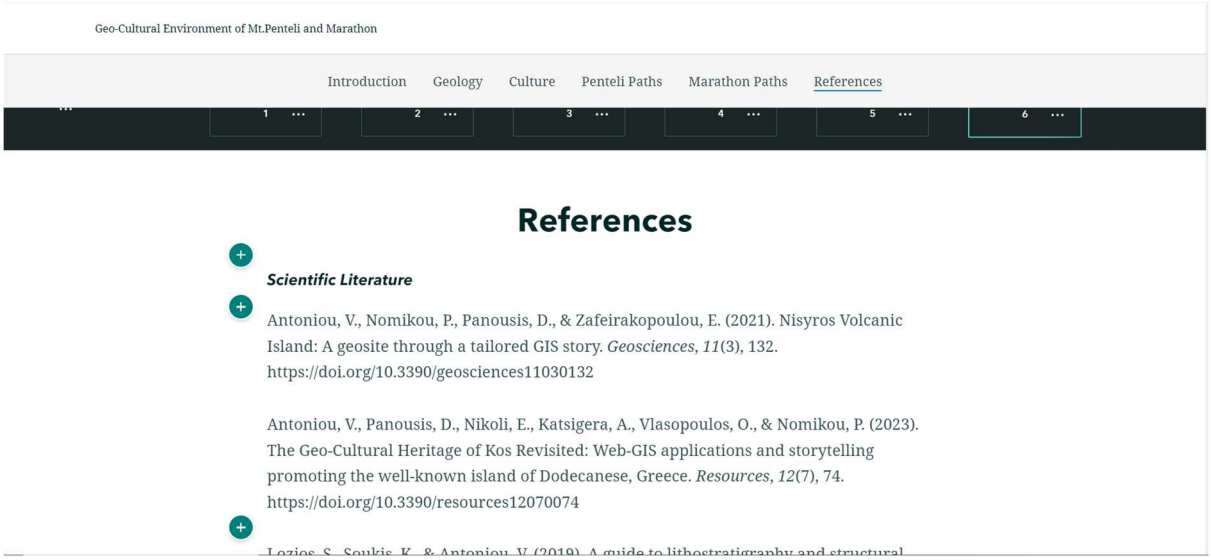

Fig.75) The References tab, the final section of the Story Map.

5. References

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