A Topographic Analysis of The Aspra Marmara Quarries– Aerial Imaging and Photogrammetry use in the Study of Marble Quarries in Antiquity

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Section 1: Introduction and Background

1a. Archeological significance

Attica, Greece is a region rich in geological formations and history. Civilizations from the Bronze, Roman, and Classical time periods left behind a vast array of sculptures, structures and relics in demographically active areas. These lasting fragments of ancient Greece open sight into archeological, sociological, and geological significance of ancient societies and their corresponding civic development. The study of marble typology and ancient marble quarrying assists the understanding of these artifacts and the cultural significance surrounding them. The understanding of the topographic make up of ancient marble quarries paired with the current database on known marble types can provide sufficient context in furthering archeological studies. Some of this possible context includes mapping ancient mining patterns, volume calculations, progression of activity involving relics and artifacts, enforcing cultural significance, and identifying matching dislocated fragments.

The current scope of dating at matching worked marble is a combination of stable isotope analysis (see section 1b), epigraphy, spectroscopy and geographical analysis. Although useful in the context of identifying and analyzing smaller artifacts, monuments like the Parthenon in Athens, Greece are harder to identify due to inter-quarry variation in marble types and past occurrences affecting the integrity of the site. However, the use of these tactics combined with additional modes of data collection could begin to reveal previously unknown information and interpretation of geographic clues to these larger ancient sites. Unmanned aerial photography can assist in generating 3D models that can be used to analyze larger sites which can provide a to-scaled perspective as well as a volumetric analysis of the terrain. An Unmanned Aerial System (UAS), otherwise commonly known as a drone, can cost-effectively contribute to the study of archeology– more specifically, worked marble and quarrying in antiquity.

This analysis seeks to both corroborate the current geographic knowledge of Mt. Pentelikon– Attica, Greece— and provide grounds for the furthering of UAS and 3D modeling software use in the sciences and academia.

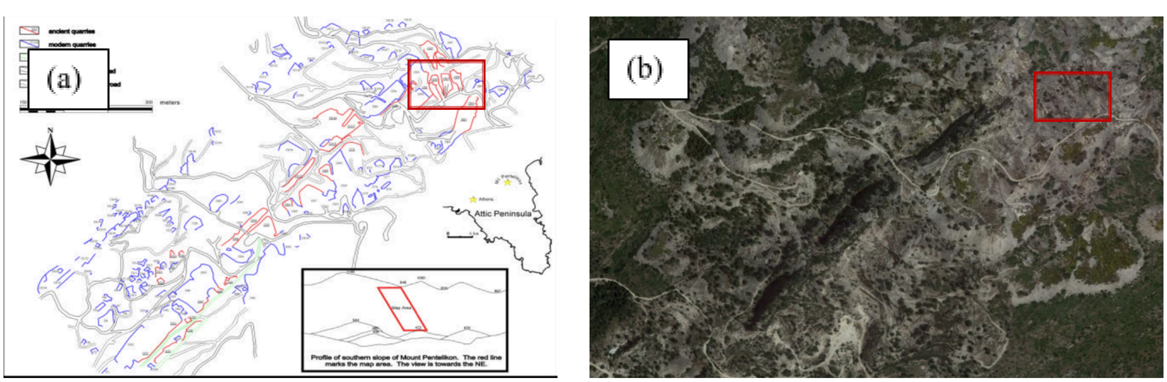
1b. Stable Isotopes

The process of analyzing stable isotopes can be used to distinguish origination of material used in the creation of sites and relics. Specifically in the study on ancient Greece the discrimination between white marble types provides an extensive view into the history behind artifacts. Before the development of the use of stable isotopes as the main mode of differentiation between Aegean and Mediterranean white marbles, the standard classification was mainly based on aesthetics; a system created by German geologist G. R. Lepsius in 1890. (Lepsius 1890) Using a combination of microscopic and petrographic survey, Lepsius classified marble by their differing color and grain size, these differentiations were often considered to be regionally consistent which ultimately led the different categories to be named after regions; Pentellic, Naxian and Hymettian are all classifications of Lepsius. (Lepsius 1890, Pike 2000) This mode of classification was first criticized by petrologist H. S. Washington in 1898, –who challenged the usefulness of these broad classifications– and later in 1953 by the American School of Archeology by Herz, N. and W. K. Pritchett. (Herz, N. and W. K. Pritchett. 1953, Pike 2000, Washington 1898) However, in 1972 Valerie and Harmon Craig applied isotopic ratio analysis to white marble and began the database of Aegean and Mediterranean marble types, which proved to become the next standard of marble classification. (Craig, H. and Craig, V. 1972) In short, different marble types can be distinguished by discriminations in the stable isotope ratio between oxygen and carbon, the stable isotopic ratio in a marble sample is caused by the metamorphic process, making a vast array of compositely unique marble types among any given location. This is the source of inter-quarry variation, which in some cases marble in a given location in a quarry can be compositionally unique from marble as close as 10 meters away.

The original data set created by the Craigs was far from extensive, but it was later developed by additional geologists including Norman Herz from 1985-1988, K. J. Matthews in 1992, and P. Lapuente in 1995. (Herz 1985a, 1985b, 1987, 1988, Matthews 1992, Lapuente 1995, Pike 2000) Relevant contributions to the data set have made it possible to match artifacts made from recorded marble types, a process highly contributive to archeology as a science. An example of this contribution is in the analysis ran on a Roman marble statue that currently resides in the Yale University Art Gallery. The statue, originally auctioned off by Sotheby's of Sussex in 1987, developed a scope of interest with Yale University in 2007. As part of Yale's analysis of this relic, they elected one of Norman Herz former students, Dr. Scott Pike, to run a stable isotopic analysis on the statue. Working in the Stable Isotope Laboratory of the University of Alabama, Pike was able to run an assessment on three samples of the statue. The results showed that the statue most likely came from the Choradaki quarries on the Aegean Island of Paros, and that the head and body were likely carved from the same block. Although not entirely definitive answers, the data set was able to provide relevant context for Yale to continue their exploration into the origination and history of the Roman statue. (Brody, Snow u.d)

1c. History of Mt. Pendelikon

Mt. Pentelikon lies on the face of the Hellenic Subduction zone, where the African Plate slides under and the Aegean Sea Plate. This is the cause of the mountainous terrain and marble quantity dispersed across Attica. Mt. Pentelikon is rich in various types of marble and has been home to mass exploitation of these resources. The first evidence of organized quarrying of Mt. Pentelikon occurs at the beginning of the 5th Century, most notably 489 BC with the large-scale excavation for the construction of the "old" Parthenon. (Pike 2000) Pentelic marble was most often desired for its fine grain size and bright white completion, prime for statuary desires of the time. Mt. Pentelikon was exploited by both the Romans and Greeks in its heyday and was finally retired from quarrying in 1974. Although Pentelic marble was widely used and exploited for many years, and the remains of this exploitation are still vivid among Athens and Athenian culture, the Parthenon stands as Athens' supreme connection to Mt. Pentelikon. Theories have emerged attempting to decipher the origin of the marble used to construct the Parthenon, including lower pits for convenience, or mid-slope pits based on the sheer size of excavation. However, results from samples taken from the Elgin Parthenon sculptures –that are currently located at the British Museum- in 1992 suggest that the relics originate from the uppermost ancient quarries on the south slope of Mt. Pentelikon; these samples are recorded in the 1992 additions to the stable isotope data set. (Matthew 1992, Pike 2000) Later samples taken from the pediment and entablature examined by Dr. Scott Pike revealed the specific quarries some relics from The Parthenon originated from. The quarries are colloquially known as *Aspra Marmara*, which are the quarries central to this analysis and their topographic relevance will be addressed.



(Figure 1.1) (a) Hand drawn map made by Dr. Scott Pike labeling all quarries on the southern slope of Mt. Pentelikon, quarries π88, π89 and π90 marked within the red box. (Pike 2000) (b) Google Earth Image of the southern slope of Mt. Pentelikon, quarries π88, π89 and π90 marked within the red box. (2022)

Past efforts to map the quarries of Mt. Pentelikon in the past have mainly consisted of hand drawn images or satellite mapping on sites like Google Earth. For the basis of this research a map published by Dr. Scott Pike (2000) provides a standard labeling system of all Pentelic quarries. (See figure 1.1) On the basis of this standard labeling system the quarries that will be evaluated in this paper are officially known as π88, π89 and π90. Quarry π88 is the largest of the three quarries, with the highest walls reaching up to 40 meters in height; additionally, the floor of this quarry is littered with debris which suggest that the actual bottom of the quarry is several meters below the current surface level. Quarry π89, 35 meters in depth, has evidence of ancient quarrying with obvious substantial modern work. The quarry has large blocks of debris making the northern end of the quarry hard to access, debris is considered to be a mix of both modern and ancient fragments. The last quarry, π90, is the smallest of the three observed for this study, reaching heights of twenty meters. Although the quarry is small in comparison to the other quarries referenced, the pit is rich with ancient remnants and displays the aesthetic differences in ancient and modern worked marble. (See Figure 1.2c) Quarries π88, π89, and π90 collectively are known as Aspra Marmara, these three quarries are specifically known to be ancient, and have not had modern excavation activity, unlike surrounding quarries. (Pike 2000)

1d. Tactical and Relevant use of Photogrammetry and Aerial imaging

Unmanned aerial systems first entered the realm of tactical use in the 19th century, originally common for military services, the UAS has slowly integrated its way into daily use, scientific research and academia, opening new territory to study and observe from a new perspective. To date the UAS has been applied to fields such as traffic surveillance, natural disaster response, meteorology, media and –in the case of this analysis— archeological research. (Colomina et al. 2008, Remondino et al. 2011) The development of the UAS has allowed for the progression of payload adaptations including high-precision cameras, LiDAR sensors, multi-spectral sensors, GPS units, and other advancements. These advancements have developed the information collection and research that is possible with UAS. (Colomina et al. 2008)

	(Figure 1.2a) North wall of π88 reaching 40 meters in height.
	(Figure 1.2b) Vegetation and debris pile of π89.
	(Figure 1.2c) Side by side distinction between modern and ancient marble exposure.

Primary to the recent development of the UAS and its payload, the origination of the UAV (Unmanned Aerial Vehicle) in replacement of manned aerial photography was a highly cost-effective development in aerial photography. (Colomina et al. 2008) The use of the UAS in aerial research lacks the cost of training pilots, paying said pilots, fuel, and large aircrafts. Additionally, the process of obtaining an image set with a UAS in comparison to a manned aerial system is a substantially shorter and less complex operation. Considering these two advantages already makes the use of the UAS a cost-effective and accessible research tactic in contrast to the opposing previous options. Additionally, some available assistance to UAS usage such as predefined acquisition points –a code-based positioning system—and automated flight paths have drastically improved the quality of collected data sets. (Colomina et al. 2008, Remondino et al. 2011)

The data collected from the use of a UAS can be used and manipulated to further the knowledge of the research in question. One main use of data collected from aerial imaging is to further make an orthoimage or a 3D model. Current software paired with geo-location can produce incredibly accurate and to-scale manipulable models that can assist in many academic and scientific settings. Some of these software programs include Pix4D mapper, ArcGIS and AutoCAD. Depending on the software used to generate an orthoimage, it is possible to take inter-model measurements post processing of the data. Pix4D Mapper allows not only for standard measurements but also the volumetric analysis of a model that has been geo-located.

In the field of archeology, the use of the UAS and 3D modeling has emerged as a reliable way to accurately observe a site as well as document elements in their current conditions. An excavation site in Pava, Italy has used aerial imaging to document progress and analyze new findings from the excavation. A flight is conducted once a year at the end of a designated period to track not only the visual progress but also record the excavated amount from the concluding season and record mass of the exposed site. These images provide baseline information of the functionality of the excavation and can assist in not only the research of the project but also the publicity. (Remondino et al. 2011)

Section 2: Methods

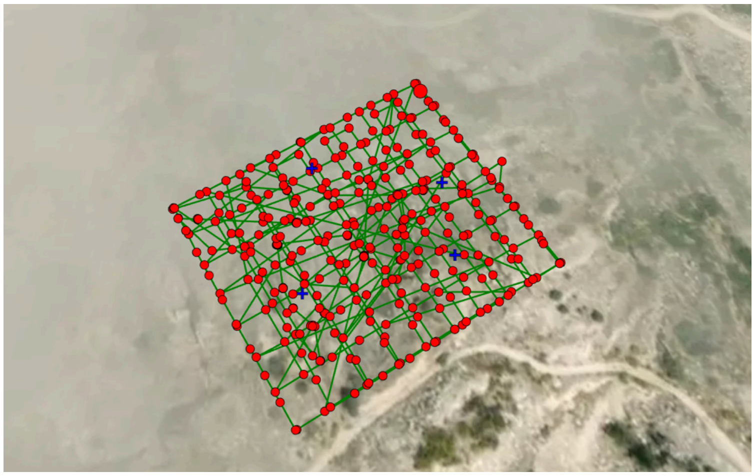
2a. The UAS and Imaging Equipment

This research was conducted on the premise of a goal two-fold; first, to generate a 3D model of quarries π88, π89, and π90, secondary to the initial creation of the model is the volumetric analysis of the same quarries. Following the primary inquiry into these quarries, the topography was searched for evidence of ancient quarrying and aesthetic differentiation between recently worked marble faces and ancient surfaces. To strive to achieve the initial goals to the fullest existent, a precise culmination of equipment was chosen that was deemed best suitable for analyzing Mt. Pentelikon. The UAS employed on this project was a Matrice 200vl, a larger drone weighing in at approximately 4.5 kilograms. The Matrice uses a quad-copter system and a vertical take-off application. Max flight times can reach up to thirty-eight minutes without payload attachments and minimal hindering conditions. With a DJI 3515 motor, the Matrice 200v1 can function in temperatures ranging from -20° to 45° C and wind speeds up to 12m/s making this UAS optimal for flying pentelic quarries if conditions remain moderate. The Matrice 200v1 is equipped with a downward gimbal mount with a max payload weight of 1.61kg. During flight, the Matrice was equipped with a DJI X5 payload to improve the overall quality of the images, and subsequently generating a more detailed model.

<u>2b. Field Methodology</u>

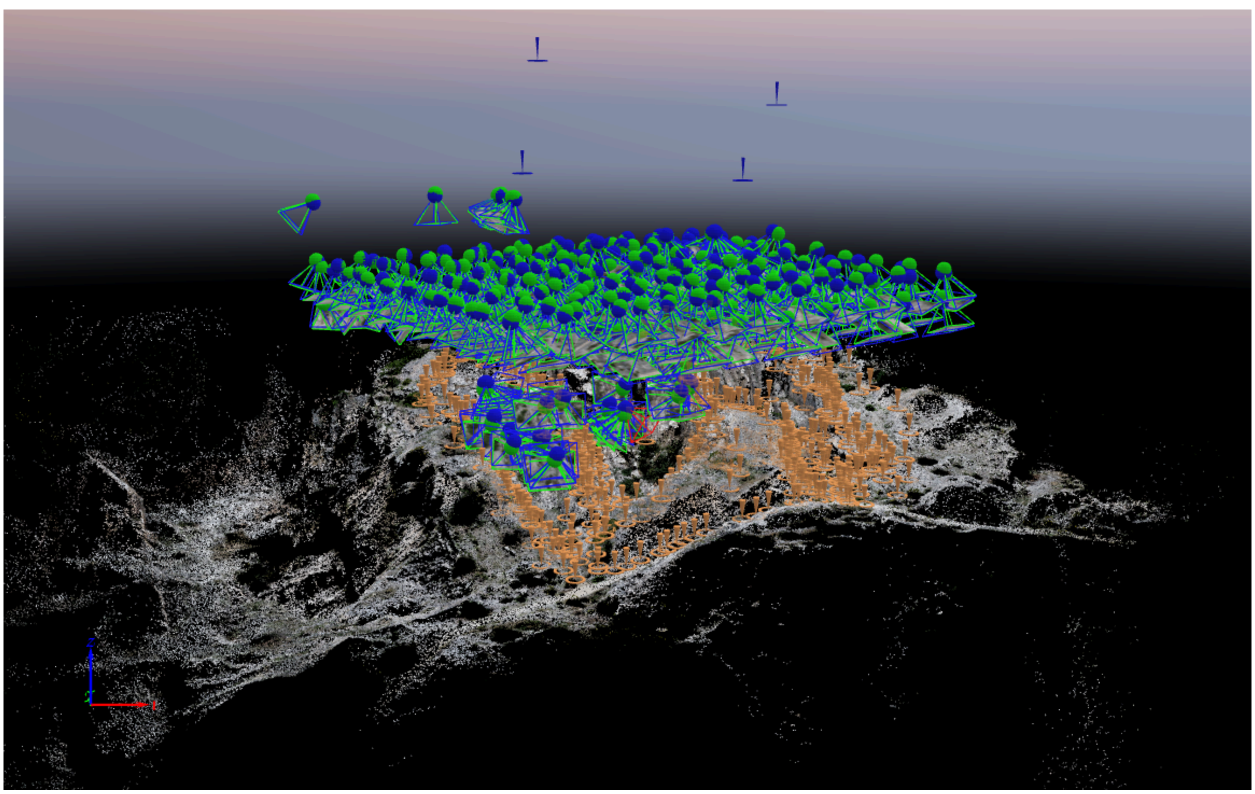
Based on the nature of the level of detail desired for this model specifically, in partnership with the aerial images taken with the Matrice, conducting terrestrial imaging was applicable in this situation. Using a Panasonic Lumix DC-ZS200 Digital Camera. approximately three-hundred images were taken from the ground within the quarry. The images were taken with automatic IOS, automatic shutter speed, Aperture 11 and automatic white balance with dual formatting which processed the images in both raw and JPEG. The JPEG were used for the generation of the orthoimage, and the RAW were used for manual analysis of images. The images collected were taken at approximately 15-30 meters away from the subject, every face section identified in the terrestrial imaging had three images taken of them from high, medium and low angles. Both tactics were in effort to advance the precision and detail of the 3D model.

At the time of flight, it was 26.1 degrees Celsius and slightly overcast with a wind speed of 11mph –which was mainly blocked by the mountain face; these conditions made for optimal flying with minimal interruptions. The quarries were flown with an automated flight path set to safety mode, double grid flight path, 75% overlap, and a height of 55 meters. Additionally, manual photos were taken after the initial automated flights in areas with vertical decline to ensure minimal gapping in the model. Flight operations for these quarries were concluded in one working day.



(Figure 2.1) Aerial prospective map of all geo-located images taken with the Matrice 200vl on quarries as π88, π89 and π90, Mt. Pentelikon

In the field, 4 GCPs –ground control points—were placed throughout the quarries. These points assist in the development of the 3D model as well as provide code-based reference points to assist the geo-location of the orthoimage. Using a GNSS–Global navigation satellite system– coordinates were recorded into a data set that were later uploaded into the Pix4D software following the initial processing stage.

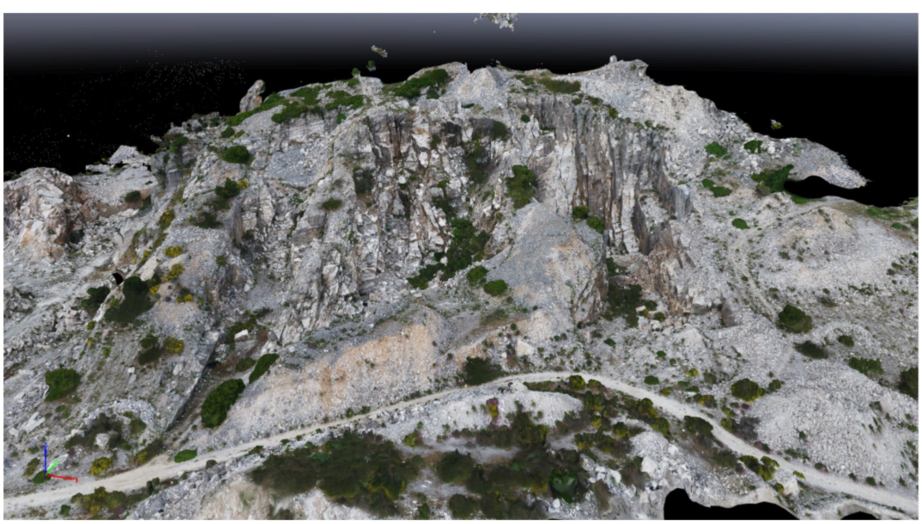


Data; Section 3

3a. Data Collection

The tactics employed in the field, including the double-grid flight path, the use of GNSS and the combination of aerial and terrestrial documentation produced nearly four hundred geolocated images, three hundred non-geolocated images, and four precise coordinate points around the quarry which corresponded with accompanying ground control points. All aerial documentation was taken within a singular project to allow for the smoothest possible transfer of data into the Pix4D software. The recorded coordinate points were imported into the software as a Microsoft Excel file after initial processing. Non-geolocated images were processed at the same time as the images taken with the Matrice to allow for optimal exploitation of the data in the images. By processing these images together, Pix4D was able to generate a to-scale orthoimage of the three quarries and match the terrestrial images to pixels found in the aerial images. Including the terrestrial images in this phase of data processing generates a more detailed model of the quarry walls and floor while still maintaining the accurate scale of the model from the geolocation.

The data collection was conducted under what can only be considered as optimal considering the unpredictability of outdoor conditions. The minimal interference, lack of harsh lighting, surplus battery power, and all other equipment in assistance to this project generated a precise and accurately scaled model. The extent of these quarries is quite vast, and the nearly seven hundred images collected for this model captured all elements of the quarry features and scale absent of any major warps or holes in the model.



(Figure 3.1) Entirety of the 3D model generated by Pix4D containing quarries π 88, π89 and π90.

The following images display the orthoimage perspective generated in Pix4D, on the left, and the collected terrestrial images, on the right. The terrestrial images have been altered from the original with lens correction to allow for the most comparable perspective to the true dimensions of the quarries.

(Figure 3.2) Aspra Marmara π88

(Figure 3.3) Aspra Marmara π90 (slightly different camera angle)

Interpretation; Section 4

<u>4a. Field Observations</u>

The success of this research revealed not only further proof of the efficiency of UAS use in the sciences and academia, but also provided previously unknown information of the Aspra Marmara quarries on Mt. Pentalikon. Previous to this research, public information about these quarries included but were not specifically limited to the general knowledge of the functionality of the mountain as a quarry–implying the use of π88, π89 and π90– and hand drawn map of all pentelikon quarries from Scott Pike's deposition, as seen in figure 1.1. (Pike 2000) In concluding this research, data regarding textural patterns from ancient marble excavation, vegetation, terrain, dimensions and volumetric analysis, and modern erosion has all been documented.

Images collected from the field reveal different phases and development of the Aspra Marmara quarries. Lichen deposits on the marble faces reveal a brief reference for dating any changes in the quarry; as seen in figure 1.2c, a section of the marble face has a distinct lack of lichen deposits–indicating that this section has more recently been exposed than the surrounding surface. Additionally, throughout these quarries there are specific topographic indicators that imply ancient excavation occurring in this location.

Figure 4.1 "Wedge holes" found in marble near the top of π89

This image includes a close up perspective of "wedge holes," these are known to be some of the best evidence of ancient greek excavation tactics.

Figure 4.2 Markings from modern tools. (Image not taken within the Aspra Marmara Quarries)

Additionally the Greeks employed the use of crack expansion where wood would be jammed between cracks and then soaked in water to expand the breakage; areas within the quarries were identified where activity of this nature seemed probable, but no definitive conclusions were recorded. These markings are highly distinguishable to their modern day counterparts. As seen in Figure 3.5.

Surrounding quarries within close proximity to the Aspra Marmara quarries contained identifiable Roman activity. These markings were identified by Dr. Scott Pike upon arrival to the quarries due to the distinct etching tactics that share no resemblance to the Greek wedge holes. Differentiation and identification between these quarrying tactics could allude to an expansion of knowledge about Mt. Pentelicon and Marble in antiquity.

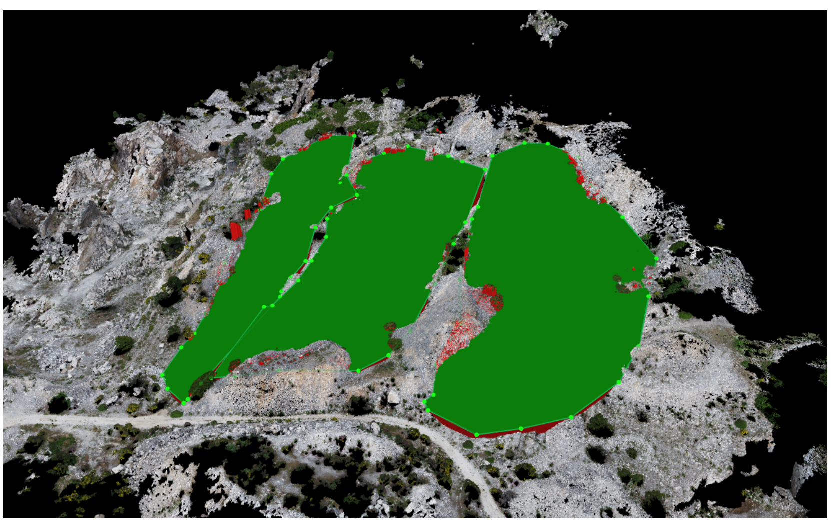
<u>4b. The Orthoimage</u>

The data collected at Aspra Marma was extensive in means of observations and obtaining general knowledge about the topography and state of the quarries that likely supplied the marble for the parthenon. However, the main goal of this land survey was to collect aerial photographs and geolocated images to generate a malleable 3D model of π88, π89, and π90. This model will serve as a virtual perspective that will offer volumetric analysis, terrain perspective, and access to different aerial perspectives that are otherwise unavailable with other technology and in person observation. This accessibility allows us to know dimensions, volume, and elevation within the quarries at the disposal of a few moments. The orthoimage currently exists at a p4d file developed in June of 2022; the following images are screenshots of the different quarries mapped during the allotted survey time.

Figure 4.3; 3D model of π88

	Figure 4.4; 3D model of π89
	Figure 4.5; 3D model of π90

4c. Volumetric Analysis



Upon completion of the 3D model of Aspra Marmara, a volume analysis was conducted. This analysis was run entirely within the functionality of pix4D software.

Figure 4.6; Aerial perspective of entire orthoimage during the volumetric analysis process.

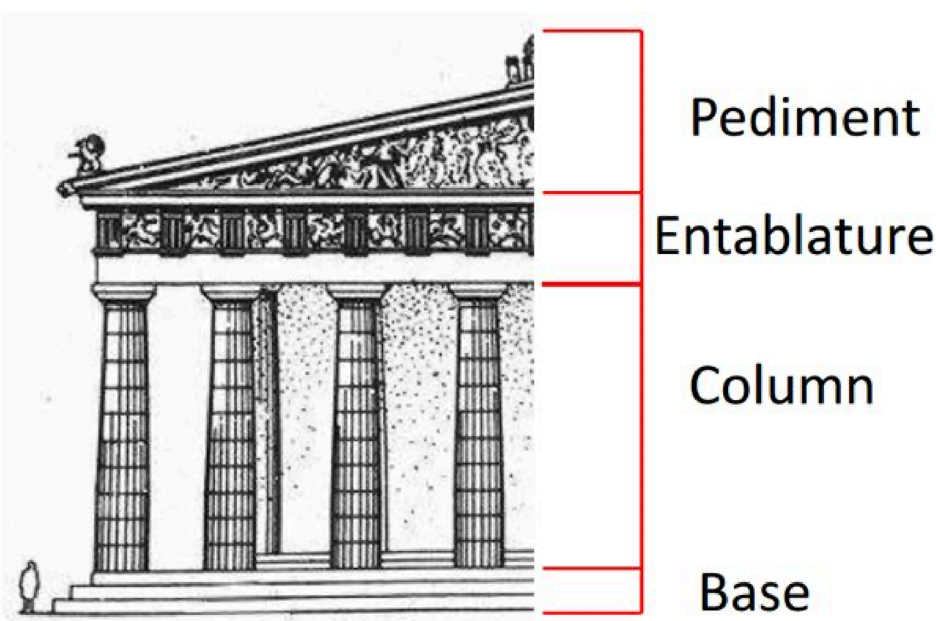
The goal of computing the volume of these quarries is two fold; first, to further the scope of the use of UASs and orthoimage software in the sciences and academia. However, the primary reason for this analysis was to compare the volume of ancient excavated marble from the Aspra Marmara quarries to the volume of the marble used to construct The Parthenon.

Findings from this analysis found promising results. The first– and largest–quarry, π88, had a volume of 36,306.91 cubic meters, with an error margin of ±58.21 cubic meters, 0.16% of the volume.

Secondly, π89 had a volume of 30707.46 cubic meters, with an error margin of ±51.24 cubic meters, 0.167% of the volume. Lastly, π90–the smallest quarry–had a volume of 11107.61 cubic meters, and had the highest error margin at ±33.97 cubic meters, 0.26% of the volume. Although still a small error margin, the increase in comparison to π89 and π88 can be summed up to the consideration of the condition of the quarry. π90 had a significant amount of floor debris and what appeared to be a landslide and the northern side of the quarry. displacing a significant amount of material causing uneven textures and small holes which are hard for pix4D to compute. Considering the small error margins, we can conclude that the amount of Marble excavated from Aspra Marmara was approximately 78,121.98 cubic meters, 233,456.99 US tons

4d. Evidence Connecting Aspra Marmara and The Parthenon.

Although mostly destroyed in the 1687 Siege of the Acropolis, The Parthenon still stands as Greece's most notable relic of ancient times. As mentioned before, pieces from The Parthenon were tested using stable isotope analysis by Dr. Scott Pike. The samples collected were sourced from the east pediment and from the North-East Entablature; these samples verify that the figures along these pediments originate from the Aspra Marma quarries. The amount of marble ejected from the quarries is more than enough to supply all fifty of the original pediment statues.



Considering the largest dimensions of each statue; the maximum height stands at 3.41 meters, 2.4 meters in maximum length, and 1.1 meters in maximum width. Consider that all fifty statues have a combination of the maximum lengths, which even for the largest statue is a gross over estimate, let alone the smaller statues, the carving block ejected from the quarry for any given statue would be 9.002 cubic meters in size, meaning that if all fifty statues exhausted this same amount of marble, it would take 450.12 cubic meters of marble to complete all statues from the east and west pediments, stressing the fact that this is a gross overestimate of the actual amount of marble used in the creation of these artifacts. This estimate accounts for only 0.576% of the total amount of marble removed from Aspra Marmara. Considering the second sample, taken from the entablature; this sample verifies that not only the statues but also a considerable amount of structure of The Parthenon also was supplied by Aspra Marmara. Unfortunately taking samples from every corner and column of The Parthenon is not applicable, so the origination of every piece of The Parthenon may not ever be clear. However, considering the fact that two separate samples matched the marble from Aspra Marmara, it is safe to assume that more Pentelic Marble from Aspra Marble can be found among the immense stature of the site.

Suppose that all the marble sourced from Aspra Marmara was intended for the Acropolis structures, would these quarries have supplied enough marble for the construction of the entire Parthenon or would there have had to have been a nearby additional source? The known dimensions of The Parthenon are approximately 69.51 meters in length, 30.88 meters in width, and 18.162 meters in height. (Sakoulas, T.) Because calculating the approximate ejected mass for a block is a non applicable option at this moment. Consider The Parthenon to be made from one solid building block. This is far from the reality of the construction of this temple, but considering the space within The Parthenon, it may serve as somewhat of a reference for that may have been excavated for the entirety of the project. For the purpose of logistics, one meter has been added to each dimension. This calculation projects that a building block of this size would be 43073.47 cubic meters, accounting for only 55.14% of the total extracted amount recorded from Aspra Marmra. Taking into account the nearly 45% of additional marble left behind for use, it seems plausible that Aspra Marma could have been the primary or even sole provider of marble for The Parthenon.

Section 5: Conclusion

1e. Conclusion

This analysis has laid out reverent collected information that validated the use of UAS and aerial imaging in Archeology, or more specifically marble excavation for temples and structures in Greek antiquity. The data collected generated a precise 3D model of the Aspra Marmara quarries which provided volume analysis and a readily available aerial perspective for future work on the upper slope of Mt. Pentelikon. A continuation of this research could benefit greatly from LiDar equipment which would produce a more accurate and precise model better fit for volume calculations and topographic survey. This analysis focused on using volume to supply grounds to connect Aspra Marmara and The Parthenon more directly. However, future research using these systems can assist in the modeling of structures, quarries, or any sort of site. This information can be utilized to document a site, provide images for museums or other modes of academia, or assist in respiration and preservation efforts. The overall success of this project along with exploration into the relevance of UAS research, has found useful evidence about the origin of The Parthenon, confirming the potential this field has for future research in Archaeology and other fields.

References

Remondino, Fabio & Barazzetti, Luigi & Nex, Francesco & Scaioni, Marco & Sarazzi, D. (2011). UAV photogrammetry for mapping and 3D modeling-Current status and future perspectives. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. XXXVIII-1/C22. 10.5194/isprsarchives-XXXVIII-1-C22-25-2011.

Craig, H. and V. Craig. 1972. Greek marbles: determination of provenance by isotopic analysis. Science 176:401-403.

Herz, N. and W. K. Pritchett. 1953. Marble in Attic epigraphy. American Journal of Archaeology 57:71-83.

Lepsius, G. R. 1893. Geologie von Attica.

Herz, N. 1985a. Isotopic analysis of marble. In Archaeological Geology, edited by Rapp, G. Jr. and J. A. Gifford (New Haven: Yale University Press), 331- 351.

Herz, N. 1985b. Stable isotopic signatures applied to problems of classical Greek marble. National Geographic Society Research Reports 20:353-363.

19 Herz, N. 1987. Carbon and oxygen isotopic ratios: classical Greek and Roman marble. Archaeometry 29:35-43.

Herz, N. 1988. The oxygen and carbon isotopic data base for classical marble. In Classical Marble: Geochemistry, Technology and Trade, edited by Herz, N. and M. Waelkens ASI Series E. (Dordrecht-Boston-London: NATO), 305-314.

Matthews, K. J., L Moens, S. Walker, M. Waelkens , and P. de Paepe. 1992. The re-evaluation of stable isotope data for Pentelic marble. In Ancient Stones: Quarry, Trade and Provenance, edited by Waelkens, M., N. Herz, and L Moens (Lueven: Leuven University Press), 203-112.

Washington, H. S. 1898. The identification of the marbles used in Greek sculpture. American Journal of Archaeology 2:1-18.

Lapuente, P. 1995. Mineralogical, petrological and geochemical characterization of white marble from Hispania. In The Study of Marble and Other Stones in Antiquity, edited by Maniatis, Y., N. Herz, and Y. Basiakos (London: Archetype), 151-160

Brody, L. R and Snow, C. E. u.d A Mystery in Marble:
Examining a Portrait Statue through Science and Art, Yale University, 31-42

Colomina, Ismael & Blázquez, Marta & Molina, Pere & Parés Calaf, M.Eulàlia & Wis, Mariano. (2008). Towards a new paradigm for high-resolution low-cost photogrammetry and remote sensing. 37.

Lynn Byrne. (2019, August 16). *Design dictionary: Entablature*. Lynn Byrne. Retrieved September 13, 2022, from https://www.lynn-byrne.com/posts/design-dictionary-entablature

Sakoulas, T. (n.d.). *The parthenon*. Parthenon. Retrieved September 13, 2022, from https://ancient-greece.org/architecture/parthenon2.html

Pike, S. H. (2000) Archaeological Geology and Geochemistry of Pentelic Marble, Mount Pentelikon, Attica, Greece. Retrieved June 26, 2022.
https://getd.libs.uga.edu/pdfs/pike_scott_h_200012_phd.pdf