The Story Map for Metaxa Mine (Santorini, Greece): A Unique Site Where History and Volcanology Meet Each Other

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Abstract: Story maps are widespread as an interactive tool used for science and spatial data communication, information and dissemination. A Web-based application using story mapping technology is here presented to show the historical importance of Metaxa Mine, known also as Mavormatis mine. This mine is characterized by the presence of several key outcrops where the pumice layers of the Late Bronze Age (Minoan) eruption are very well exposed. We made up a tailored story map that combines maps, narrative texts, multimedia content and a brand-new 3D model. Its purpose is to highlight the visualisation and the exploitation of Metaxa Mine as a unique "geotope" of Santorini volcano, to enable users to interact with data and maps, texts and images, and to inform academic and non-academic audience about the historical and volcanological aspects of this geological site. The spatial and geological data of this story map involve thematic maps entirely created by a Geographic Information System.

1 INTRODUCTION

Recent improvements in digital Geographic Information Systems (GIS) technologies can provide new opportunities for immersive and wide engaging public audiences with complex multivariate datasets.

Story Maps can be not only robust but also versatile tools for visualizing spatial data effectively and when combined with multi-media assets (e.g. photos, videos, 3D representations) and narrative text, they can provide support for scientific storytelling in a compelling and straightforward way.

Thereby, Story Maps can be used in order to disseminate and understand scientific findings to broader non-technical audiences (Janicki et al., 2016; Wright et al., 2014).

Santorini Volcanic Complex is consisted of Thera, Thirasia, Aspronisi, Palea and Nea Kameni volcanic islands, located in the most southern part of the Cyclades in the Aegean Sea (Fig. 1). Using Story Maps along with novel methods and research tools is an attempt to visualize the volcanic landscape of Metaxa Mine, as a unique geotope of Santorini volcano where the pumice layers of the famous Late Bronze Age (LBA) (well-known also as Minoan) eruption (Fig. 1) are exposed.

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Figure 1: Location of Santorini group in the Aegean Sea (A) and Metaxa Mine at the southern part of Santorini's caldera (B-C).

Adopting Story Maps for this study, offers a number of advantages compared to traditional methods: the friendly mapping, the ease of use and understanding of the provided information, the increased interactivity comparing to analogue or simple web maps, the customized display based on the user's needs, the ability to import different kind of media (images and videos) and ultimately the ability to add explanatory text covering a wide range of heterogeneous information.

This paper presents a web-based application to disseminate information to geologists, earth scientists, tourists and other non-expert users to explore the LBA volcanic outcrops in Metaxa Mine.

2 HISTORY OF METAXA MINE

"Balades" (or mines in the local dialect) had been in operation for over 140 years (up to May 1979). The mortar produced from Thera's terrestrial land had been used in several ancient construction projects such as the great fortification in Crete during the Cretan Revolution, but also in earlier periods. Their strength is even increased when construction occurs with sea water.

In the beginning, the mining operation was performed by simple means using a method called "cut", which is, probably, a unique process globally (Tsoutrelis and Livadaros, 1995). The method was based on supporting large volumes of land, each with a height of 20 to 70m. This was done by opening in parallel covered galleries of around 1.2-1.5m wide and 2m high, in a direction perpendicular to the slope and at a depth of 10-15m. The opening was done with simple tools and the distance between the galleries was typically 3.5-5m (see Fig. 5). This mining method was dangerous, and several accidents had occurred before 1970, when the method was in use. In Metaxa mine, the "cut" method was applied at the initial stages of its operation only and no accidents have been recorded.

A total of 4.5 million m^3 is estimated to have been extracted from the mine. Transportation of the mined material was done by rail wagons to the so called "ruler" (or storage tank) and from there through a conveyor belt loaded into ships. The use of machinery and new technological developments changed the way and the rates of mining and transportation to the "ruler".

Metaxa mine also contains the so-called "famous section", as it is known to geologists, and more. The famous section (Fig. 2) shows the pumice layers of the LBA (Minoan) eruption along a length of 150m.

The LBA eruption of Santorini has influenced the

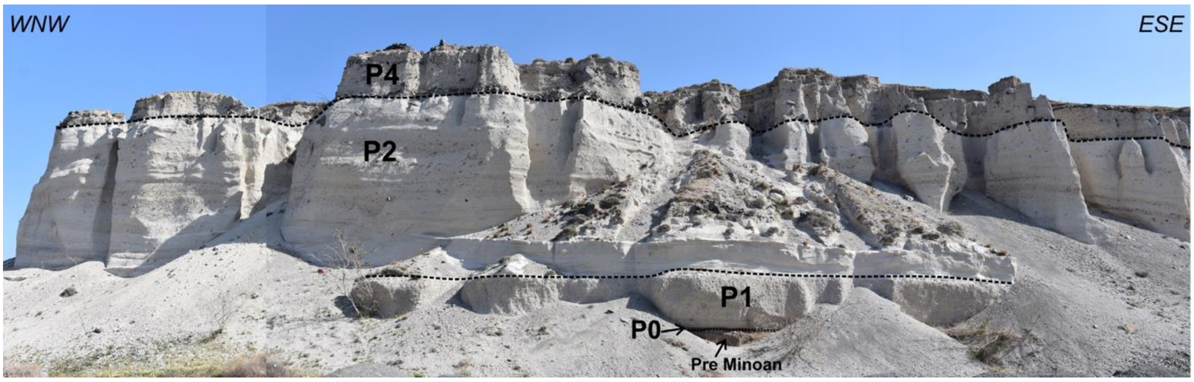

Figure 2: Panoramic view of the best volcanological outcrop in Metaxa Mine, the different Minoan eruption phases are highlighted. Pre-Minoan landscape, P0 – Phase 0, P1 – Phase 1, P2 – Phase 2, P4 – Phase 4. The location of the panoramic view is shown in figure 1C.

decline of the great Minoan civilization on Crete, making it an iconic event in both volcanology and archaeology disciplines (e.g., Manning et al. 2006; Druitt, 2014).

The eruption impacted the LBA Mediterranean world through a combination of ash fallout (Johnston et al., 2014), climate modification (Pyle, 1997) and tsunamis (Bruins et al., 2008) and it was the last plinian eruption of Santorini (Sparks and Wilson, 1990; Druitt, 2014). It discharged between 30 and 80km^3 (dense-rock equivalent; Johnston et. al., 2014) of rhyodacitic magma, mostly as pyroclastic flows which entered the sea, and which are preserved as ignimbrite in the surrounding submarine basins (Sigurdsson et. al., 2006). According to numerous volcanological studies, there is a consensus that the eruption occurred in four major phases with an initial precursory phase (P0) (Fig. 2; Reck, 1936; Heiken and McCoy, 1990; Druitt, 2014):

- **Phase 0:** The eruption began with precursory explosions that left two lapilli fallout layers and a phreatomagmatic ash totaling 10cm in thickness (Heiken and McCoy, 1990). Druitt (2014) call these explosions eruptive phase 0. The two lapilli layers were laid down from a subplinian plume 7–10km high. The plume was blown to the SSE, so that P0 is restricted to that sector.
- **Phase 1:** The first main Plinian eruption, generated a sustained plume estimated at a height of 36 ± 5km and produced a reverse-graded pumice fall deposit that ranges from 6m to less than 10cm in thickness on the islands of Santorini, Therasia and Aspronisi (Sparks and Wilson, 1990; Sigurdsson et al., 1990; Druitt, 2014).
- **Phase 2:** During Phase 2, access of seawater to the vent initiated violent phreatomagmatic explosions and triggered the generation of base surges that spread radially away from the vent and formed stratified deposits up to 12m thick (Sparks and Wilson, 1990; McCoy and Heiken, 2000). The phase 2 products are dominated by pyroclastic surge deposits with multiple bedsets, dune-like bedforms with wavelengths of several meters or more, bomb sag horizons, and TRM temperatures of 100–250°C (Heiken and McCoy, 1984; McClelland and Thomas, 1990).
- **Phase 3:** The increasing water–magma ratios produced denser, partly wet, low-temperature pumiceous pyroclastic flows transitional to mud flows. In this phase, significant column collapse produced the most prominent unit of the eruption on land. This is a coarse-grained, massive, phreatomagmatic ignimbrite up to 55m thick (Druitt et al., 1999), still reflecting magma-water interaction and deposited at low temperatures (Druitt, 2014; McClelland and Thomas, 1990). The third eruptive phase may have created a tuff cone (Nomikou et al., 2016), possibly a large pyroclastic construct filling the caldera bay (Johnston et al., 2014). This phase is thought to coincide with the explosive disruption of the Pre-Kameni island (along with other parts of Santorini), given the occurrence of abundant, evenly distributed lithic clasts up to 10m in size in the deposit (Karatson et. al., 2018).
- **Phase 4:** This Phase saw the venting of high-temperature (300–500°C) pyroclastic flows, which produced fine-grained, nonwelded ignimbrites around the caldera rim and the coastal plains (Heiken and McCoy, 1984; Sparks and Wilson, 1990; Druitt et al., 1999). The dominant facies is a tan-to pink- colored compound ignimbrite ("tan ignimbrite") (Druitt, 2014). The ignimbrite is mostly fine grained (ash and lapilli grade), with a high abundance of comminuted lithic debris in the ash fraction. This phase may have been coeval with

major caldera collapse (Sparks and Wilson, 1990; Druitt, 2014). Minoan ignimbrite, possibly up to 80m thick, lies offshore of Santorini (Sigurdsson et. al., 2006) and is the most voluminous Minoan unit.

3 METHODOLOGY

To tackle the challenge of creating the Story Map of Metaxa Mine, the open geo-museum of LBA (Minoan) eruption, different types of datasets have been compiled (historical, geological, and topographical data together with geospatial data from open source portals). Moreover, three field trips have taken place in September 2017, March and October 2018, for field data collection, such as photographic material, in order to better recognize and map the layers of LBA eruption in the Mine.

In order to enrich the webgis application with webmaps and scenes giving the sense of spatial distribution of text described, a geodatabase containing all the available data (literature and field data) was created in ArcGIS Desktop - ArcMap environment. The feature layers were then uploaded to the ArcGIS Online platform for further processing (Antoniou et al., 2018). Also, ArcGIS Desktop – Pro version was used to create 3D animations using the available spatial data.

Regarding field activity, several parts of the mine were surveyed, focusing the main areas of interest. Pictures and videos were collected using classical cameras as well as a campaign with an unmanned aerial vehicle (UAV) was conducted. This allowed the collection of pictures with a high level of detail for the lower part of the mine and, much more important, for the upper part of mine walls.

Using the Aerial Structure from Motion (ASfM) technique (e.g. Turner, Lucieer and Watson, 2012) the western part of the mine was reconstructed, where the layers related to the famous LBA eruption are well exposed and where the processing machinery are also presented (Fig. 3A). Pictures have been taken using the DJI Phantom 4 PRO that is equipped with a 20 Megapixels camera, including EXIF information (Exchangeable image file format) together with GPS coordinates, provided by the integrated Satellite Positioning Systems GPS/GLONASS (referred to the WGS84 datum).

Two missions were performed, the first one was devoted to capture a set of photos in nadir camera view (Figs. 3A-B) to cover the whole selected area (Fig. 3A) with an overlap of 90% along the path and 80% in lateral direction; the high overlap ratio is useful to obtain a good alignment of images. The photos have been captured every 2 seconds (equal time interval mode), at an altitude of 20 m from the highest point of the ground (Home point – Fig. 3A) and with a constant velocity of 2 m/s in order to minimize the motion blur, as well as to achieve well-balanced camera settings (exposure time, ISO, aperture) and ensure sharp and correctly exposed images with low noise. The UAV flight mission has been planned and managed using DJI Ground Station Pro software (https://www.dji.com/ground-station-pro) and is represented by black arrows in Figure 3A.

The second mission was devoted to collect photos of the vertical outcrops and the camera was oriented orthogonal (oblique) to vertical cliff (e.g. Fig. 3C), in order to add as much details as possible to the model. In this latter case, the UAV was manually driven, maintaining a constant velocity of 2-3 m/s, and the pictures were automatically taken every two seconds using the DJI GO 4 app (http://www.dji.com/). A set of 20 uniformly distributed Ground Control Points have also been included in order to co-register the 3D model to the World Geodetic System (WGS84) (e.g. Smith et al., 2016; Esposito et al., 2017).

The 3D model reconstruction has been performed using Agisoft PhotoScan (http://www.agisoft.com/), a commercial Structure from Motion (SfM) software with user-friendly interface, intuitive workflow and high quality of points clouds (Benassi et al., 2017; (Burns and Delparte, 2017; Cook, 2017).

The resulting 3D model (Fig. 3D) is as large as 349 x 383 m and the resulting pixel resolution is 8 mm, allowing to recognize all the volcanic layers in the scene (Fig. 3E) through the navigation software developed in the framework of the 3DTeLC Erasmus+ project (http://3dtelc.lmv.uca.fr/).

4 THE STORY MAP

In order to compose a Story Map, all available data must be uploaded to an online platform, either a private server, or ArcGIS Online. The latter approach was followed during the deployment of this Story Map (https://goo.gl/scE4fg).

A template called Cascade Story Map was implemented, to present the available information. Webmaps, narrative texts, images, tables, multimedia content, scenes which correspond to 3D presentation of data, were used.

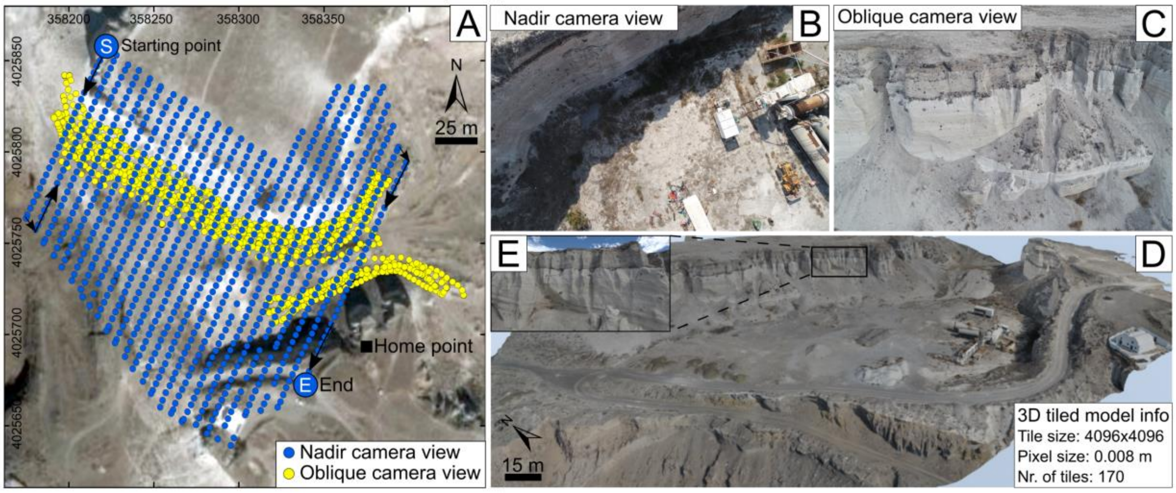

Figure 3: (A) Location of UAV-captured images, spatial reference: WGS 84 / UTM zone 35N. Examples of pictures captured in nadir (C) and orthogonal view (C). (D) 3D tiled model of the western part of the mine. (E) Details of the 3D reconstructed famous outcrop where the Minoan eruption layers are recognizable.

The thematic maps which are presented in the application, were created in ArcGIS Online (https://goo.gl/7sJ8ca), based on the collected data, fieldwork and literature review, depicting the most important and unique points. Although the use of this template does not require the knowledge of language programming, ArcGIS Assistant was used (https://goo.gl/PmHrwM), to perform certain modifications, e.g. text formatting, using CSS.

This specific linear template combines all the presented information in full-screen scrolling method. This is an advantage, because it is easy for the users to navigate following the “path” that the developer has chosen rather than jump from one tab of information to the other.

User’s first experience entering the web application is a three-dimensional navigation through the entire mine. Results from ASfM were used to create a 3D animation in ArcGIS Pro

The narrative starts giving general information about the location of Santorini’s group of islets, along with representative photos of the area. A video, using spatial distribution of feature layers along with an imagery basemap animate the location and the boundary of Metaxa Mine. This video, in MP4 format, was made in ArcGIS Pro, combining successive thumbnails of the spatial data.

The volcanic history and morphology of Santorini volcanic complex is presented subsequently. Starting with a scene, meaning a 3D representation (Fig. 4), of the spatial distribution of geological formations across Santorini volcanic complex a narrative text using multimedia content describes the unique steep morphology of the caldera. Users can select a formation to obtain further information through a pop-up window and can also use the tools on the right bottom of the map, to zoom in and out or right-click anywhere on the scene to tilt and rotate.

Further information about the onshore-offshore morphology of the entire area follows using a photo showing the digital elevation model (DEM) of Santorini complex along with subaerial topography and submarine morphology, accompanied by narrative text. The information on the volcanic activity of Santorini is completed by the representation of volcanic eruptions in Palea and Nea Kameni in the center of the caldera.

Nine volcanic eruptions took place giving the opportunity to create equal number of successive web maps, including the onshore and offshore spatial distribution of lava in each eruption, highlighted, along with the previous ones overlying a shaded relief. In this way, by successively scrolling, the volcanic formation of Palea and Nea Kameni islands is revealed up to their recent morphological shapes. Narrative text along with multimedia content describes each eruption while users can select an area to see representative photos through a pop-up window and can also use the tools on the right bottom of the map, to zoom in and out.

Having gained a full knowledge of Santorini volcanic history, which is essential to understand the importance of Metaxa Mine, users scroll down to reveal the history of Metaxa Mine. Explanatory text along with representative multimedia content (photos, videos and 3D model) describe the unique mining operations (Fig. 5) while Prof. Druitt, explains the importance of the mine, summarizing the LBA eruption and its phases in the mine.

Narrative text gives more detailed information about the LBA eruption while representative schemas show the distinguished pumice layers.

Finally, sections showing the pumice layers of the different phases of LBA eruption and other volcanic formations are following (Fig. 6). The panoramas reveal different locations inside the mine, as shown in the representative photos.

All the available information (texts, multimedia, etc.) that was used in this GIS application, is properly mentioned, along with the research team responsible for its creation, at the end of the story map.

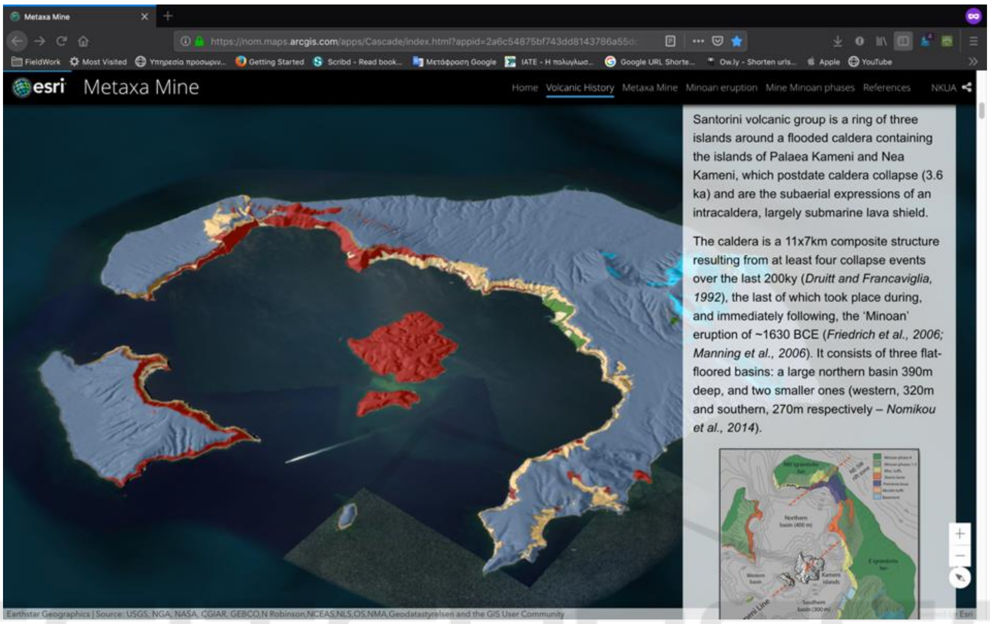

Figure 4: Screenshot showing in 3D the spatial distribution of geological formations across Santorini volcanic complex. Web scene is accompanied by narrative text and multimedia content in order to explain the volcanic history of the islands.

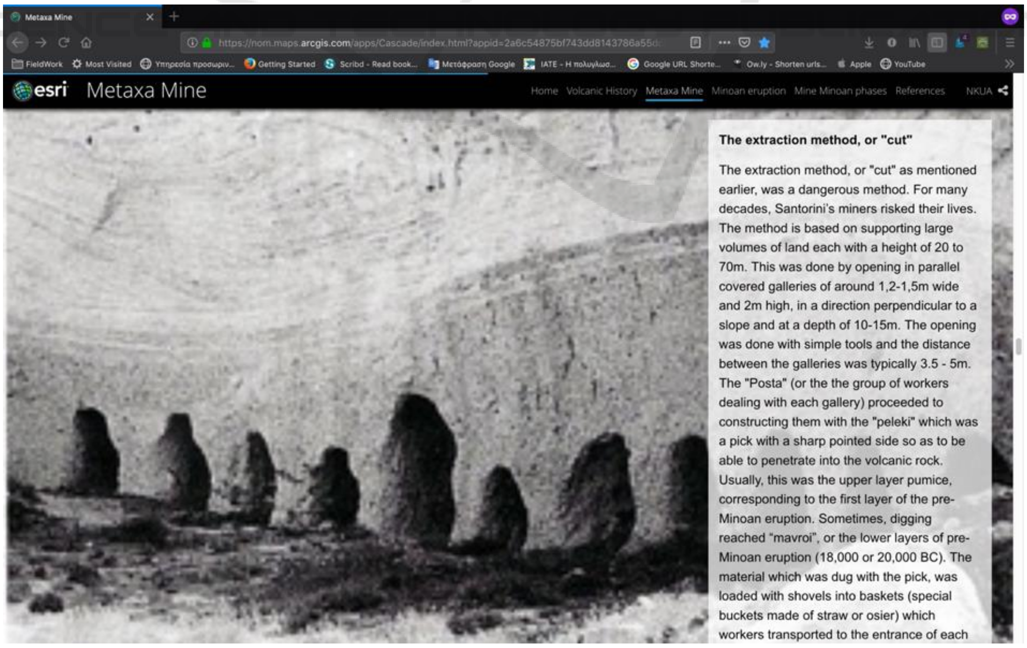

Figure 5: Screenshot showing a representative photo of the covered galleries while narrative text explains the extraction method, or “cut”.

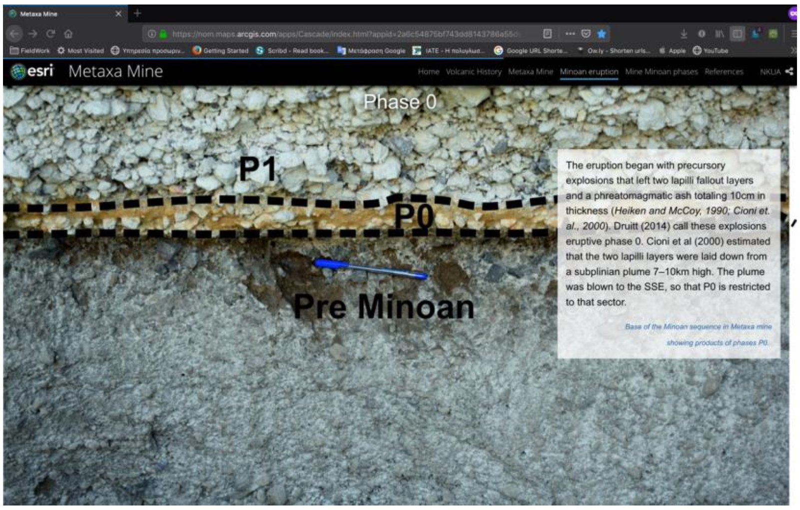

Figure 6: Screenshot showing a representative photo of the Pre Minoan-landscape and the distinguished phases: P0 and P1 while narrative text gives further information.

5 DISCUSSION

The use of GIS technology has a great impact on web-based visual presentations. A flexible and interactive application has been created in order to strengthen the use of story maps in disseminating scientific information concerning geodiversity. Two totally different subjects were presented, using just one application: the volcanic history of LBA eruption and the exploitation history of Metaxa Mine, allowing users to understand the importance of the mine as geological and historical site while using and integrating modern technology for data.

The created story map is based on webmaps and scenes while it is enriched with the integration of different data like images, narrative texts and multimedia that help the end users to engage in scientific knowledge. Users can navigate easily through the content, either using the predefined "narration path" or swiping up and down or even through the predefined bookmarks. In addition, the use of ASfM technique allowed the acquisition of a very high-detailed 3D model of the western part of the mine (pixel size 8 mm), providing better definition of the different volcanic layers even in inaccessible outcrops like vertical cliffs or landslides and addition of representative snapshots in the app.

This new geographical approach, having open source code, provides many possibilities, as it is easy to be used both from the developer and from the end user and allows integration of new functions, combining many scientific fields. Furthermore, it is responsive, and it can be also as interactive as the developer wishes. In the presented application, having as main aim to present a fundamental geological site using modern technologies and techniques the already provided functions have been used. Further improvement of the available functions can be made, giving the possibility of interactive exploration of 3D models.

Story maps are used the last 3-4 years and have already been adapted for many different scientific disciplines, as well as for touristic purposes, being useful to both academics and non-academics. Their value, among others, is also recognized by the efforts made by the scientific community which developed similar platforms with reduced capabilities compared to the one described in this paper, but with free access (e.g. https://goo.gl/6LB1Qe, https://goo.gl/bHwZJE).

The developed application can be an ideal way for presenting the geological, geomorphological and historical contents of other places, especially those that can be characterized as geotopes or protected areas (e.g. Natura 2000 areas, Antoniou et al., 2018). Such examples have already been created worldwide (e.g. https://goo.gl/g2p89P). Finally, as Metaxa Mine portrays a possible geotope, this application provides a quick access of the available information to a wide audience, developing the interest and possibly motivating the public to learn more (or even to visit) about the display area.

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REFERENCES

Antoniou, V., Ragia, L., Nomikou, P., Bardouli, P., Lampridou, D., Ioannou, T., Kalisperakis, I. and Stentoumis, C. (2018). Creating a Story Map Using Geographic Information Systems to Explore Geomorphology and History of Methana Peninsula. *ISPRS International Journal of Geo-Information*, 7(12), p.484.

Bruins, H., MacGillivray, J., Synolakis, C., Benjamini, C., Keller, J., Kisch, H., Klügel, A. and van der Plicht, J. (2008). Geoarchaeological tsunami deposits at Palaikastro (Crete) and the Late Minoan IA eruption of Santorini. *Journal of Archaeological Science*, 35(1), pp.191-212.

Burns, J. and Delparte, D. (2017). Comparison of commercial structure-from-motion photogrammety software used for underwater three-dimensional modeling of coral reef environments. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W3, pp.127-131.

Cook, K. (2017). An evaluation of the effectiveness of low-cost UAVs and structure from motion for geomorphic change detection. *Geomorphology*, 278, pp.195-208.

Druitt, T.H., Edwards L., Mellors R.M., Pyle D.M, Sparks R.S.J., Lanphere M., Davies M., and Barreirio, B. (1999). Santorini volcano. *Geological Society Memoir. Journal Geological Society London*, 19, p.165.

Druitt, T. (2014). New insights into the initiation and venting of the Bronze-Age eruption of Santorini (Greece), from component analysis. *Bulletin of Volcanology*, 76(2), pp.794-8141.

Esposito, G., Mastrorocco, G., Salvini, R., Oliveti, M. and Starita, P. (2017). Application of UAV photogrammetry for the multi-temporal estimation of surface extent and volumetric excavation in the Sa Pigada Bianca open-pit mine, Sardinia, Italy. *Environmental Earth Sciences*, 76(3), p.103.

Heiken, G. and McCoy, F. (1984). Caldera development during the Minoan eruption, Thira, Cyclades, Greece. *Journal of Geophysical Research*, 89(B10), p.8441.

Heiken, G. and McCoy, F. (1990). *Precursory activity to the Minoan eruption, Thera, Greece*. London: Hardy DA (ed.) Thera and the AegeanWorld III, 2, Thera Foundation, pp.13–18.

Janicki, J., Narula, N., Ziegler, M., Guénard, B. and Economo, E. (2016). Visualizing and interacting with large-volume biodiversity data using client–server web-mapping applications: The design and implementation of antmaps.org. *Ecological Informatics*, 32, pp.185-193.

Johnston, E., Sparks, R., Phillips, J. and Carey, S. (2014). Revised estimates for the volume of the Late Bronze Age Minoan eruption, Santorini, Greece. *Journal of the Geological Society*, 171(4), pp.583-590.

Manning, S.W., Ramsey, C.B., Kutschera, W., Higham, T., Kromer, B., Steier, P., and Wild, E.M. (2006). Chronology for the Aegean Late Bronze Age 1700-1400 BC. *Science*, 312(5773), pp.565-569.

McClelland, E. and Thomas, R. (1990). *A palaeomagnetic study of Minoan age tephra from Thera*. London: Hardy DA (ed.) Thera and the AegeanWorld III, 2, Thera Foundation, pp.129–138.

McCoy, F. and Heiken, G. (2000). Tsunami generated by the Late Bronze Age eruption of Thera (Santorini), Greece. *Pure and Applied Geophysics*, 157(6-8), pp.1227-1256.

Nomikou, P., Druitt, T., Hübscher, C., Mather, T., Paulatto, M., Kalnins, L., Kelfoun, K., Papanikolaou, D., Bejelou, K., Lampridou, D., Pyle, D., Carey, S., Watts, A., Weiß, B. and Parks, M. (2016). Post-eruptive flooding of Santorini caldera and implications for tsunami generation. *Nature Communications*, 7(1), p.13332.

Pyle, D.M. (1997). The global impact of the Minoan eruption of Santorini, Greece. *Environmental Geology*, 30(1-2), pp.59-61.

Reck, H. (1936). *Santorini: Der Werdegang eines Inselvulkans und sein Ausbruch, 1925–1928*. Reinser, Berlin.

Smith, M., Carrivick, J. and Quincey, D. (2016). Structure from motion photogrammetry in physical geography. *Progress in Physical Geography: Earth and Environment*, 40(2), pp.247-275.

Sigurdsson, H., Carey, S. and Devine, J. (1990). *Assessment of mass, dynamics and environmental effects of the Minoan eruption of Santorini volcano*. London: Hardy DA (ed.) Thera and the AegeanWorld III, 2, Thera Foundation, pp.100–112.

Sigurdsson, H., Carey, S., Alexandri, M., Vougioukalakis, G., Croff, K., Roman, C., Sakellariou, D., Anagnostou, C., Rousakis, G., Ioakim, C., Goguo, A., Ballas, D., Misaridis, T. and Nomikou, P. (2006). Marine investigations of Greece's Santorini Volcanic Field. *Eos, Transactions American Geophysical Union*, 87(34), p.337.

Sparks, R.S.J. and Wilson, C.J.N. (1990). *The Minoan deposits: A review of their characteristics and interpretation*. London: Hardy DA (ed.) Thera and the AegeanWorld III, 2, Thera Foundation, pp. 89–99.

Tsoutrelis C. and Livadaros, R. (1995). Method of exploiting the Thiraean land at Santorini Mines. *Pyrophorus*, NTUA, 17, pp.64-69.

Turner, D., Lucieer, A. and Watson, C. (2012). An Automated Technique for Generating Georectified Mosaics from Ultra-High Resolution Unmanned Aerial Vehicle (UAV) Imagery, Based on Structure from Motion (SfM) Point Clouds. *Remote Sensing*, 4(5), pp.1392-1410.

Wright, D.J., Verrill, A., Artz, M. and Deming, R. (2014). Story maps as an effective social medium for data synthesis, communication, and dissemination. San Francisco CA: Proceedings of the Fall Meeting 2014.