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DIGITAL MYSTRAS: AN APPROACH TOWARDS UNDERSTANDING THE USE OF AN ARCHAEOLOGICAL SPACE

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ABSTRACT

The archaeological site of Mystras, located in western Laconia, is the best-preserved Byzantine site in Greece also known as the "Castle City of Mystras" (Odysseus). Mystras was founded in 1249 by the Frank commander William II of Villehardouin who built a castle fortress on top of Myzithra hill on his return from the conquest of the Castle of Monemvasia. The castle fortress overlooked the Valley of Evrota 6km southwest of Sparta creating a control point for his regime. The city passed to Byzantine rule in 1259 and expanded outside the Acropolis. Mystras eventually developed into the powerhouse of the Peloponnese, capital of the Despotate of Morea. The city flourished through a significant number of phases, different rulers and population changes (Sinos, 2009).

This study aims to visualize the history of Mystras through a digital depiction of the different phases of the city providing a digital product where the archaeological data concerning the area of the Byzantine city are projected. Through the use of modern spatial technologies, an unmanned aerial vehicle (UAV), a GPS and ground control points, the area was photographed and georeferenced using photogrammetry software to provide a true orthophoto of the study area, which in turn, provide the base map for its subsequent analysis via Geographic Information System (GIS). The objective is to create a temporal and spatial presentation of the evolution of the city while providing additional data such as population fluctuations, structural elements, ecclesiastical and secular buildings as well as fortifications available to researchers. With the digital depiction of the evolution of the urban fabric, the narration of the history of the city itself begins, highlighting the contribution of digital technologies in Cultural Heritage Management.

KEYWORDS: UAV Photogrammetry, Mystras, GIS, Cultural Heritage Management, Digital Applications, Byzantine, Georeferencing

1. INTRODUCTION

"Digital Mystras" is an ongoing project that involves the creation of a temporal and spatial presentation of the evolution of the Medieval city of Mystras located in the south east Peloponnese. The project includes the multifaceted analysis of the development of the city taking under consideration political, economic and spatial parameters. Available data regarding architecture, building usage, art etc. is integrated into a geodatabase presented over a georeferenced background of the area. The application of digital spatial technology in the creation of a working database for the presentation and management of an archaeological site while providing additional data such as population fluctuations, structural elements, ecclesiastical and secular buildings as well as fortifications is a particularly challenging endeavor especially in the case of the archaeological site of Mystras.

The digital era taking over the world has infiltrated most aspects of life including cultural heritage. This digital "Cultural Revolution" can be interpreted as a coalition of science, technology and art openly combined. Digital cultural heritage has undisputedly been enriched with new fields originating from natural sciences and most recent advancements of optical techniques in marine and terrestrial space sciences. GIS, UAV, photogrammetry, structure from motion, specialized high-resolution cameras and cave-cam technologies, point clound representation, LiDAR and more are some of the major tools in the field of documentation, reconstruction and management.

Geodatabases for the documentation, presentation and monitoring of archaeological sites is a recent, but radically increasing practice, though laborious and time consuming. Such applications of internationally acknowledged significance include the archaeological excavations of Ancient Corinth also in the Peloponnese (American School of Archaeological Studies at Athens, 2021), the documentation of antiquities at a national level in Iraq and Jordan (Kalaf et al., 2018; Getty Conservation Institute; Howland et al., 2014), the technological applications in Catalhouyuk, Turkey (Forte et al., 2020), the documentation and digital reconstruction of the Delphi sanctuary (Liritzis et al., 2016; Hatzopoulos et al., 2017), the documentation of Roman sites in Croatia (Popovic et al., 2021), as well as for monitoring vulnerability and at-risk archaeological sites (Moreno et al., 2019; Sideris et al., 2017).

Mystras has a rich history and several phases that are characterized by intense changes in political and economic status which inevitably affected the population and development of the city around the Acropolis castle fortress. Geographic Information Systems (GIS) in collaboration with location-based application software provide a friendly, digital platform for the management and enhancement of archaeological and cultural heritage environments and in this case for the spatial presentation of the multidimensional development of Mystras.

The archaeological site of Mystras is situated in western Laconia, 6km southwest of Sparta, and 55km from Kalamata (Fig. 1). In 1989 the Medieval City was included by UNESCO in the list of World Cultural Heritage sites and is considered the best-preserved Byzantine state of Greece covering more than 540 acres (54.43 hectares) over the east side of Myzithras hill (UNESCO). Situated on the extent of the slope the challenging study area includes sharp slopes (>45%) in cases as well as extensive dense vegetation, high and low. In many cases areas of the city are inevitably inaccessible.

These, in other cases, prohibiting parameters make the archaeological site of Mystras an ideal case study for the application of advanced technological equipment in the site survey and documentation. The methodological approach to the site survey included the use of an unmanned aerial vehicles (UAVs), the DJI Mavic 2 Pro UAV in collaboration with the Top Con GR5 geodetic station GPS in order to visualize the history of Mystras through the first attempt to a digital depiction of the different phases of the city providing a digital product where the archaeological data concerning the area of the Byzantine city are projected. Geographic Information Systems (GIS) are integrated in the study for the temporal and spatial presentation of the evolution of the city providing additional data in the digital depiction of the narration of the history of the city itself, highlighting the contribution of digital technologies in Cultural Heritage Management (Panagiotidis et al., 2019).

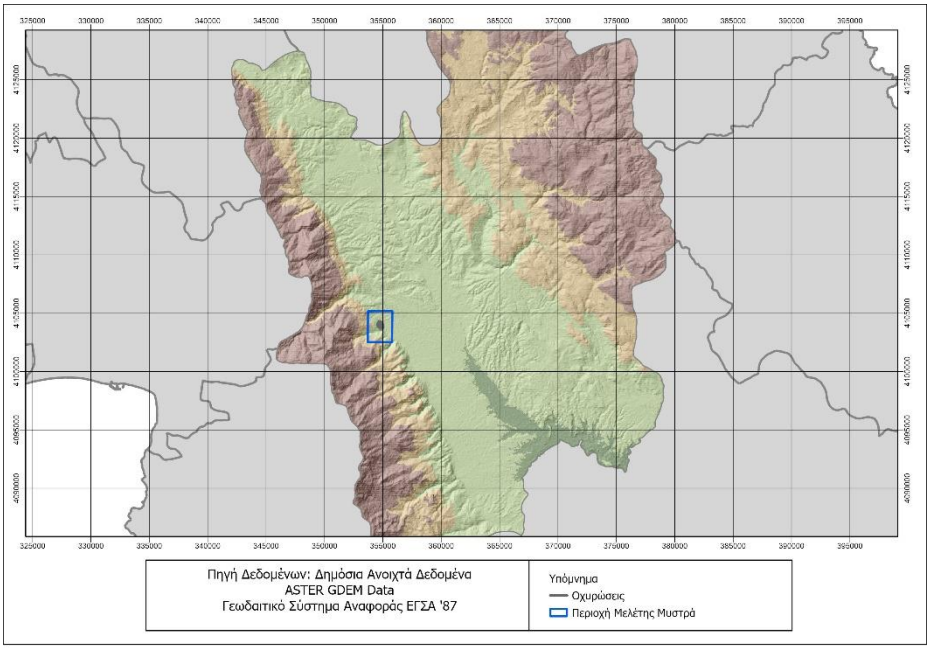

Figure 1. South Peloponnese – Mystras

2. METHODOLOGY

Structurally Mystras is divided into three zones (Fig. 2) the Acropolis, the Upper City and the Lower City. At the highest altitude in the archaeological site (600m) the Acropolis with the Frankish castle is situated. From the foot of the steep summit from the Acropolis the area of the Upper City or Ano Chora extends below to the first walls of the city, from the Monastery of Pantanassa to the Palace. The Lower City or Kato Chora extend from the walls of the Upper City to the lower walls outside the Monastery of Odigitria, the Metropolis of Aghios Dimitrios and the Monastery of Perivleptos to the east.

For the purposes of the survey of the archaeological site the city was separated into five regions in order to deal with issues that occur with extreme elevational fluctuations as well as dense vegetation and inaccessibility (Fig. 3).

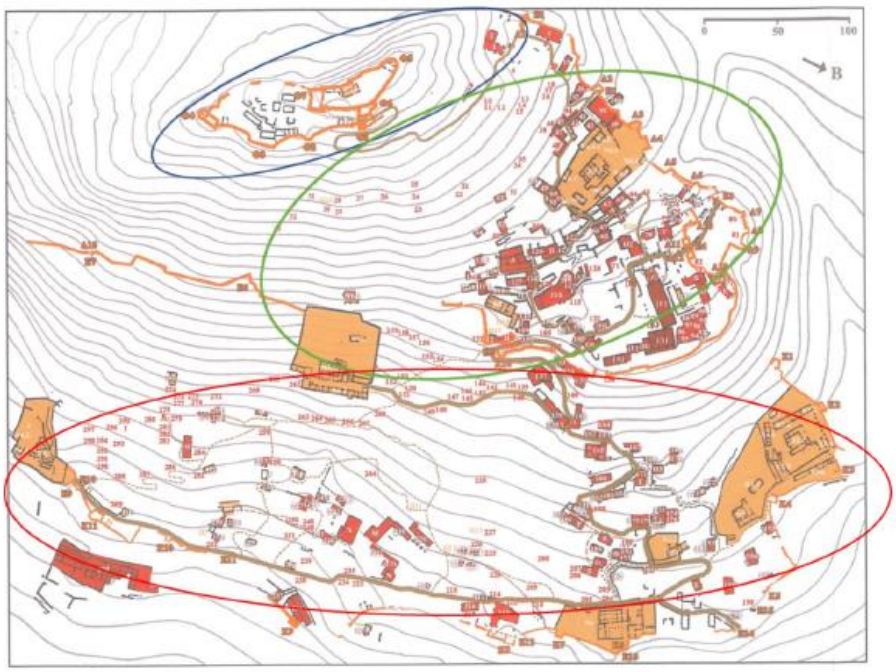

Figure 2. Map of Mystras and its structural segmentation, Acropolis (blue), Upper City (green) and Lower City (red)

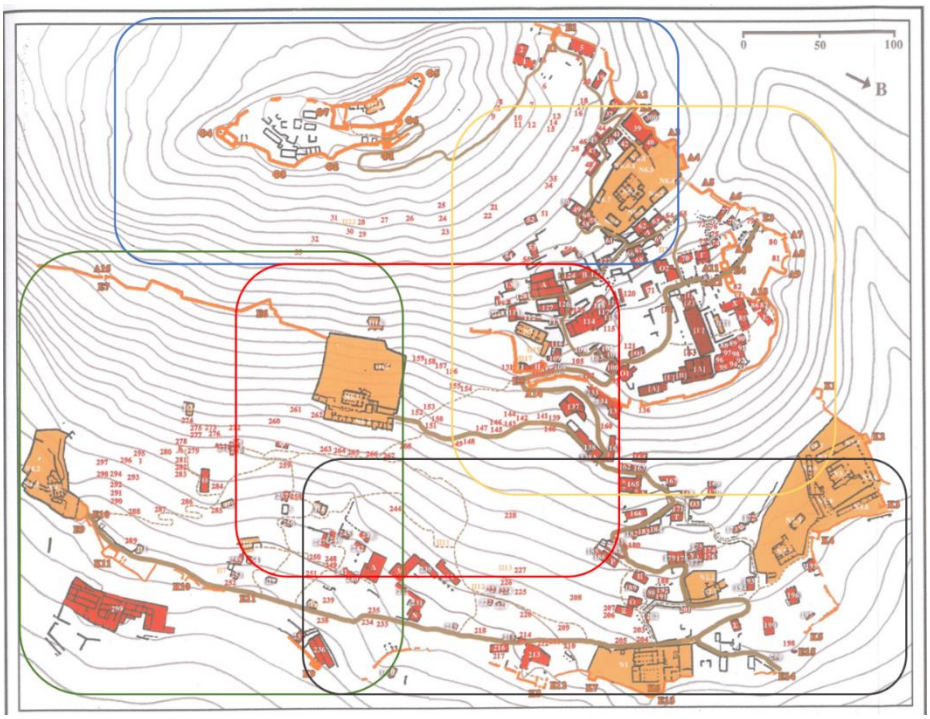

Figure 3. Survey segmentation - Five regions

The study area was photographed using the UAV. Ground Control Points (GCPs) where set over the study area for further georeferencing of the model. GCPs' exact coordinates were measured using the GR5 GPS. All data was collected in the Greek coordinate system EGSA '87. Images for the photographic overview of the study area were captured with the UAV at a relative altitude of 80m and 100m from take-off point. Each area was photographed separately and data was combined during processing. GCPs were placed on site in order to be visible from the UAV.

It should be noted that the abrupt and significant elevation differences did not allow a single flight over larger areas resulting in a number of flights per surveying region in order to successfully adjust the relative altitude of the UAV with the terrain and remain at approximately 80m, 100m and 120m from the ground. Multiple flights have the disadvantage that the area is captured with different lighting conditions each time depending on natural light and weather conditions. Especially, in the case of Mystras higher altitudes were used in order to avoid obstacles at different elevations in the same flight. Higher altitudes result in lower resolution photos.

The surveying process using a UAV such as the Mavic 2 pro includes flight planning, placement of GCPs throughout the surveying area, measuring the exact coordinates of each GCP with the GPS in order to ensure the greatest possible accuracy in determining their position (Meouche et al., 2016). Due to the morphological characteristics of the area significant problems occur also in the placement and measurement of the GCPs, an extremely time-consuming process in order to properly place them in inaccessible terrain. The position of each GCP is later verified in each photograph during the photogrammetric analysis for the point cloud georeferencing process in the photogrammetry software as described below. The flight plans followed the formation of a single grid (Fig. 4) through the Litchi UAV navigation application which allows the pilot to configure all parameters before flight. The route, the formation of the flight, the relative altitude of the UAV, flight speed, camera tilt as well as photo capture frequency were determined in advance. For best results an overlap of at least 75% was maintained (Gutiérrez, et al., 2016).

The surveying process for the entire archaeological site with the Mavic 2 Pro resulted in over 1000 photographs with 5472 X 3648 pixels analysis with 62 GPCs set during the process.

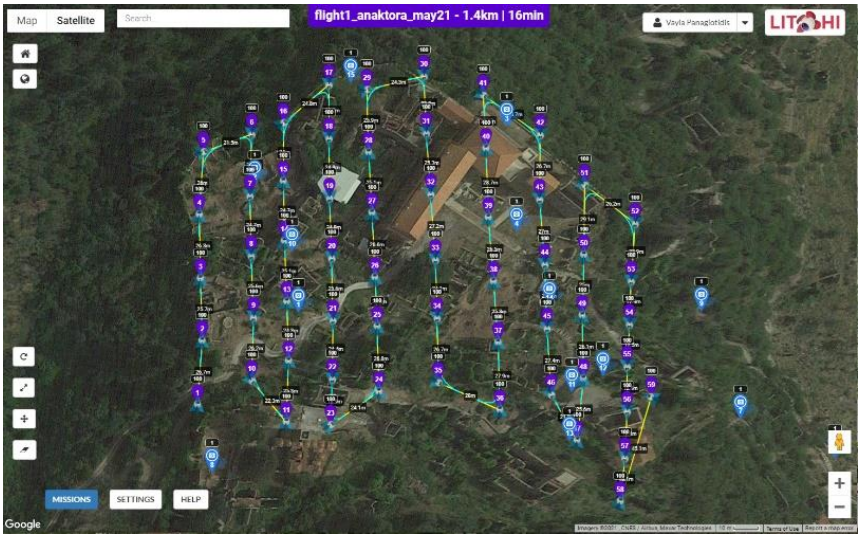

Figure 4. Litchi application screenshot UAV flight plan

Following flight, the photographic documentation from the survey along with the GCP coordinates are transferred to a computer for processing using the photogrammetry software Agisoft Metashape, top all-around drone mapping software (Jackson, 2021).

The processing procedure is quite strenuous for a conventional computing system. Briefly the processing procedure includes image (camera) alignment, referencing system conversion, importing target coordinates (GCPs), generating the dense point cloud, classification, mesh creation, generating the DEM and orthomosaic. Align photos translates into the software identifying the camera positions and orientations for each photo. This positioning creates a rough three-dimensional model of the space in the form of a sparse point cloud (Fig. 5).

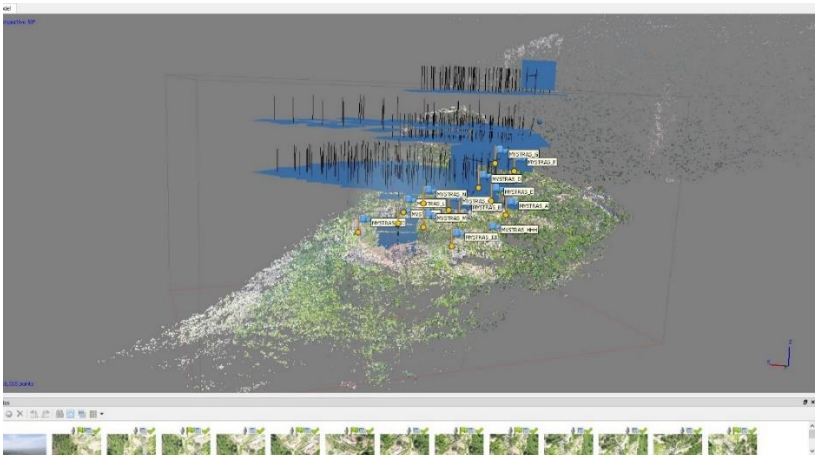

Figure 5. Camera positions, alignment and sparse point cloud.

In order for the software to accurately define the model's (in reality each camera's) position, GCPs are necessary. The GCPs coordinates are identified as markers and added to the model. The position of the markers in each image must be adjusted separately to confirm the correct placement above the visible GCPs within each image. This procedure ensures better georeferencing results compared to using only the UAV's GPS. Following optimization, a dense point cloud of the study area is generated. The dense point cloud creates a detailed three-dimensional model of the examined area is created (Fig. 6).

Figure 6. 3D perspective of archaeological site (mild processing).

Figure 7. Study area's Orthophoto

The dense-point cloud produces the study area's digital elevation model (DEM) from which in turn the high resolution orthophoto (200MB) is produced (Fig. 7).

The generated orthophoto is used as the georeferenced basemap for the development of the geodatabase of the study area.

3. THE GEO-DATABASE

As mentioned above the geodatabase includes representative data of Mystras regarding the structural development of the city such as construction phases in correspondence to the political changes in the city, building types and change in usage as well as individual examination of the additions made. In order to organize the data, the spatial depiction of the archaeological data was divided chronologically into five time periods based on the administrative state of the city.

These chronological phases are:

I. Period of Latin occupancy 1249 – 1262
II. Late – Byzantine I 1262 – 1348 (seat of the Byzantine General)
III. Late – Byzantine II 1348 – 1384 (Reign of Kantakouzenos)
IV. Late – Byzantine III 1384 – 1460 (Reign of Palaeologos)

V. Post - Byzantine 1460 – 18218.

Multiple layers of information concerning Mystras were developed in the GIS environment. The published doctoral dissertation of Dr. St. Arvanitopoulos titled: "The City of Mystras: Aspects of the organization and operation of a late Byzantine urban ensemble" was used extensively for the descriptions and identification of the buildings of the city as well as documentation of the monuments according to the restoration program of Mystras as published in "The Monuments of Mystras". The work of the Committee for the Restoration of Mystras Monuments" under the scientific supervision of Prof. Stefanos Sinos was also used. The geodatabase includes records of all the buildings of the city, ecclesiastical, administrative, secular as well as fortification structures, the road network, latrines, cisterns and water basins.

The first phase of the study area is that of its establishment and first settlement. The city of Mystras was founded in 1249 by the Frankish Prince of Achaia following the three-year siege of the castle of Monemvasia on an island off the east coast of the Peloponnese. It was on the Franks return from Monemvasia in 1249, when William II built the Castle of Mystras, in a key position to control the valley of Evrotas, six kilometers southwest of Sparta, built the emblematic fortress at the top of Myzithra Hill. Structurally, the fortress is divided into three sections, the exterior wall, the interior wall and a large building within the second enclosure. The Frankish citadel is the main fortification complex in the overall organization of the city (Georgiadis, 2002).

During this phase only the castle/fortress exists as well as building A which will later serve as the core of the development of the palatial complex (Fig. 8).

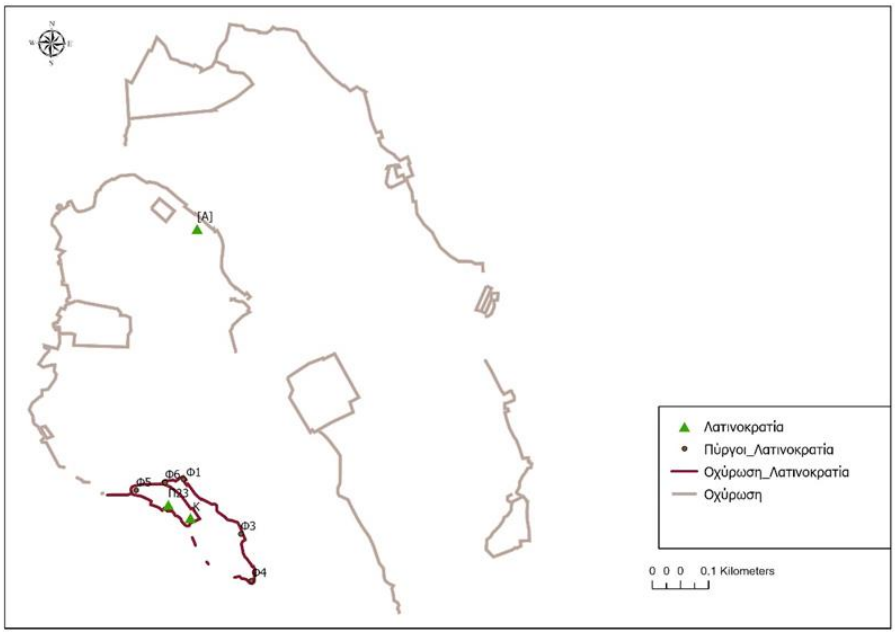

Figure 8. Structures built during the first phase of Latin occupancy (1249 - 1262)

In 1262 Mystras was surrendered to the Byzantines following William II's capture during the Battle of Pelagonia in 1259. During the negotiation for his release, he bestowed the castles of the Great Maina, Monemvasia and Mystras to the Byzantine Emperor Michael VIII Palaeologos (Kalonaros, 1940). Regardless though of the Franks agreement with the Byzantines, William II maintained his interest in Mystras. His continuous claim on the city created tension for the local populations of Lacedaemonia (Chatzidakis, 1992). The Byzantines quickly begin their campaign over the total of Lacedaemona. It was at this time that the population of Lacaedomonia began to resettle on the hillside of Myzithras under the shadow of the Acropolis. The resettlement in Mystras was reinforced when the Christian Orthodox Bishop established his seat in the city after transferring the Metropolis of Lacaedemonia from Lacaedemonia to the newly constructed church of Hagios Demetrios at the lowest part of the city. Hagios Demetrios essentially defined the lower border of the city (Sinos, 2009).

As Mystras grew in population and area over Myzithras hill summit, the city experienced a number of phases. Following the battle of Makryplagi in 1262 Chora of Myzithras was established and fortified below the Castle (Chatzidakis, 1992). During the first Byzantine Period from 1259 to 1348, Mystras became the seat of the Byzantine General, titled "Sevastocrator". The Sevastocrator ruled the entire Peloponnese and was replaced yearly (culture.gr).

Through the spatial depiction of the geodatabase the fast development of the city is visible with the extensive fortification, gates, towers and dated buildings are distinguishable according to the map legend (Fig. 9).

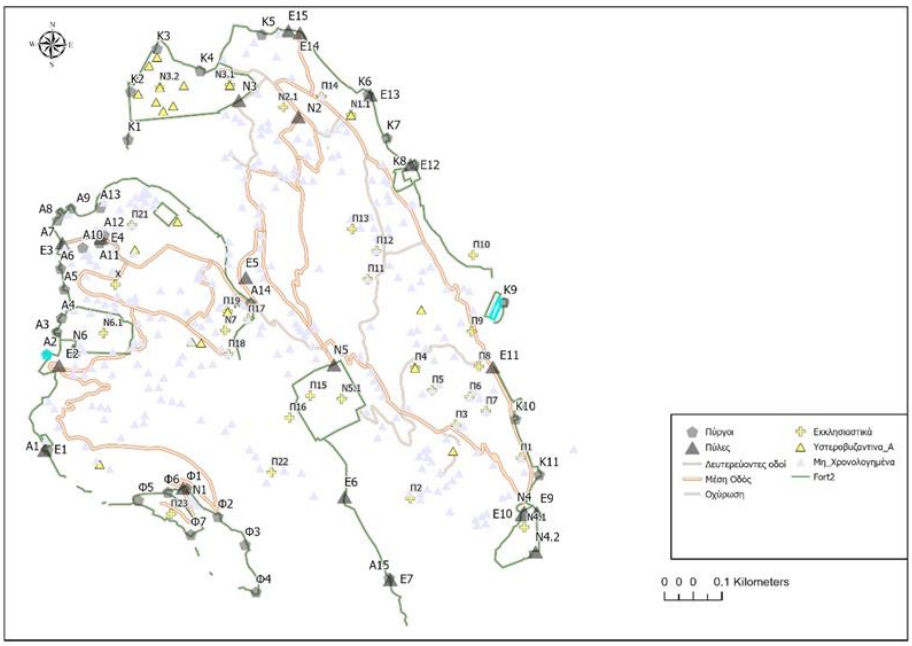

Figure 9. Spatial depiction of the first Late Byzantine period of Mystras (1262 - 1348)

It should be mentioned that the grey marked buildings are those that have not been substantially dated. It is important to include them in the database since they constitute a significant part of the city.

The next phase, 1349 – 1383, during the reign of the Dynasty of Kantakouzenos, Mystras was upgraded to a Despotate, becoming one of the most important provinces of the weakened Byzantine Empire. The city experienced great prosperity during this period and played an important role in Byzantium until the fall of the Empire (Sinos, 2009). Emperor Ioannis Kantakouzenos VI, founded the Despotate of Morea with Mystras as its capital by appointing Manuel, his second son, as Despot of Mystra. The city's expansion and evolution into the Despotate of Mystras made it the epicenter of Byzantine power in the Peloponnese (Figure 10).

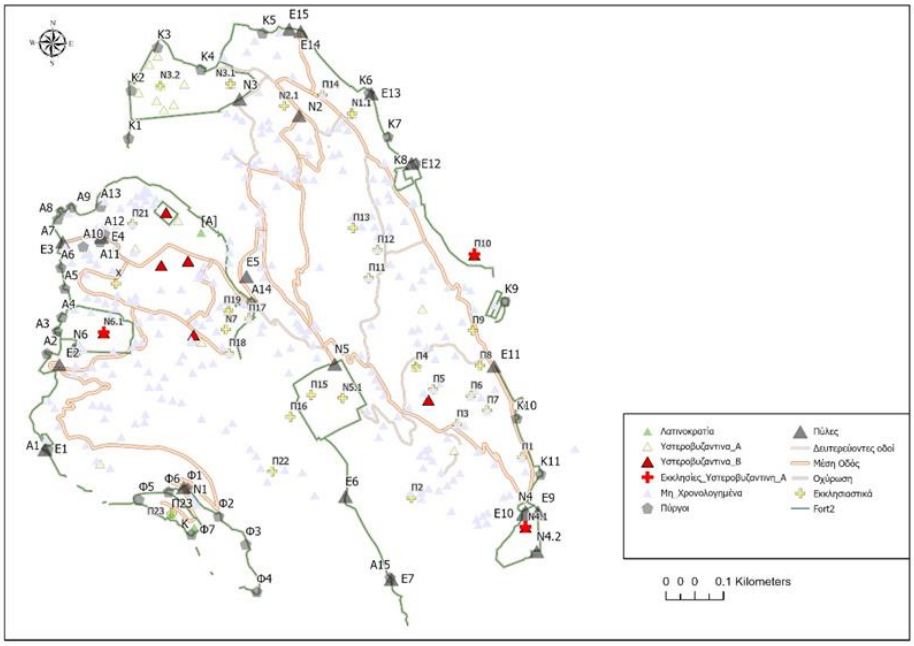

Figure 10. Spatial depiction of the Late Byzantine II period of Mystras (1348 - 1384)

With the predominance of the House of Palaiologos in the Despotate, the third late Byzantine period of Mystras is determined between 1384 to 1460. During this period the Monastery of Pantanassa is built south of Hagia Sophia in a prominent position on the steep slope of the hill at the southwestern end of Kato Poli. The Catholicon of the Monastery is the last great Byzantine ecclesiastical work of the city (Fig. 11). The period 1384 - 1460 is the last period of Byzantine rule in the city which will be succeeded by the Ottoman rule of the region.

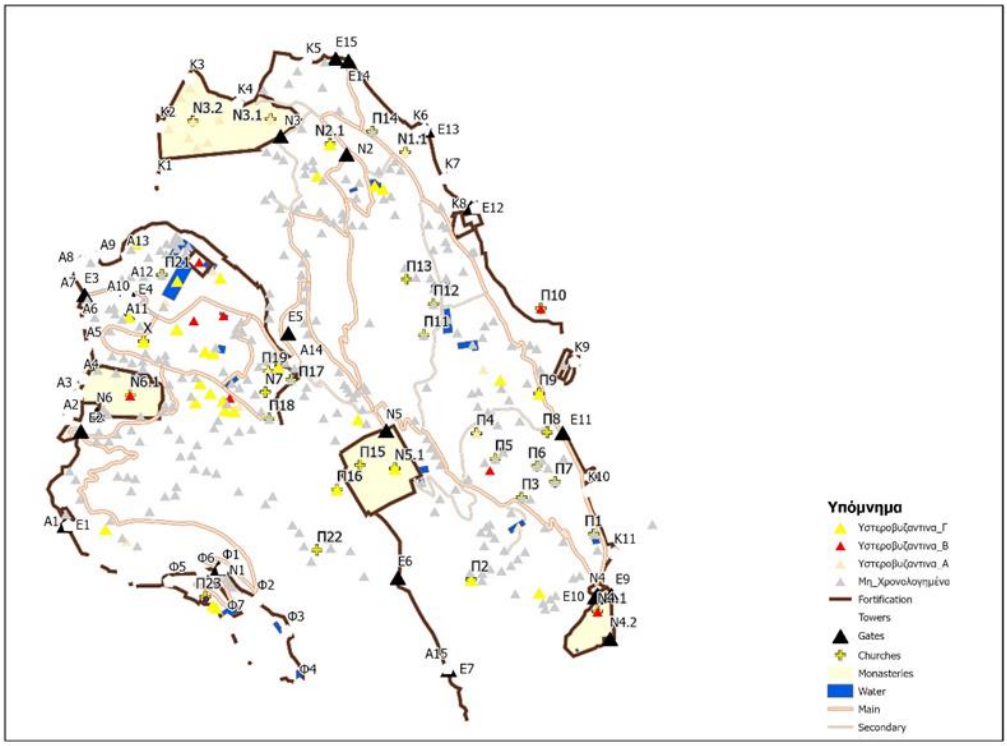

Figure 11. Spatial depiction of the Late Byzantine III phase of Mystras (1384 - 1460)

Mystras was surrendered to the Ottoman Turks in 1460 following extensive pressure from their presence and occupation of the northern Peloponnese (Fig. 12). During the period of Ottoman occupation, 1460 – 1821 Mystras held an important position in the Ottoman Empire and was one of the most important silk production centers in the Eastern Mediterranean (Sinos, 2009) (Runciman, 1986). The Ottoman period of Mystras was interrupted in 1687 until 1715 when the Peloponnese was occupied by the Venetians. During the Venetian period significant part of the Greek population was killed or forced to leave (Arvanitopoulos, 2004).

After the establishment of the Greek State in 1834, the new city of Sparta was founded and a large part of the inhabitants of Mystras left the Castle City situated on Myzithra Hill. The Castle city was declared in 1921 a prominent Byzantine monument, the last inhabitants finally left Mystras in 1953. The archaeological site was included by UNESCO in the list of World Cultural Heritage sites (UNESCO) in 1989, making it the best-preserved Byzantine state of Greece (culture.gr).

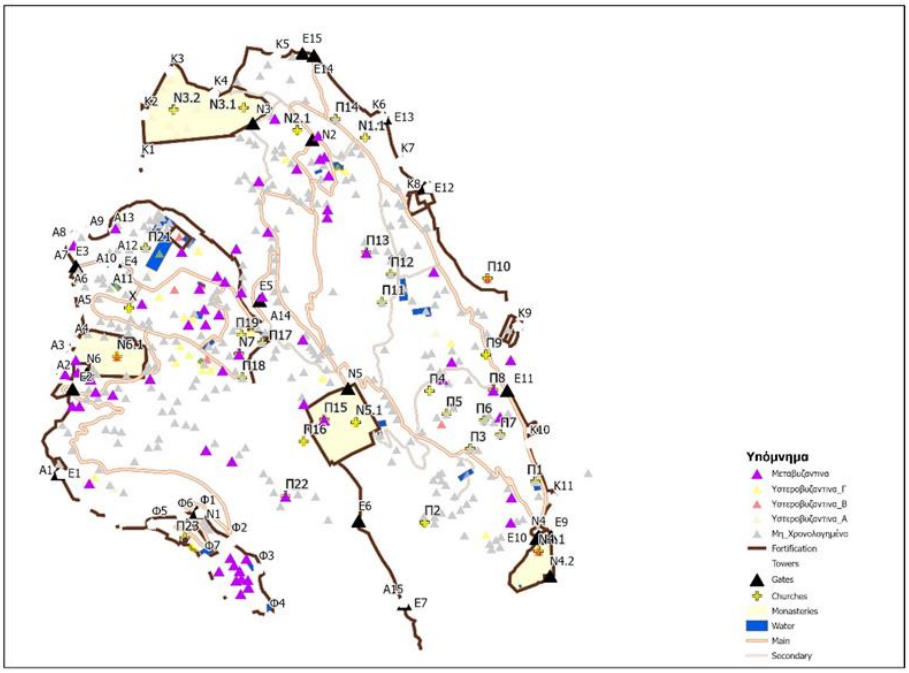

Figure 12. Spatial depiction of the Post Byzantine phase of Mystras (1460 - 1821)

4. APPLICATIONS

Maps, plans and sketches even photographs have been preserved, such as the Venetian era plan from Levasseur and the topographic plan by Gabrielle Millet from 1910. The previous spatial representations offer additional insight when examined in comparison with historical maps. The topographic depiction of the city by the archaeologist and historian, Gabrielle Millet was used for the comparison with data from the geodatabase (Fig. 13). Millet's plan of the city was scanned and imported to ArcGIS Pro, the GIS package used in this study. The digitized map is referenced by recognizing elements of the current landscape as reference points and scale matching. In the case of Millet's plan, the Castle fortress is visible as well as a number of other buildings, the Palace, Pantanassa Monastery etc. in order to create the matching reference points to the base map generated from Agisoft's Metashape. Each collection of data is created in separate layers in the ArcGIS environment, thus composing a database of historical information (Anagnostakis et al., 2014).

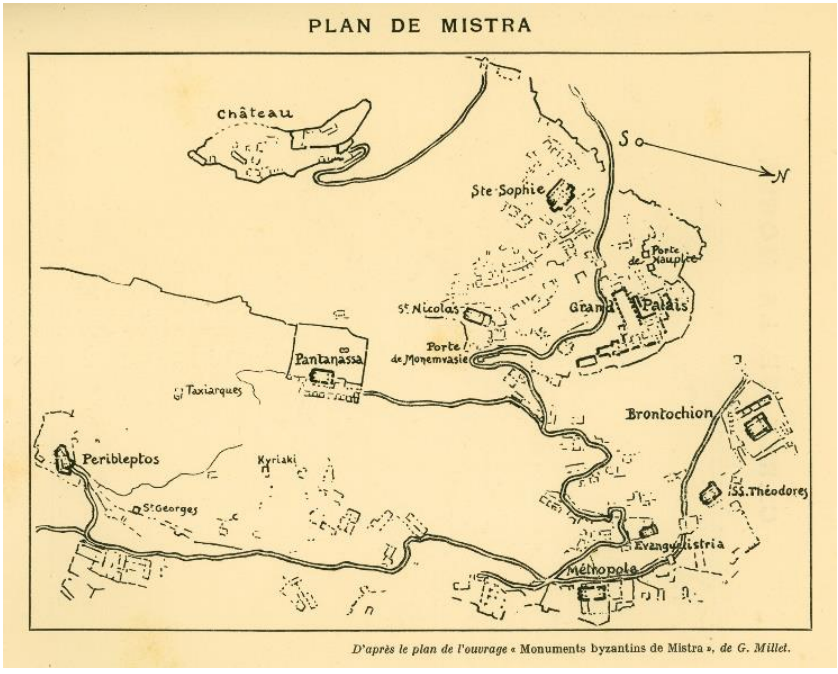

Figure 13. Plan of Mystras [plan de Mistra, Monuments byzantine de mistra, de G. Millet]

The digitization of the phases, structural and temporal is presented overlapping Millet's historical topographical plan offering unique perspective in relation to the archaeological study and the remains that exist today (Fig. 14 & 15). Millet's plan clearly depicts the Palace and its surrounding buildings and structures many of which have been identified on the orthophoto of the area today. Fig. 14a offers a clear depiction of the geodatabase information overlaying Millet's plan while maintaining a view of the orthophoto in the background. Similarly, comparing the database to Millet's diagram offers an alternative view for studying the city remains (Fig. 14b).

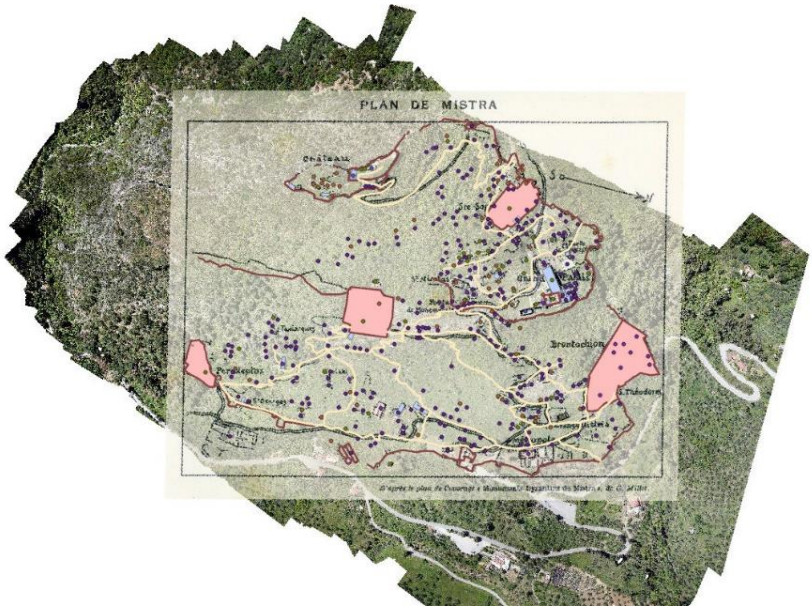

Figure 14. Basemap overlayed with Millet's plan and the generated geodatabase

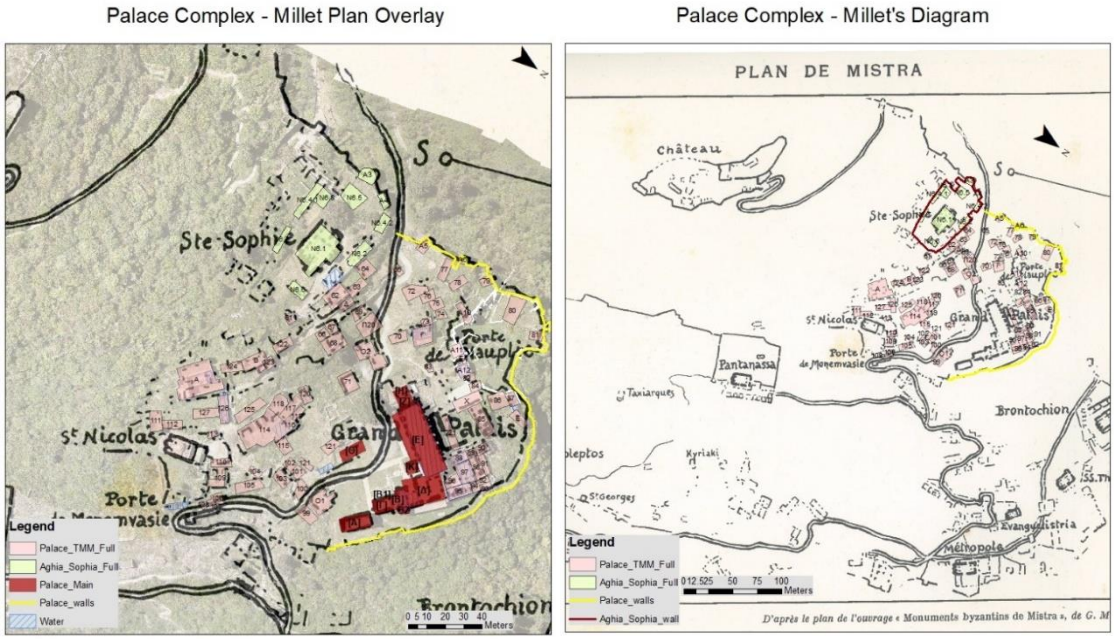

Figure 15. Overlaying the database to Millet's diagram (a) left and (b) right

Through the spatial visualization of Mystras, unknown to the public areas and aspects of the urban fabric area revealed.

Another use of the geodatabase is the study of the buildings in the case of structured units of the Hagia Sophia Monastery or Zoodotou Christou which includes remains beginning from the Late-Byzantine period when Mystras was the Despotate of the Peloponnese. Additions to the structure of the church itself as well as the ancillary buildings of the Monastery

were constructed throughout the Late Byzantine period and continued their use during the Ottoman occupation when Hagia Sophia was transformed to a mosque (1460 – 1821). The main buildings credited to this first establishment of the Monastery are the church of Hagia Sophia (N6.1), the refectory (N6.2), the cistern (N6.3) and the Cells (N6.4.1). The majority of the structures where erected during the Late Byzantine period. (Fig. 16).

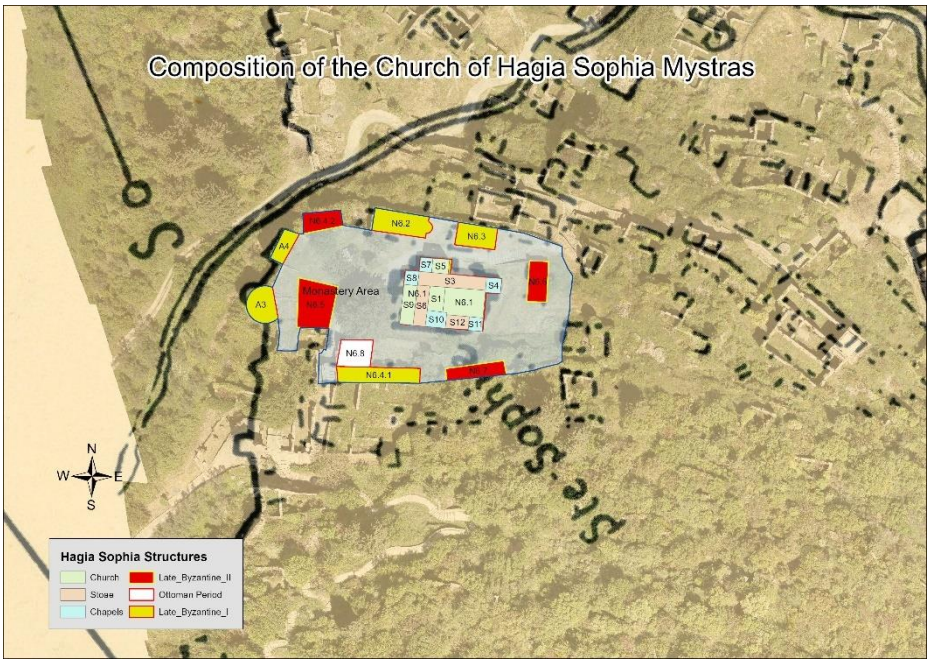

Figure 16. Structural composition of "Hagia Sophia" Monastery

The geodatabase for the spatial study of the whole city of Mystras has been developed in ArcGIS Pro. Without the installed software, however, it can only be published or studied as static maps. For this reason, a web application was developed that contains the study information available through the ArcGIS Online platform. ArcGIS Online allows, among other things, the development of stories, called Story Maps. The Castle City of Mystras is presented as an interactive application in ArcGIS Online with Map Series. The application is divided into sections via tabs that appear at the top of the page

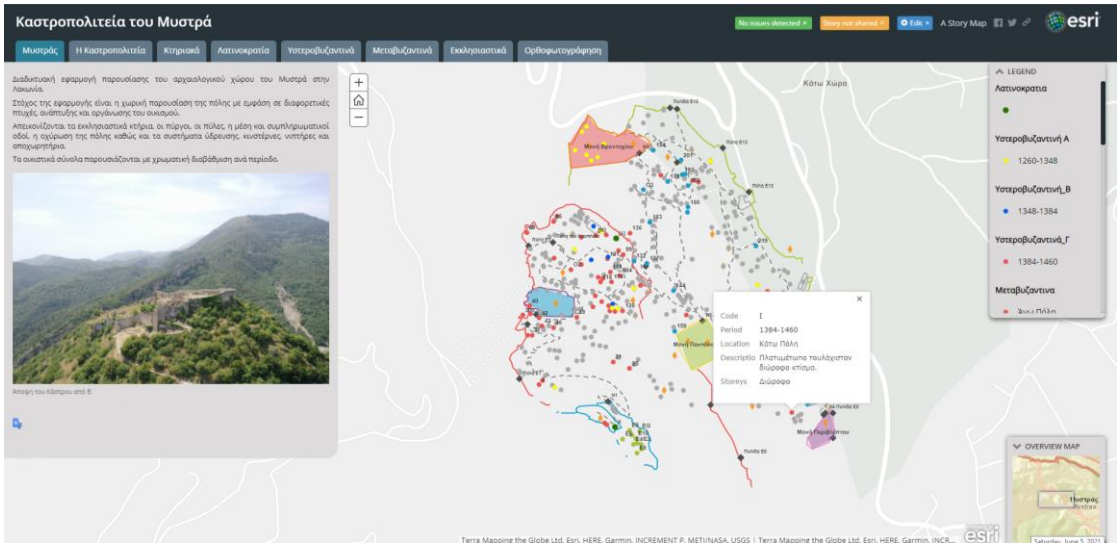

Figure 17. Introductory page to ArcGIS online application "The Castle City of Mystras"

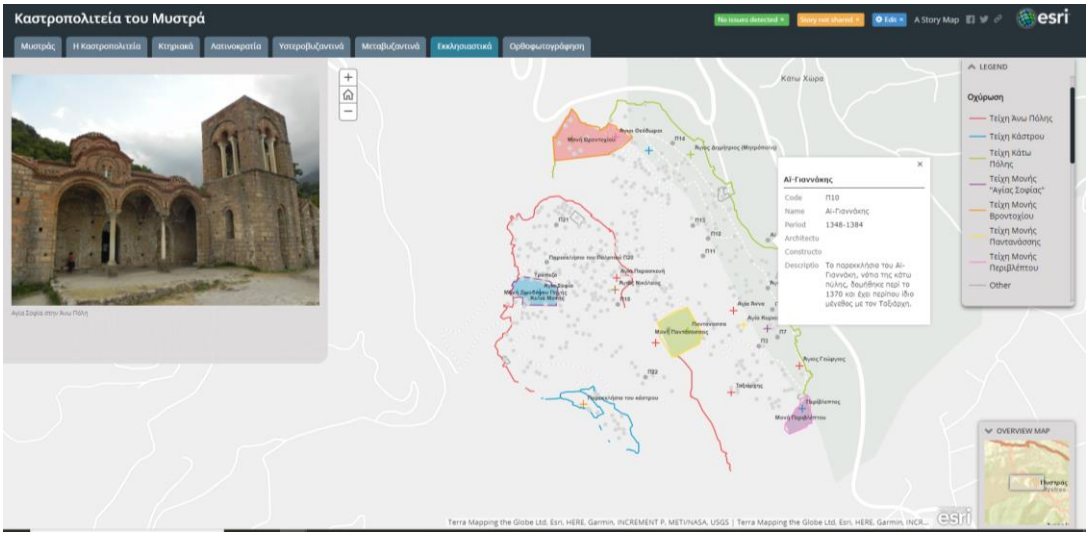

Figure 18. Ecclesiastical tab of ArcGIS online application "The Castle City of Mystras"

Each section presents the archaeological site from a different perspective. The introductory section refers generally to Mystras with a brief description of the application in superposition with an interactive map of the entire residential fabric, churches, fortifications, etc. (Figure 17) The third section introduces the user to the residential organization of Mystras. There is a brief presentation of the structure of a typical house in Mystras with photos of indicative buildings within the settlement today. The information is presented superimposed on an interactive map containing all the houses and buildings, except churches, chapels and gates. Each building is depicted on the map with a location and its code. Clicking on the position opens a window with the code of the building, its chronological classification in the five study periods, its location in the settlement, a brief description and the number of floors. The caption shows the classification of the buildings on floors and whether or not the building was equipped with a balcony.

The layer "Ecclesiastical" includes a representation of all churches and chapels of Mystras. Each item includes the name of the church or chapel, the time period of its initial construction, the architectural type, its founder and a short description (Figure 18).

The geodatabase developed in this study works as a dynamic tool for the study of the urban development of the city over the course of 600 years with correlations between buildings and building complexes, infrastructure and infrastructure usage in relation to the political/historical status. The users easily witness the rapid transformation of a fortress outpost into a prominent city. The format of the georeferenced base map provides the means to further identification of new structures and encourages enrichment with new data arising from archaeological and historical studies. The information gathered on such interactive platforms expand the scope of existing published research while enhancing dissemination to a larger audience. Through the applications presented in this project a more thorough insight on the use of space is available for research and educational purposes.

5. CONCLUSION & FUTURE AIMS

The work presented in this study is part of an ongoing research effort for the mapping and high-resolution depiction of the archaeological site of Mystras including a detailed geodatabase of all the structures of the city. Through the overall presentation of the medieval city via GIS and the developed geodatabase users have the opportunity to study the site depending on their research interests through a centralized application containing a significant segment the published research data regarding Mystras. The database layers can be used in a variety of additional applications from AR and VR applications, to 3D visualization projects, educational games and digital smart guides. Future aims include the continuation of the development of the geodatabase in English and enhanced information. Additionally, the archaeological site will be scanned using LIDAR technology in order to obtain a better view of the site surface which is covered by the extensive vegetation over Myzithra hill.

AUTHOR CONTRIBUTIONS

Investigation, resources, visualization, data curation, writing—original draft preparation: V.P.; Writing—review and editing, supervision & project administration: N.Z.; Conceptualization, methodology, validation: V.P., N.Z. All authors have read and agreed to the published version of the manuscript."

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