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Spectral and GIS Analysis for Quarry Location in Ancient Messene, Greece

Abstract: The goal of this project was to locate previously unrecorded ancient quarries in the Greek Peleponnese, near Ancient Messene, during the summer of 2006 with limited time and resources. Through the aid of GIS techniques, the aim was to discover, document and study these quarries in a large and topographically diverse area. The source of stone for the nearby ancient temples and towns is pertinent to the analysis of building construction, repair, and sculpture in the area. The use of ERDAS Imagine allowed the classification of a Landsat satellite image in order to analyze ground coverage information and probable quarry site locations. Known quarry sites and topographic information were incorporated into the analysis in order to aid in the hypothesis of proposed locations using an Area of Interest and Alarm Mask. Following GIS analysis, ground truthing took place to evaluate known quarries and proposed quarry locations, resulting in successful findings in several areas.

Background

During the summer of 2006, a project was begun with Frederick Cooper, made possible by the University of Minnesota Graduate Research Partnership Program Fellowship, in which it was hoped to discover, study, and document the location of previously unrecorded ancient quarries. The area of study was in the area of Mount Ithome in the southwestern Peleponnese in Greece, near the site of Ancient Messene founded in 369 BC. This undertaking used Geographic Information Systems (GIS) methods for analysis of spatial and spectral interpretation along with ground cover classification. Additionally, topographic maps were used to locate known ancient quarries. The known locations were studied to gain further knowledge of general appearance and tool marks in order to assist visual recognition of possible quarry sites during field exploration on Mount Ithome. The main goal was to find quarried areas of Mount Ithome for future stone and sculptural analysis of the site of ancient Messene, as some features of the site appear to have been built quickly with a lesser quality limestone, presumably from a local location. Ancillary goals included finding these areas with limited funds and time, which meant exploring how effective an already obtained, low-resolution image could be in a time frame of a few weeks.

The site of Messene has been under excavation since 1895, and has been directed by Petros Themelis since 1986. See Themelis (2003) for a history of the site, explanation of finds, and discussion of ongoing work taking place at the site .The site sits at the base of Mount Ithome and adopts the peculiarities of the landscape, conforming smoothly to the natural environment *(Fig. 1)*. Interest in the stone and quarries at Messene became more prevalent in 2004 when reconstruction began to take place on the Heroon, a small commemorative building at the site. As some of the blocks were too damaged to be used in this reconstruction, the search for limestone at nearby modern quarries began. In light of this, we became curious about the original quarry sites of the stone, and began to develop a project in order to see if these ancient quarries could be located.

Although GIS has been used in the field since the mid 1980s, and aerial photography has had a long history of use, the employment of these technologies in archaeology has grown substantially within the past decade and contributed to digital image processing capabilities. Remotely sensed data such as Landsat imagery can be processed for exploration and discovery and identification of landscape features, and has been successfully carried out by many projects (Ben-Dor et al. 1999; Cooper / Brenningmeyer / Downey 1998; Campana / Forte 2001; Fowler 2004; Ladefoged et al. 1995; Mueller 2007). Data obtained from these images are valuable for predictive models which can classify the probability of landscapes or features yielding archaeological evidence. Archaeological data is inherently spatial and distribution patterns can be used to analyze topics such as settlement locations, social complexity, size of settlements, and use of resources. GIS allows database management and analytic methods providing a multitude of tools which allow for flexibility of criteria.

Methods

A Landsat satellite image of the Peleponnese was used to create a false color composite *(Fig. 2)*. The Landsat image was used because it was already in our possession and covered the entire Peloponnese, cutting out the time and cost of obtaining a higher resolution image. Additionally, one of our goals was to see how effective this imagery was for our purposes. Near Infrared, red, and green bands were used for this image and were selected after completing a Principal Component Analysis in Idrisi which indicated these bands contained the most information. An unsupervised classification was then performed using the raster dataset, resulting in a definition of varied ground coverage areas. The classification was performed with the default standard deviation of one, ten classes, six iterations, and a threshold of 0.950. A classification was performed on the entire image, rather than just the area of proposed exploration, since the locations of known quarries were also considered *(Fig. 3)*. These known locations were sprinkled throughout the Peleponnese, and required the classification to encompass this entire region. The unsupervised classification was selected because not enough features were known about the landcover at any specified location to warrant choosing pixels for individual training classes required of a supervised classification. The unsupervised option facilitated the aggregation of the Peleponnese into a set number of groups and clusters without having to initiate what those classes were.

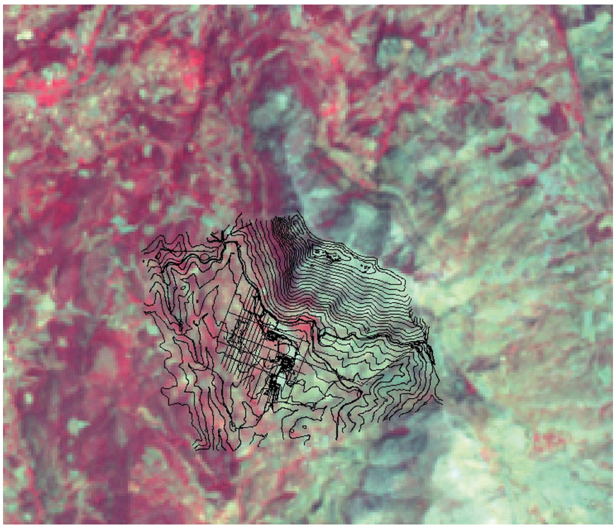

Fig. 1. View of Mount Ithome with site of ancient Messene. (2001 site plan courtesy of Silke Mueth-Herda).

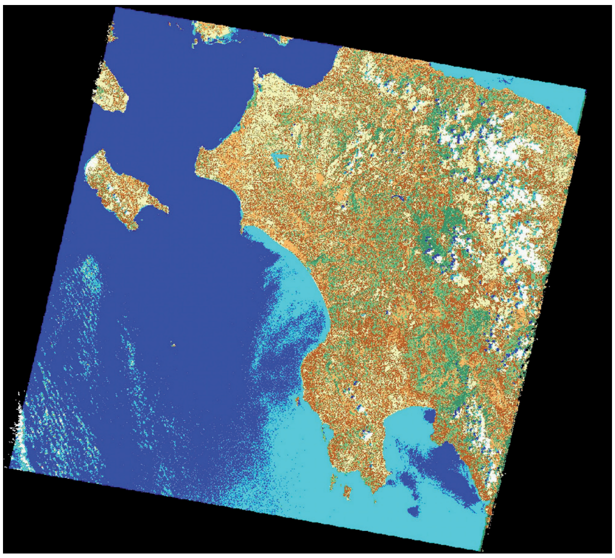

Fig. 2. Unsupervised classification of Peloponnese including Mount Ithome.

In this case, each of the clusters or classes was statistically separate from the other classes based on the values of the pixels as chosen by ERDAS. The classification was set for ten classes for which the signature file was evaluated after the function was completed. It was noted that some of the classes included areas such as cloud lines along the edges of the image. These were not displayed because they offered no data about the landcover, and the colors were changed slightly for visual analysis. The classes were roughly assessed with the aid of a Quickbird image which yielded greater detail of land coverage based its higher resolution. Although the Quickbird image showed higher resolution, it was limited to a small area near Mount Ithome, and not adequate for assessing known quarry locations in the whole of the Peloponnese, which required the use of the Landsat image. Additionally, it should be noted that the exact classes of ground coverage were not necessarily the objective, but rather, more important to show where known quarries fell within this classification.

Topographic maps from the Hellenic Army Geographical Service were used which showed existing known quarries, although the maps do not actually make a distinction between ancient or modern quarries. The locations of these quarries were scaled to convert the decimal degrees to UTM coordinates for use in later field exploration. Eleven sites were used including quarries near Kalamata, Filiatra, Gargaliani, Olympia, and Nemea *(Fig. 4)*.

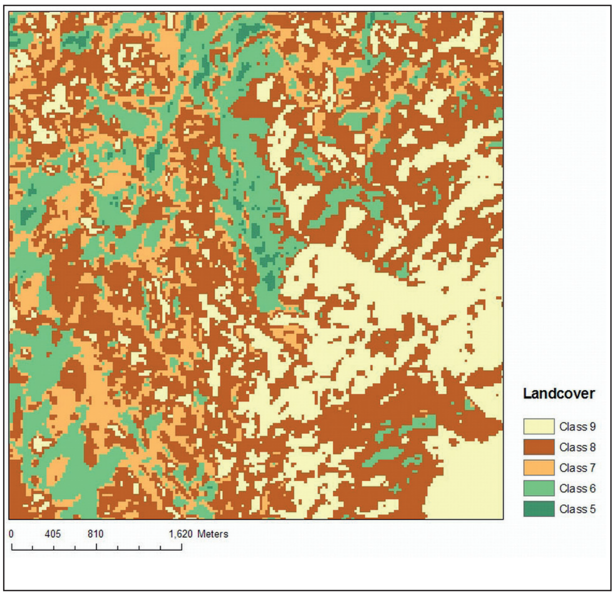

Fig. 3. Classification in area of Mount Ithome.

Fig. 4. Known quarry sites.

In ERDAS, an Area of Interest (AOI) layer was created in which polygons were drawn to show the coordinates for the known quarries *(Fig. 5)*. Since the Landasat image has a resolution of 20–30 meters, and some of the quarries were in areas smaller than this, it was apparent that the dataset was not fine enough to capture only the signatures of the quarries. The signature was going to combine with anything surrounding the quarry, as well. Additionally, because the satellite took the image from overhead, the signatures of quarries on vertical areas such as mountainsides would be inevitably obscured due to shadows. Despite this, it was still a tool which could be effectively used to narrow down the search area at least. Once the AOI was overlaid on the classification layer, it was possible to see in which classes the quarries were present *(Fig. 6)*. The intention was to see if the quarries consistently occurred within the same classes of ground coverage, which proved to be true in this case, as many of the quarries lay on the edge between classes eight and nine in most instances. As stated earlier, it was not our aim to determine what these classes were, but to see where the quarries fell within the classes in order to carry out analysis. With this noted, the general classes known quarries fell between were often those of thick vegetation and shorter scrub vegetation mixed with stone.

Following this, a Quick Alarm was performed on the satellite image in ERDAS. The Quick Alarm involves selecting the pixels from the AOI in which

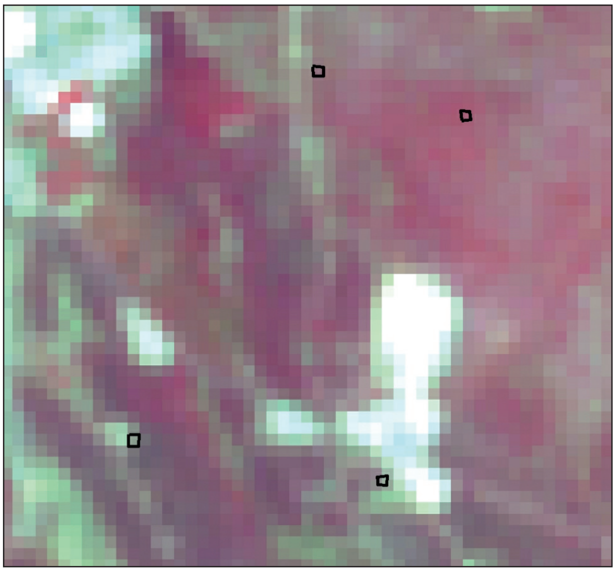

Fig. 5. AOI showing quarries of Gargaliani.

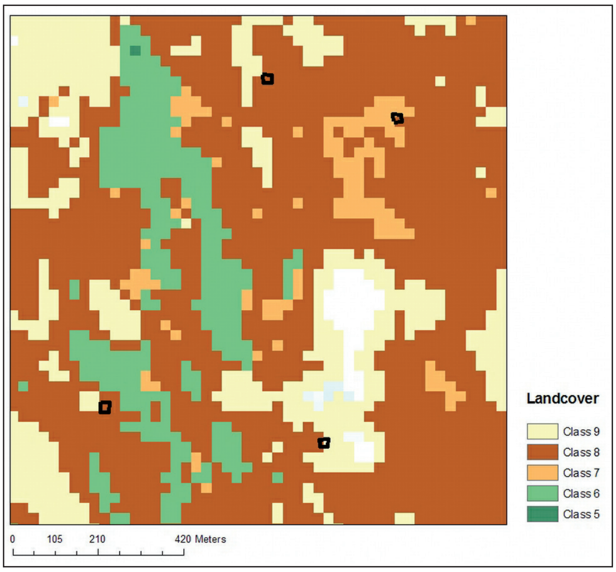

Fig. 6. AOI with classification.

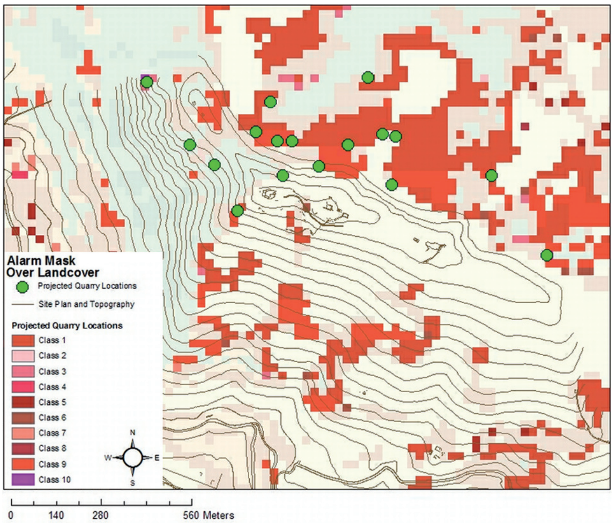

Fig. 7. Possible sites on Mount Ithome.

the quarries existed and using them to set up a new signature. Once this is established, the Quick Alarm function can choose similar areas on the image which indicate the same signature. Pixels from each quarry area were selected from the AOI layer of the false composite and then added to the new signature editor. Each of the known quarries was added to the signature editor box to be used in the Quick Alarm. These were collectively used by the program to generate an output or Alarm Mask showing other areas of the image which contained these same signatures and possible quarry locations. The Alarm Mask was overlaid on the classification in order to obtain proposed sites of field exploration *(Fig. 7)*.

The image was composed in ArcMap and shows the classification as partially transparent, allowing it to remain visible under the Alarm Mask in order to assess within which land classes the pixels of the Alarm Mask were lining up. Sites for exploration on Mount Ithome were compiled by analyzing which projected areas of pixels were falling within the same classifications as the known quarries, i.e. classes eight and nine. The coordinates of locations were marked on a printout of the Classification and Alarm Mask overlay to take into the field for ground truthing.

Exploration

Over the course of eight days, the known quarries, as well as the projected location of quarried stone on Mount Ithome, were explored. The known ancient quarries were visited in order to gain knowledge of how different quarries appeared in terms of tool marks, weathering, and location. Two caves at Gargaliani, a modern quarry at Filiatra, a recently excavated quarry near Nemea, a porous quarry near ancient Messene, and the marble quarry near Marathi on Paros were all visited. Distler's report provides description of overgrown quarry locations at Gargaliani, which aided in ground exploration (Distler in press). GPS points were taken to compare the accuracy of the scaled UTM coordinates from the topographic maps, which proved to be quite accurate and easily identifiable. The type of ground coverage was also noted, along with detectable tool marks and degree of weathering. The recently excavated quarry at ancient Nemea, which is dated circa 330 BC, proved to be very well preserved and several examples of tool marks were visible, as well as the characteristic trenching and benching of quarried stone *(Figs. 8 and 9)*. Although it lacked the signs of weathering that an exposed ancient quarry would have, it was the site which was closest in date to the buildings at the site of ancient Messene.

Fig. 8. Tool marks at Nemea.

Fig. 9. Nemea.

The final step was to perform field exploration on Mount Ithome based on the proposed locations obtained from the satellite imagery. While ground truthing to verify ground coverage, navigating the terrain to the proposed locations, and studying areas of limestone, record was kept through GPS points, photographs, and a written log. There are three sides to Mount Ithome: the northwest, south, and northeast *(see Fig. 1)*. The northwest side was addressed first, and was covered with thick vegetation and many cliffs. By using a topographic overlay on the map, it was easier to decipher at what elevation the coordinates were located. It was clear that on this side, the pixels were indicating higher locations on the vertical cliffs, which were inaccessible from this side. Fortunately, what was evident was that the signatures and the Alarm Mask were, at the very least, correct in indicating areas of limestone.

The south side of the mountain was hiked to reach the top of Mount Ithome, and there was noticeably less green vegetation on this side, instead covered by lower brush and thickets of prickly oak, as well as many areas of large limestone. The top of the mountain was replete with limestone and a few locations indicated possible areas of quarrying. There is a wall of stone similar to the quarry at Kalogerorachi, although the quarry at Kalogerorachi is of a porous limestone unlike that of Mount Ithome *(Figs. 10 and 11)*; both show striations in the stone. The area on Mount Ithome begins with a short portion of stone, then angles back to a relatively smooth, even surface, comparable to the porous quarry which showed a flat quarried surface that then angled back, continuing on with an even surface for another ten meters.

Fig. 10. Mount Ithome.

Fig. 11. Kalogerorachi.

Other locations also indicated stone worked in a way which showed stepped, or benched areas *(Figs. 12 and 13 – center)* which were extremely similar to features seen in the Nemea quarry. In this case, the stone has been exposed and weathered for 2000 years, whereas at the Nemea quarry, it has only recently been uncovered. However, it was clear that these areas on Mount Ithome looked distinctly different than the other stone around them and characteristic of quarried stone.

Results

The final results for this part of the project showed three sites of quarried stone, and two of those sites matched up with the proposed sites and the third was in close proximity to prospected points *(Figs. 14 and 15)*. Four days were spent on Mount Ithome looking for quarry location – one on the northwest side, one on the south side, one on the ridge of the northeast side, and one back up the south face to explore the top. All areas fell within the same general classes as the known quarries, which included thick vegetation and shorter scrub vegetation mixed with stone. One of the goals of this project was to see how much analysis could occur away from the site and how useful that information would be in the field. It is hoped to fine tune the ground coverage assessment, signature analysis, and incorporation of elevations in order to provide more specific and accurate information in future quarry evaluation of other areas. However, the data

Fig. 12. Mount Ithome.

Fig. 13. Mount Ithome.

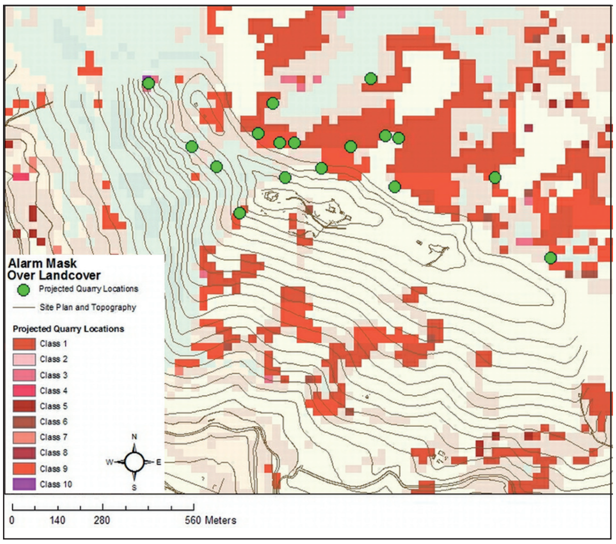

Fig. 14. Projected quarry locations on Mount Ithome.

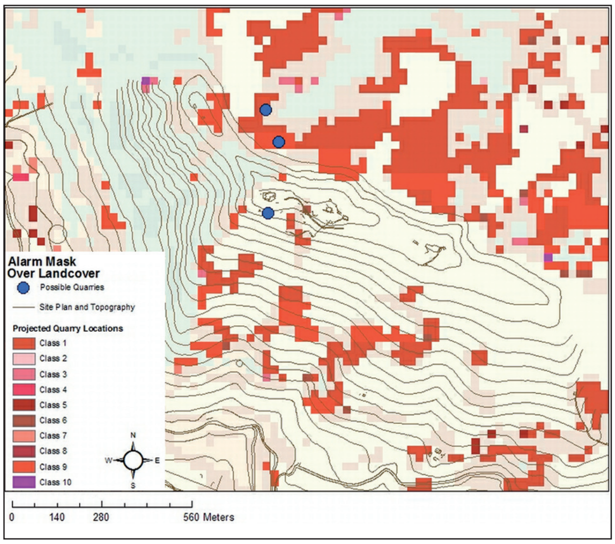

Fig. 15. Quarried stone on Mount Ithome.

was developed enough to carry out the early stages of this project and yield results for within a limited amount of time in the field, not to mention within a large, topographically diverse area. Ultimately, locating the areas of ancient stone quarrying or extraction lends itself to analysis regarding the transport of stone and building construction methods at a particular site. In light of this, the next goal is to complete a cost-distance analysis to determine the route from the quarried areas to the site of ancient Messene.

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