Pastoralism and Peak? A GIS Study into the Origins of Minoan Peak Sanctuaries in Eastern Crete

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Abstract
The development of Minoan Peak Sanctuaries in the Middle Bronze Age has long been seen as a ritual response to agricultural changes resulting in increased reliance on pastoral activities and the exploitation of previously nonviable land. This paper proposes that sanctuaries may have been deliberately situated on locally prominent sites intentionally incorporating views of these newly exploited areas. It begins by exploring the difference between topographical dominance and visual prominence before focusing on sanctuaries in Eastern Crete. By using cumulative viewshed analysis, landscape classification, stratified sampling and statistical testing it is possible to show, with a .01% chance of error, that Peak Sanctuary sites afforded a significantly superior view of agricultural land than randomly seeded points.

Keywords
Minoan Peak Sanctuaries, Cumulative Viewshed Analysis, K-S Testing.

Greece and especially Crete, has been the subject of extensive research for well over a century. This interest has resulted in a vast amount of both fieldwork and academic publications, providing us with one of the best explored and understood areas of the Prehistoric world. While this research has uncovered, explored and provided fascinating insights, it has often been conservative in both its methods and conclusions. The purpose of the paper is to show how GIS can be used to provide, not only confirmation to many past theories, but new insights into the origins of ritual landscapes, specifically Peak Sanctuaries, in the Middle Bronze Age. The paper will provide both a review of past scholarship surrounding these ritual phenomena as well as looking at some of the theoretical aspects which concern GIS practitioners in the study of past landscapes and the use of computer systems. The more specific aim of this paper is to use cumulative viewshed analysis and Monte Carlo simulation to explore the origins of Peak Sanctuaries in the Middle Bronze Age.

During the Protopalatial period of the Middle Bronze Age, around 2000 BCE, extra-urban Peak Sanctuaries begin to appear on and near mountain tops throughout Crete. These sites attracted a diverse and intense following reflected in a rich and varied archaeological record. At the outset of the Neopalatial period, around 1750 BCE, towards the end of the Middle Bronze Age, many of these sites were abandoned as ritual practices were consolidated under the control of large urban centres and palaces. Their stunning locations coupled with the assorted nature of the surviving material record from sites have resulted in a wealth of past scholarship proposing disparate theories regarding site relationships, origins, ritual practice and even identification and classification of sanctuaries. Many of these hypotheses relate to casual observations concerning the topological situation of the sites; however, due to the previous lack of suitable tools, few theories have been formally tested or quantified. Geographical Information Systems offer a unique and varied set of tools ideally suited to explore and test previously proposed theories. This paper uses some of these tools to investigate some of these proposals, specifically sanctuary origins and visual connectedness of the peak sites with their surrounding areas.

A substantial amount of analysis, using GIS, has been carried out on Minoan peak sanctuaries in recent years (For examples see Soetens *et al.* 2001a and 2001c). Much of this work has focused on defining the topological characteristics of the sanctuaries including

[1] This research was (partly) done at the Wolfson Archaeological Science Laboratories at the UCL Institute of Archaeology, funded by the European Union under a Marie Curie Host Fellowship for Early Stage Researchers Training, contract MEST-CT-2004-514509. Thanks are also due to Dr. Andy Bevan and Dr. Mark Lake (UCL) and Dr. Alan Peatfield (UCD).

slope, aspect and geological relationships between site locations and rock types. Visual comparisons between Middle and Late Bronze Age sanctuary sites highlighted the changing nature of viewsheds between the two periods (Soetens *et al.* 2001b, 7). While these studies have provided interesting and valuable results, the purpose of this paper is to take them one step further by applying rigorous statistical confirmation to my results thus providing more confident and empirically quantifiable results.

Obtaining accurate digital data is crucial when compiling a GIS. For my research, a digital elevation model derived from ASTER satellite imagery and manually collected GPS ground control points is used.[2] Some peak sanctuary locations were recorded by myself during a visit to Crete using a GPS. Other sanctuaries were identified and manually digitised using 1:5,000 Hellenic Military Geographical Service Maps and larger scale 1:50,000 topographical maps. Sanctuary locations where then manually repositioned to the highest neighbouring cell within a 3x3 neighbourhood to account for potential GPS error margins.

The number of Peak Sanctuaries identified on Crete varies from publication to publication. Evan's suggested only two, a number reflecting the early date of his research (Evans 1936, 153–59). The French scholar Faure, on the other hand, proposed 52 sites; however, this number may indicate a past inclination to casually identify any site with either Bronze Age material or a prominent topological position as ritual practice (Faure 1967, 1969 and Briault 2007, 123). Peatfield has proposed a more watertight definition, proposing that a Peak Sanctuary is:

A site on or near the summit of a mountain, situated to maximise human interaction (visually and physically accessible from areas of human habitation and exploitation), and identified as a shrine by the presence of specific groups of animal and human clay figurines, including anatomical models, and interpreted as votive offerings (Peatfield 1992, 60).

Peatfield's definition assists our identification of peak sites by proposing two sets of criteria: one topographical and one material. Topographically a site needs to be elevated in a position of visual dominance over the region or settlements it served and to have been accessible from these areas. The presence of certain material objects, remains and cult paraphernalia must also be evident, alongside the topographical factors, to accurately identify a site. Taking both factors into account, the number of accurately identified sanctuaries on Crete falls to 27, located mainly in the central and eastern parts of the island as shown in *Fig. 1* (Peatfield 1989). While the material evidence from sanctuaries plays a vital role in our understanding of Bronze Age Minoan ritual practice, this paper is primarily interested in their topographical positions. These positions are visually dominant offering superb views of the surrounding landscape. While some sites are clearly situated on the highest points of mountains others are located on lower peaks. It is important to note that this prominence does not equate to geographical altitude. Although the site of Atsiphades Korakias in Central Crete is located some 300 metres below the Kouroupas mountain summit it is both clearly visible from and affords a far superior view of the surrounding countryside (*Fig. 2*). This tendency to locate sanctuaries according to perceptual prominence rather than topological situation indicates the

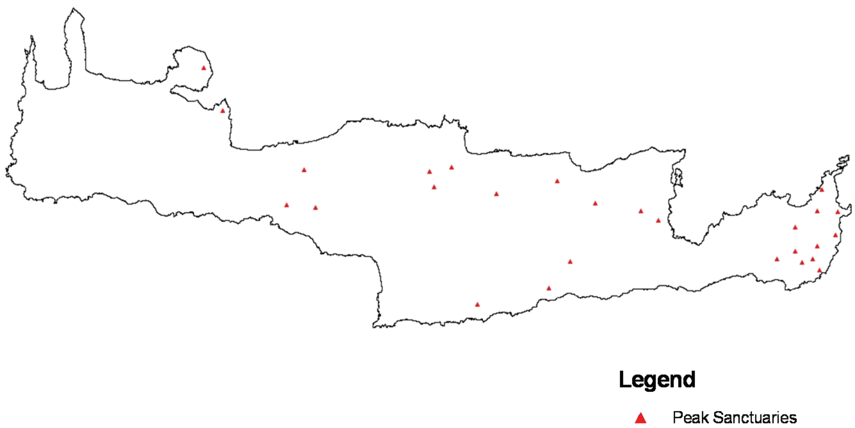

Fig. 1. Map of Crete showing the locations of the 27 Peak Sanctuaries identified under Peatfield's criteria.

[2] This DEM was developed and constructed by The Greek Foundation for Research and Technology in partnership with The California Institute of Technology, The University of the Aegean in Mitiline and the PLANO Institute in Athens. Is has a resolution of 15 x 15 metres and was created by digitally cross-correlating ASTER 3N and 3B channels and then auto-rectifying the result according to photographic tie-points and the GPS control locations (Chrysoulakis 2004, 1–11).

Fig. 2. The Sanctuary site of Atsiphades Korakias from the west.

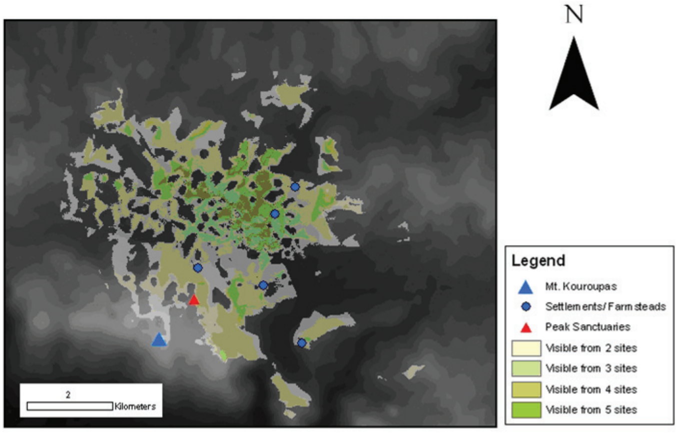

Fig. 3. Map showing the cumulative viewshed from the 5 major settlements in the Ayios Vasilios valley, Central Crete and the Peak Sanctuary at Atsiphades Korakias. Viewer offset is set to 1.5 metres and viewing radius to 8km.

interactive relationship which existed between the sites and their surrounding areas (Peatfield 1983; 1989, 338; 1990, 119 and Nowicki 1994, 41). Simple viewshed analysis involving the abovementioned site of Atsiphades clearly indicates this point (*Fig. 3*). Viewsheds were generated from contemporary settlements in the valley below the sanctuary and the results were cumulated. The Korakias sanctuary site is visible from four out of the five major settlement sites in the valley. The fifth settlement, at the base of the spur itself, is located in such close proximity to the sanctuary that the slopes of the mountain obstruct its view. In comparison, views from the peak of Mt. Kouroupas itself afford superb vistas of the region but lack any visual connection with the valley itself looking over it towards the surrounding mountain peaks. The peak itself is only visible from 2 of the 5 settlements in the valley (*Fig. 3*). It is clear that while the mountain summit may appear dominant on a regional scale it lacks a visual connection with the valley on a smaller local scale.

While opinions differ (for examples see Watrous 1996), many scholars have linked the emergence of Peak Sanctuaries in the Early Middle Bronze Age period to agricultural changes resulting in increased reliance on pastoral activities and the exploitation of previously nonviable land. This theory is further supported by Peatfield who proposed that the sanctuaries actually predate the first palaces (Peatfield 1987, 89–90). Moody and Rackham have shown through pollen coring that climatic changes resulted in a slight temperature increase around this time (Rackham and Moody 1996, 125–126). Such an increase, coupled with a rising population, would have put strain on traditional agricultural activities and necessitated greater diversification resulting in the exploitation of previously unused land and an increased dependence on animal husbandry (Peatfield 1989, 86; 1990, 126 and Rutkowski 1972, 185). This hypothesis is further supported by finds from the rural sanctuary at Atsiphades including a large number of bovine figurines believed by the author to indicate a local switch to cattle pastoralism. Peak Sanctuaries emerged to replace the large communal tombs which had previously served as focal points for community worship (Peatfield 1987, 89–93). The concentration of sanctuaries in Eastern Crete where steep valleys and fertile plateaus make for ideal grazing conditions may further indicate such a shift.

If the origins of Peak Sanctuaries can be seen as a reaction to new agricultural tendencies then it should be possible to test this hypothesis using simple GIS techniques and tools. If the sanctuaries primarily served dispersed agricultural communities in newly exploited areas, we would expect then to be situated in elevated and visually commanding positions in close proximity to areas of human occupation and exploitation. More specifically, we would expect to see a visual connection between the sanctuaries and surrounding arable land, thus confirming their importance to rural agricultural communities. Testing this hypothesis on an island-wide level is difficult as the sanctuaries are not evenly distributed around Crete. While this pattern may reflect genuine local differentiations in prehistoric religious practice across the island it may reflect a more recent research bias towards certain parts of the island. In order to account for this difference this research only focused on the Sitéia region of Eastern Crete where the highest concentration of sanctuaries has been identified.

Eleven sanctuaries are known about in the region spread across the Zíros highlands. The sites range in altitude between 186 and 817 metres in altitude and are mostly situated on or near local peaks. In order to access the visual connection between the sanctuaries and agricultural communities viewsheds were generated from each of the peak sanctuary sites and the amount of potentially arable land within each viewshed calculated. Defining an appropriate viewing radius involved calculating the straight-line distance between each sanctuary in the region and their nearest neighbour. *Table 1* records the results of this analysis. Most sanctuaries are located within 6km of their nearest neighbour. It was therefore decided to use a viewing radius of 10km to ensure that potential areas of shared visual control could be identified.

SITE	AMB	KEP	KAL	KOR	MOD	PET	PLA	PRI	TRO	VIG	XYK
AMBELOS		13	22	4	16	17	6	14	11	7	9
ETIANI KEPHALA	13		23	11	18	22	8	10	19	13	6
KALAMAKI	22	23		19	6	8	20	13	13	15	18
KORPHI TOU MARE	3	11	19		13	15	3	10	10	4	6
MODHI	16	18	6	13		6	15	8	9	10	13
PETSOPHAS	16	22	8	15	6		17	13	6	11	16
PLAGIA	6	8	20	3	15	17		10	12	6	4
PRINIAS	14	10	13	10	8	13	10		12	8	6
TROSTALOS	11	19	13	10	9	6	12	12		6	13
VIGLA ZAKROU	7	13	15	4	10	11	6	8	6		8
XYKEPHALO	9	6	18	6	13	16	4	6	13	8	

Table 1. Straight-line distances between sanctuaries in Eastern Crete (Nearest-Neighbours in red).

The classification of arable land within a GIS is not an easy task. Many factors including palaeo-environment, climate and soil quality need to be taken into account. A lack of such data necessitated an alternative approach. Bevan *et al.*, when studying the relationship between slope and built structures on the Island of Kythera, noted that the transition zone where paths, field enclosures, terraces and buildings begin to substantially decline in the landscape occurs between 10 and 12° (Bevan *et al.* 2003, 233–234). While such a figure does not directly refer to agriculture it does appear to mark out a point at which direct human action in the landscape declines. Other studies have placed the agricultural threshold at a similar mark between 10 and 15° (Bevan 2004, 126 and Wagstaff and Gamble 1982, 101). Assessing land suitable for pastoralism and animal husbandry is somewhat more difficult. While sheep and goats are known for their ability to feed in arduous locations studies have shown that the optimum slope gradient for grazing cattle is between 0 and 10° with severe hindrance encountered about 15° (Wade *et al.* 1998 and Ganskopp *et al.* 2000). These figures enable us to, albeit roughly, classify land below a certain threshold, set at 12° for the present study, as potentially arable while land above this figure can be regarded as unsuitable for crop growth or extensive bovine pastoralism.

By running a line-of-site algorithm from each sanctuary point with a viewing radius of 10,000 metres and a viewer offset of 1.5 metres it was possible to generate a binary raster map where all visible cells had a value of 1 and every other cell had a value of 0. For this analysis the GRASS GIS program was used. Using basic map algebra it was then possible to return the number of cells of arable land within each viewshed. This process was repeated for each peak sanctuary in the region and the totals were recorded. The results appear to confirm the hypothesis that sanctuary sites were located to intentionally include viewsheds of arable land. As already mentioned above, it is important to quantify these results in a way which proves they are significant and are not just the result of random chance (Fisher *et al.* 1997, 582). As Lake had noted, *it is important to distinguish association from causation* (Lake and Woodman 2003, 693).

This analysis then follows past examples in using a method called Monte Carlo testing to prove the significance of the viewshed results (Fisher *et al.* 1997; Wheatley 1995). This method compares viewsheds from sets of randomly seeded points within the same landscape with the observed results. As already discussed above, the sanctuaries are located in elevated positions on or close to mountain peaks. It is therefore important to stratify our random sampling to only include areas which share the same basic topographic considerations as our observed sites. Defining geomorphic phenomenona like peaks, ridges and valleys within a GIS has been the source of much discussion in recent decades (for example see Fisher *et al.* 2004). Landscapes exist as parts of complex socially mediated environments. While a mountain may visually exist, defining its spatial extent is secondary as its true identity is most likely embedded in local social memory. This has led to the development of *fuzzy* definitions which attempt to account for the vagueness often inherent in defining ambiguous features.

For this study, a multi-scale landscape classification algorithm was employed, using the GRASS program, to identify morphometric classes in East

Crete. This algorithm works by fitting a bivariate quadratic polynomial to a given cell neighbourhood (Wood 1996, Chapters 4 and 5). *Fig. 4* shows examples of the six main landscape features identifiable in landscapes using a 3x3 cell neighbourhood. The size of the neighbourhood used for this classification is very important as features may change at varying scales. For the analysis, cell neighbourhood of 41x41 cells was chosen. This number reflects not only the highest optimum neighbourhood computationally possible but also a large enough area to allow for a certain amount of local variation given the DEM resolution.

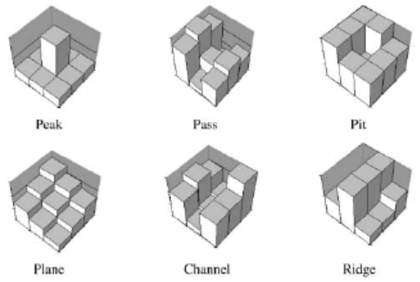

Fig. 4. Six geomorphic features are represented in a raster elevation model (from FISHER *et al. 2004: 108).*

Following the classification, peak features were extracted and then further refined by extracting peaks above 186 metres thus ensuring all features met the same basic topographical variables as the actual sanctuaries. Not all sanctuaries are located directly on mountain peaks. As we have already seen with the sanctuary at Atsiphades Korakias, this pattern most likely reflects a tendency to situate sites not on topographically defined peaks but on visually dominant locations affording greater views of the surrounding area. It was therefore important to compare the results of the above classification with the sites of the sanctuaries. While most peak sites are situated either on or within 150 metres of the classified peaks, some are situated at further distances. The classified peaks were vectorised and buffers were generated at 50 metre intervals around the polygons (*Fig. 5*). Random points were then seeded within these buffers according to the actual locations as shown in *table 2*. While Monte Carlo testing normally requires many thousands of sets of random points, for this analysis only 10 sets of 11 stratified points were generated. This was mainly because of the small area sampled and the computational demands of the subsequent viewshed analysis. Once the sets were seeded lines-of-sight were run from the random points in each set and cell counts of arable land within each viewshed calculated.

Bin (m)	Number of Sanctuaries
0–50 (including peak)	3
50–100	2
100–150	2
150–200	1
200–250	1
250–300	1
300–350	
350–400	
400–450	
450–500	1

Table 2. Distances of sanctuaries from classified peaks.

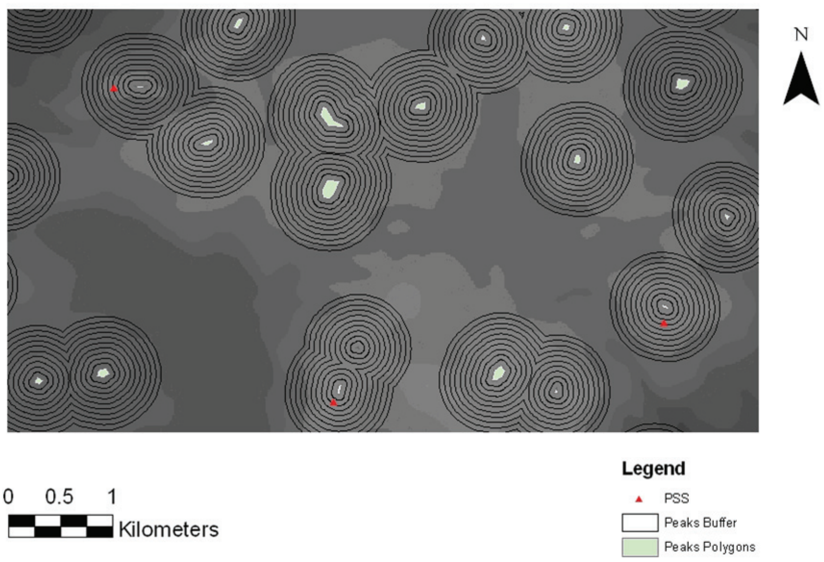

Fig. 5. Results of landscape classification, 50 metre buffers and peak sanctuary sites.

It was necessary to check the significance of these results using a test which allows for the criteria specific to the study. It must be able to check ordinal data and compare two independent observations: the actual results and the aggregated results of the Monte Carlo simulation. The test must also allow for an abnormal distribution of sites reflecting the varied landscape and topographical considerations. The Kolmogorov-Smirnov (K-S) test is a non-parametric test which meets all these criteria. The K-S tests a null hypothesis, in this case that there is no difference between the amount of arable land visible from the randomly seeded sites and from the actual peak sanctuary sites, by measuring the maximum distance between the two sets when plotted on a cumulative frequency distribution. The first step in this process involved plotting the results on bar-charts. *Fig. 6* records the cell counts for each of the randomly seeded points showing a gradual increase from the lowest to the largest viewshed size. The cell counts were the broken into bin values of 10,000 cells and the number of sites which fell within each bin was recorded. These values were then plotted on a cumulative frequency graph and the maximum distance between the two plots was calculated (*Fig. 7*).

Testing the significance of this result involves consulting a table of critical values shown in *table 3*. The lowest critical value with a 1% chance of error is .51 which is less than our *D* value of .55. We can therefore say, with 99% certainty, that viewsheds from the Peak Sanctuaries contain larger amounts of potentially arable land than those from randomly seeded points and hence reject our null hypothesis. This result is a further indication that in Eastern Crete, peak sanctuary locations were intentionally chosen to maximise their visual connection with potentially agricultural and pastoral areas.

α^a	Formula	Critical Value
.10	$1.22 \times \sqrt{(n_1 + n_2) / (n_1 n_2)}$	.38738
.05	$1.66 \times \sqrt{(n_1 + n_2) / (n_1 n_2)}$	.43184
.025	$1.48 \times \sqrt{(n_1 + n_2) / (n_1 n_2)}$	.46995
.01	$1.63 \times \sqrt{(n_1 + n_2) / (n_1 n_2)}$	.51758

Table 3. Critical values of D, K-S test for two samples where α^a is the margin of error and n1 and n2 are the two sample sizes (11 and 110). From Conolly and Lake 2006, 132

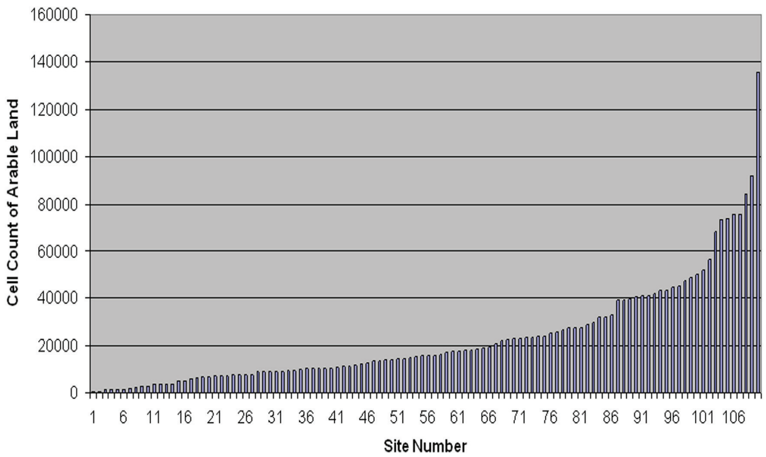

Fig. 6. Histogram showing arable cell counts for randomly seeded points.

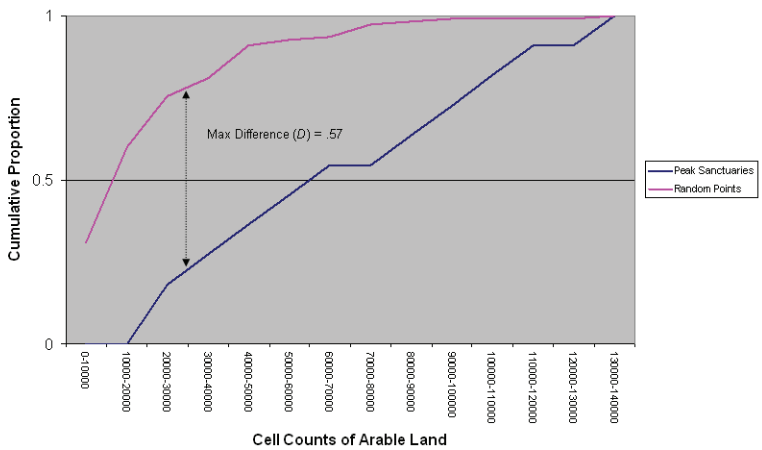

Fig. 7. Cumulative frequency graph showing the maximum distance between arable viewsheds or observed and random points.

This paper has shown how simple Geographical Information System tools, combined with spatial statistics can be used to explore issues surrounding the perceptual construction of landscapes. By bedding the investigation in archaeological theory and applying it to a specific regional and chronological issue it was possible to confirm earlier theories previously thought unquantifiable regarding visual prominence. It has also shown how these tools can offer new perspectives regarding the origins and development of sites, specifically their association with newly emerging agricultural communities in the Protopalatial period. It is, of course, possible that other factors may also have played a role in Peak Sanctuary locations and this likelihood could be further explored by more accurately classifying the potentially arable land using palaeo-archaeological data which is currently unavailable. Still, this study further indicates that, in the Protopalatial period, Peak Sanctuaries in East Crete were visually associated, not with large palatial and urban centres as suggested by some, but with dispersed agricultural communities, likely involved in growing crops and pastoralism.

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