The Samothrace Lidar Project (SaLiP)

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Introduction

This article reports on the Samothrace Lidar Project (SaLiP), a research collaboration in conjunction with the American Excavations Samothrace and as part of the Samothrace Exploration Project. SaLiP seeks to shed light on occupation and land use on the forested, mountainous island of Samothrace in the northeastern Aegean from just before its earliest human inhabitation to the present. As a whole-island investigation, our research collaboration has four primary aims: (1) to investigate the seeming void of the Late Bronze Age, a period of complex and varied patterns of transformation and transition across the regions of the northern Aegean, eastern Balkan Peninsula, and northwestern Anatolia;[1] (2) to document the agricultural landscape which is rich in agrarian ruins, distinctive water management networks, and water-driven pre-and proto-industrial installations;[2] (3) to locate anthropogenic features currently obscured by vegetation in wooded understories across the island; and, (4) to gain a better understanding of the landscape generally, given its rapidly changing geomorphology.[3] During the summer of 2023 we commissioned AeroPhoto Co Ltd of Thessaloniki to undertake the airborne laser scanning of the three most important zones of diachronic human activity on Samothrace.

The Samothrace team formed a partnership with Tom Garrison and Brody Manquen of the Lidar and Landscapes of the Ancient Mediterranean and Americas (LLAMA) Laboratory at University of Texas at Austin to process the lidar data and develop a GIS for use in the program of systematic

[1] Matsas 2007: 387-388.
[2] Matsas 2019.
[3] Pavlidis *et al.* 2005; Vouvalidis *et al.* 2005.

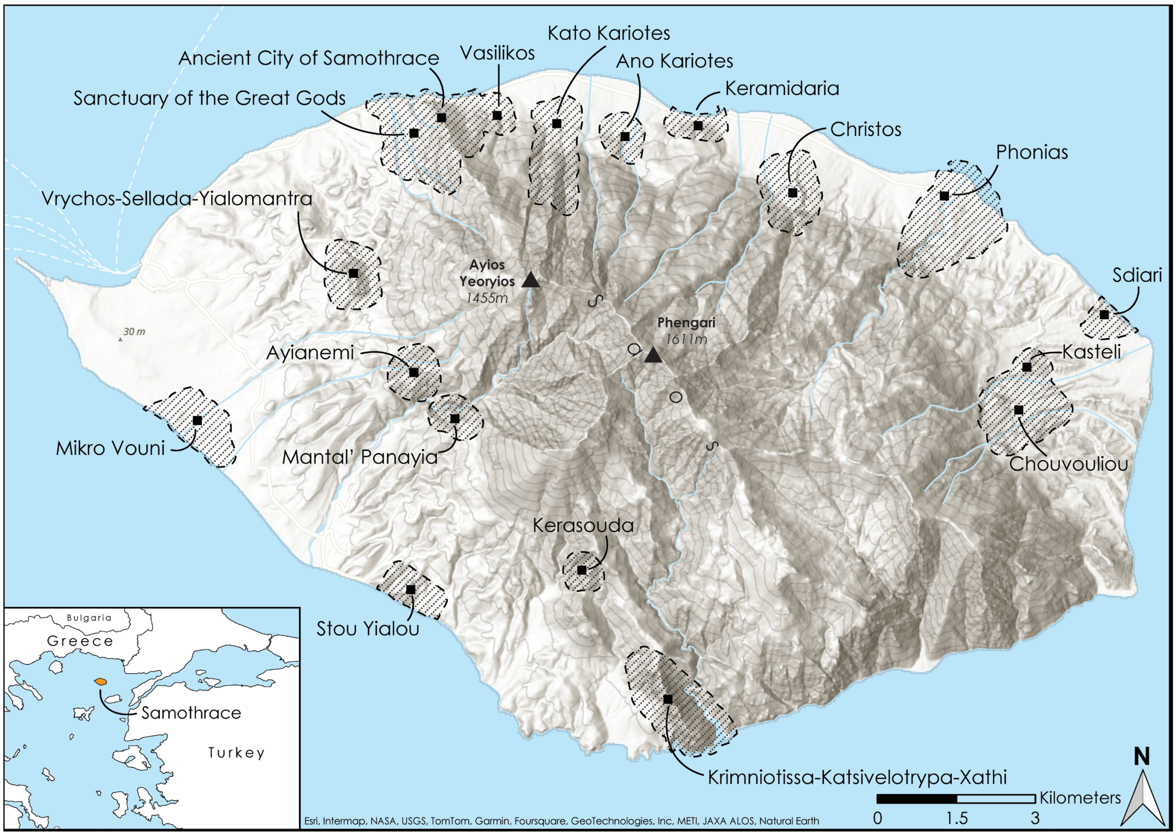

Figure 1. Map of Samothrace showing the known archaeological sites as of 2023 (D. Matsas).

ground verification beginning in the summer of 2024. LLAMA produced a Digital Feature Model (DFM) and derivative visualizations designed for preliminary feature prospection in wooded and low, dense vegetation land cover types present across the island.[4] LLAMA further designed a GIS-based verification strategy on the QField mobile application for seamless GIS integration and standardized feature verification.[5] In addition to gaining insights into the landscape of Samothrace, SaLiP contributes to the expansion of lidar-based archaeological prospection in Greece and the Eastern Mediterranean, regions where nascent lidar-based research can benefit from rigorous testing.[6]

In the 2024 field season, we began our program to verify ground objects identified through lidar. Building on survey work already taking place through the American Excavations Samothrace, verification focused on two specific areas and a series of agrarian features more broadly distributed along the northern coastal zone. Our main effort targeted the forested area south of the Sanctuary of the Great Gods and the ancient city of Samothrace (Figure 1). The second goal involved initial work at the medieval settlement of Christos. In a third initiative, we began to investigate modern features with clear lidar signals across regions, including water channels (*anegoi* in the local dialect) and threshing floors. In this article, we introduce SaLiP, present initial results from our ground verification work, and discuss considerations for the detection success rates of lidar in comparison with ground survey across a range of archaeological features.

[4] Štular *et al.* 2021.
[5] This workflow was designed in parallel with similar work done on the Small Cycladic Islands Project; see Manquen *et al.* this volume; Knodell *et al.* this volume.
[6] Manquen 2024; Vinci *et al.* 2024.

Archaeological background

Visitors to the island in mid 19th century explored the northern coast widely.[7] However, because of its renowned mystery cult, the discovery of the famous Winged Victory (Nike) in 1863, and the remains of highly innovative Hellenistic architecture revealed during Austrian excavations in 1873 and 1875, the Sanctuary of the Great Gods on the northern coast of the island attracted the sustained attention of researchers since the second half of the 19th century.[8] American investigations under Karl Lehmann and the Institute of Fine Arts of New York University began in the Sanctuary in 1938, and work continues to the present as American Excavations Samothrace.[9] These investigations have revealed that the Sanctuary of the Great Gods was a vibrant but local religious center until the second half of the 4th century BC when the interests of Macedonian royalty brought it rapidly to international prominence. Nearly a dozen buildings built between the late 4th and late 3rd century BC are among the most inventive designs of the Hellenistic period. Recent investigations of pathways, retaining walls, and bridges have placed a greater emphasis on human movement and experience within the sacred environment.[10]

By contrast, the nearby ancient city has received far less attention. The well-preserved walls attracted the interest of earlier archaeologists.[11] Currently, American Excavations Samothrace is investigating the section of fortification wall that faces the Sanctuary, from Tower A to the West Gate. The land between the Sanctuary and city wall has been the subject of intensive field survey led by Dimitris Matsas in 2022. While little is known about the intramural layout of the ancient city, small-scale rescue and trial excavations as well as spolia built into the Gattilusi Towers bear witness to several monumental marble buildings.[12] Thus far, finds from the city and Sanctuary are not earlier than the 7th century BC.[13] Because much of the ancient city is covered in dense oak forest and plane trees, airborne laser scanning offers excellent potential value in shedding further light on its urban fabric.[14]

Beyond city and Sanctuary, investigations across the island over the last 35 years have significantly expanded our understanding of the island's cultural trajectory from the early Late Neolithic to the recent past. Archaeological research at the tell-settlement Mikro Vouni opened a deep window into the island's prehistory and connections with the Balkans, the Troad, west Anatolia, the Aegean, and Minoan Crete.[15] Excavation at Mikro Vouni has established a cultural sequence extending from the beginning of the Late Neolithic to the beginning of the Late Bronze Age, with a gap in the 4th millennium BC.[16] Early and Middle Bronze Age material has been identified on the surface at two more coastal sites, Sdiari on the north-eastern part of the island and Stou Yalou on the south of the modern village of Lakkoma.

Research in the area of Vrychos-Sellada-Yialomantra has proven that occupation here started at the very end of the Late Bronze Age or the very beginning of the Early Iron Age.[17] Archaeological survey aiming at locating sites of this period verified the existence of contemporary sites at elevations

[7] Especially Conze 1860: 44-74.
[8] For the Winged Victory, see Hamiaux *et al.* 2015. For Austrian excavations conducted by Alexander Conze, see Conze *et al.* 1875 and 1880.
[9] James R. McCredie continued the excavations for the Institute of Fine Arts from 1962 to 2012. Bonna D. Wescoat now serves as director of a collaborative team, American Excavations Samothrace, sponsored by Emory Unversity and the Institute of Fine Arts. Publications appear in numerous articles as well as the excavation series, *Samothrace, Excavations Conducted by the Institute of Fine Arts of New York University*.
[10] Wescoat 2015; Wescoat *et al.* 2020; Farinhold Ward *et al.* 2023.
[11] Conze 1860: frontispiece, pl. XIV; Conze *et al.* 1875: 28–30, pls. IV-VII; Conze 1880: 12, 28, 45–46, 106–107, pls. LXVIII–LXXII; Seyrig 1927.
[12] Kourkoutidou-Nikolaïdou 1977; Karadima 1998: 488–492.
[13] Karadima 1998: 490; *Samothrace* 5, 26.
[14] Biel and Tan 2014: 45. Fig. 68 shows forest with *Platanus orientalis*, *Quercus petraea* subsp. *medwediewii*, and *Quercus pubescens*.
[15] Matsas 1991; 1995; 2023.
[16] Matsas 2013: 225-232.
[17] Matsas 2004: 234–255; Matsas 2007: 392–395; Matsas 2009: 213–216.

between 400 and 600 masl along an arc extending from the site of Krimniotissa SE to Vrychos NW.[18] Thus far, we have not located earlier Late Bronze Age surface material on Samothrace.[19] This void, unlike Troy, Limnos and Imbros, also occurs in mainland Aegean Thrace. A key research goal is to determine if the void is real or if we have not yet found the archaeological evidence.

The island also has additional sanctuaries contemporary with the Sanctuary of the Great Gods. In the locality of Mantal' Panayia, on the outskirts of an important Thracian settlement, an outdoor sanctuary dedicated to Bendis/Artemis was excavated.[20] Incised ceramic inscriptions on the lips of votive cups (late 6th–first half of 5th century BC) are Thracian, related to votive ceramic inscriptions from the sanctuaries of the Great Gods on Samothrace and of Apollo in Zone, on the coast of the opposite mainland (6th to late 4th/early 3rd centuries BC).[21] The name of the Thracian divinity Bendis can be seen in two of the inscriptions from Mantal' Panayia. To the southeast of Mantal' Panayia, in the locality of Kerasouda, another open-air sanctuary is dedicated to Cybele as 'Mother' or 'Mother of the Mountains.' The surface ceramics collected at Kerasouda date from the mid-4th century BC onwards.[22]

At Keramidaria, 5 km east of Palaiopolis, two workshops for the production of Hellenistic amphorae have been discovered. Excavation in the West Workshop brought to light a large, rectangular manufacturing area (1st century BC–1st century AD) and a neighboring dump of wasters from an older workshop. The excavation of the older dump produced a considerable number of stamped amphora handles, dating to the second half of the 4th century and to the 3rd century BC. In the East Workshop, three ceramic kilns (1st–3rd century AD) were uncovered.[23]

In addition to excavation, the intensive, diachronic Samothrace Archaeological Survey (SAS) conducted in the late 1980s through cereal fields in the southwest plain of the island determined the changing character of settlement and land use over the long term.[24] This work concentrated on the slopes under cereal cultivation to the west of the Xeropotamos and Katsampas Rivers, in proximity to Mikro Vouni, covering roughly 11% of the island. The survey excluded the coastal plain to the east of the Xeropotamos and Katsampas Rivers because this area is mostly covered by considerable stands of forest and thick maquis (see below). With two prehistoric exceptions, the material collected in the survey spans the last quarter of the 6th century BC through the 14th-15th century AD. [25] In addition to SAS, an extensive survey was conducted in the northeastern part of the island focusing mainly on its medieval past.[26]

Topography, tree canopy, and the efficacy of lidar on Samothrace

It has long been our goal to integrate these separate projects into an overarching diachronic investigation of settlement and transition across the island of Samothrace. Given the extensive forest cover over large portions of the island and the state of preservation associated with a changing agrarian landscape, the implementation of lidar is of great value to future archaeological research on Samothrace.[27] Lidar is an especially effective research tool in landscapes with extensive and diverse forest cover such as Samothrace (Figure 2).[28] When the Greek poet Homer describes

[18] Matsas 2004; Matsas 2007: 396; Matsas 2009: 228: fig. 1.
[19] Matsas 2004: 247–248; Matsas 2007: 387; Matsas 2009: 205.
[20] Matsas *et al.* 1997.
[21] Matsas 2004: 230, fig. 2; Matsas 2007: 390; Matsas 2009: 210.
[22] Matsas 2004: 232–233; Matsas 2007: 392; Matsas 2009: 212.
[23] Matsas *et al.* 1992: 608–611; Karadima-Matsa 1994.
[24] Matsas *et al.* 2023.
[25] Matsas *et al.* 2023: 45–49.
[26] Papathanasiou 2001; 2005. In addition to SAS and Papathanasiou's survey, numerous important reports of surface finds and architectural remains by archaeologists in charge at the Ephorates of Antiquities have been published in the *Archaiologikon Deltion*.
[27] Faugères and Kolodny 1972.
[28] According to Biel and Tan 2014: 53: fig. 73, the surface of the island is divided between false maquis 14.0%, inhabited areas and cultivations 13.8%, maquis 12.0%, *Juniperus matorral* 8.7%, uncultivated land with thorny bushes 7.4%, olive plantations 7.3%, *Sarcopoterium*

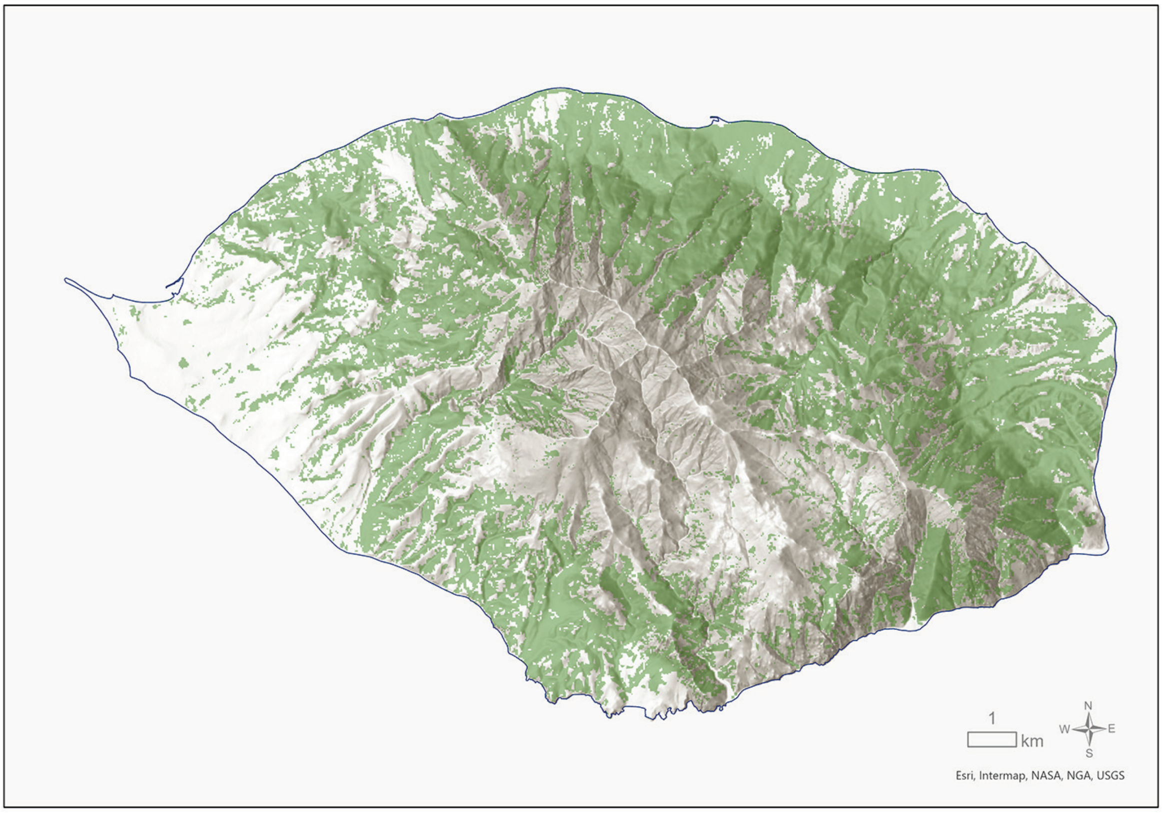

Figure 2. Vegetated areas with the potential to obscure archaeological surface remains calculated from Landsat-9 scene, captured on August 19, 2024. Courtesy of the U.S. Geological Survey, basemap World Topographic Map (ESRI) (American Excavations Samothrace).

Poseidon watching the Trojans battle the Achaeans from his high seat on Saos, he conjured a single epithet to describe the island ὑλήεσσα (yliessa), 'wooded' (Iliad 13, 10-16). It remains so today, despite the depredations of blight and the overgrazing of goats.[29] Along the largely wooded northern coastal plain of the island, ruined remains of past settlement areas are concentrated along the perennial rivers.[30] These watersheds, including the ancient city and extending eastwards from Kariotes, are shielded by a mixed canopy of plane and unbroken medium-growth, oak forests, largely Quercus petraea subsp. Medwediewii and Quercus pubescens.[31] Areas of the south coast are covered by stands of olive. In total, tree cover (with canopies 15 meters or taller) blankets 33.4 of the island's total area of 178.6 square kilometers, as calculated using 2023 data from the European Space Agency's (ESA) Sentinel-2 satellite constellation. According to calculations from August 2024 Landsat data, vegetated areas with the potential of obscuring or partially obscuring archaeological features covers 89.9 km^2. The density of overgrowth in various areas along the north coast, combined with the complexity of sites at Christos, Phonias, and Chouvouliou, has posed a challenge for detailed landscape studies of these areas. We anticipated that lidar would alleviate time-consuming fieldwork in areas with dense ground cover and provide a platform to effectively record interlinked stone enclosures, extensive terracing, and intricate habitation areas.

6.8%, garigue 6.6%, rocky slopes 6.5%, *Quercus pubescens* 3.9%, riverside forests 3.3%, tillites 3.0%, *Quercus petraea* 2.1%, areas with fern 1.7%, coasts 1.1%, coastal twigs 0.9%, marshes near springs 0.5%, artificial pine forests 0.2%, coastal lagoons 0.2%. See Löw 2017 for spatial patterns of land cover on Samothrace. See Vinci *et al.* 2024 for the extent of lidar archaeology across forested regions worldwide.

[29] Biel and Tan 2014: 54–59. The chestnut and plane trees are suffering from fungal disease. The conifers are recovering after interventions to protect them from moths. The population of sheep and goats, even after a recent decline, has tripled since 1961; see Fetzel *et al.* 2018.

[30] See Vouvalidis *et al.* 2005.

[31] Biel and Tan 2014: 45: fig. 68.

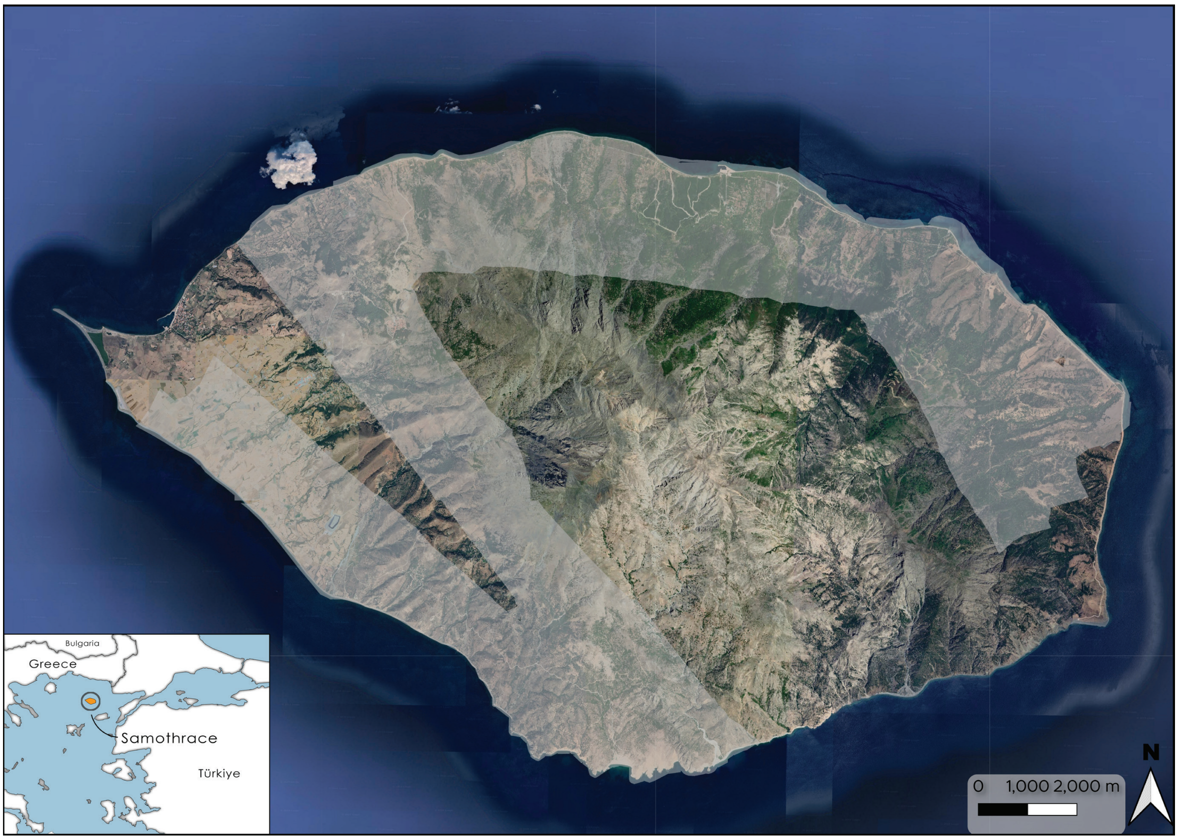

Figure 3. Map of Samothrace with the areas covered by the 2023 lidar flight shaded in white (SaLiP).

Lidar acquisition and processing

It was not feasible to collect lidar data across the entire island, especially at elevations over 700 masl. Working with AeroPhoto Co Ltd, we designed a flight plan that covered three broad strips of the island, concentrating lidar acquisition to cover the districts around the 18 major areas of ancient habitation outside the present-day urban center of Kamariotissa (Figure 3). The first strip encompassed the north-northeastern coastal zone from the agrarian landscapes west of Palaiopolis to the upper drainage of the Platypotamos River. This strip included the Sanctuary and ancient city, Kato and Ano Kariotes, Keramidaria, Christos, Phonias, Sdiari, Kasteli, Chouvouliou and their surrounding landscapes. The second strip included the central flanks of Saos from the north coast west of Palaiopolis to the Vatos River on the south coast and covered Vrychos-Sellada-Yialomantra, Ayianemi, Mantal' Panayia, Kerasouda, Pournia, and Krimniotissa-Katsivelotrypa-Xathi. The third strip included southern coast from the Vatos River to the area of Livadia, south of Kamariotissa and included Stou Yialou and Mikro Vouni.[32] These three strips were also designed so as to incorporate the three distinctive agrarian zones of the island: (1) the western plain, which is still used mostly to grow cereals chiefly for animal fodder; (2) the dry, southern slopes of Saos, which has the island's largest concentration of olive groves that constitute an important pillar of the island economy; (3) the northern and northeastern coast, which is wooded, has many perennial streams – a result of greater moisture due to orographic lift – and a more mixed regime of cereal fields and olive groves fed by stream channels.[33]

[32] See Syrides *et al.* 2009.
[33] See Pavlidis *et al.* 2005.

The total area of acquisition was 107.4km². The north-northeastern coastal zone included an area of ca. 60km², while the two southwestern flight paths contained a combined area of ca. 47km². The Saos mountain range divides these two regions. While charcoal pits, seasonal huts, and enclosures tied to modern woodland management and pastoralism are found at elevations of 1000m and higher, current evidence of concentrated human settlement does not rise above 600masl.[34] We therefore laser-scanned the slopes to the elevation of 700masl. The area below 600masl is approximately 102km². We excluded the port of Kamariotissa and have a small gap over the western plain of roughly 12km². Our lidar imagery thus covers around 90km² below 600masl. While our lidar imagery encompasses well over half of the island (which has a total area of 178.6km²), our coverage comprises approximately 90 percent of its concentrated settlement zones.[35] The airborne laser scanning was carried out at an average of 21 points per square meter from a mean altitude of 1370m, which is well above suggested standards for mapping archaeological features.[36] Because Samothrace has a broad diversity of plant and tree cover, from low-level stands of juniper and fern to mid-level oak forests to olive groves to higher canopies of mixed deciduous forests dominated by plane, scan densities of ground points varied with early-summer canopy and ground cover.[37]

We processed the lidar point clouds for the purpose of a preliminary feature prospection. The DFM was created from ground, building, and archaeological feature point classes using an Ordinary Kriging interpolation method in the lidR package for RStudio version 4.4.0.[38] We primarily used two blend visualizations, a slope raster overlaying the Visualization for Archaeological Topography (VAT) and the Red Relief Image Map (RRIM),[39] both created with the Relief Visualization Toolbox (RVT) for QGIS version 3.36.[40] These were chosen to facilitate quick topographic survey for feature detection, although we also created topographic index-based visualizations for supplemental use.[41]

Field verification and results

The preliminary survey of the island landscape aimed to test the visibility of archaeological features in the lidar visualizations. It consisted of two parts. First, we created a GIS-based survey of likely archaeological features detected in lidar-derived visualizations. Next, we conducted a ground survey aimed at verifying the results and adding features missed during GIS-based survey. For the GIS-based survey, we loaded orthophotographs and lidar-derived visualizations into QGIS, where the analyst drew potential features as line or polygon vectors with attributes relevant to future verification. This procedure was limited at present to the areas chosen for the ground survey in 2024. We then loaded the orthophotographs, visualizations, and feature vectors on the QField application for iPad to allow for verification and the quick addition of new features to the existing geodatabase. A critical aim of the preliminary survey was to establish a baseline of verified features detectable in lidar visualizations that would allow us to calibrate expectations of future imagery analysis. These images revealed objects from new angles, at times what had been unseen at ground level. Thus, they directed us to adjust our subsequent ground survey with spot checks for particular features. Verification results in the future can encourage the reverse for GIS-based survey, with knowledge of ground features adjusting how we interpret lidar-derived visualizations.[42]

[34] Witmore 2025.
[35] The gap in the lidar over the western plain and the port of Kamariotissa measures roughly 12km². The lidar covers approximately 90km² below 600m asl. Island areas were calculated using Landsat data and in QGIS.
[36] Where Bollandsås *et al.* (2013) have suggested a minimum of 5 points per square meter, Optiz (2016) has recommended 8 points per square meter (2016). See Knodell (this volume: Figure 4) for the resolution of other projects in Greece.
[37] Biel and Tan 2014: 45: fig. 68, 47-52, and 53: fig. 73.
[38] Roussel *et al.* 2020.
[39] Chiba *et al.* 2008.
[40] Zakšek *et al.* 2011. See Kokalj and Somrak 2019 for composition of blends using RVT.
[41] See Crabb *et al.* 2023 for discussion of the costs and benefits of different visualization types, especially the drawbacks of blended visualizations. For more on specific visualizations used here, see also Manquen *et al.* this volume.
[42] See also Knodell *et al.* this volume.

Figure 4. Medium-growth oak understory south of the Sanctuary of the Great Gods (SaLiP).

Our verification work during the summer of 2024 focused on ground objects detected by laser scanning in two areas: (1) the area south of the Sanctuary, on the ridge between the Ayia Paraskevi or Kopsi Stream and the Central Stream, fed by its upper tributaries, that flows through the Sanctuary of the Great Gods; and (2) part of the medieval settlement north of the monastery of Christos. We also began an investigation of modern agricultural features, which included threshing floors in Palaiopolis and Ano Meria and water channels in Palaiopolis, Kariotes, Phonias, and Ano Meria. Using two iPads loaded with QField for data entry we systematically documented objects by drawing approximate shapes in vector multilines and multipolygons and points for geotagged pictures. This work has informed a targeted examination of the original point cloud data and reprocessing to higher resolution if possible.

Area south of the Sanctuary and ancient city

We started with the area in the vicinity of the Sanctuary because we have a deep basis of previously well documented archaeological and topographical evidence against which we could compare the lidar imagery. Aerial legacy data include imagery created by the Greek Army Geographical Service in 1945, 1960 and 1977, and balloon photography made by Wilson and Eleanor Myers in 1981 and by the Greek Archaeological Service in 1996. The current program of American Excavations Samothrace includes annual aerial capture using a DJI Enterprise 3 quadcopter with Real Time Kinematic (RTK) corrections. In the area south of the Sanctuary, which like the ancient city is covered in dense medium-growth forest, lidar features visible through the understory are less

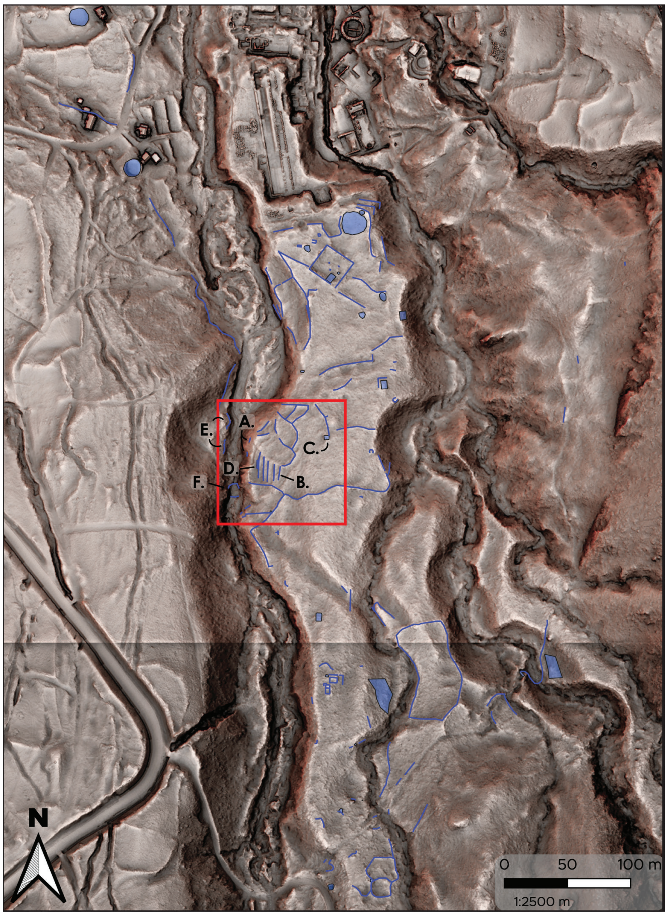

Figure 5. Archaeological features documented during lidar prospection and field verification in the area south of the Sanctuary of the Great Gods. The red square indicates the area depicted in Figure 6. The features shown in Figure 7 are located here with letters A.-F. (SaLiP).

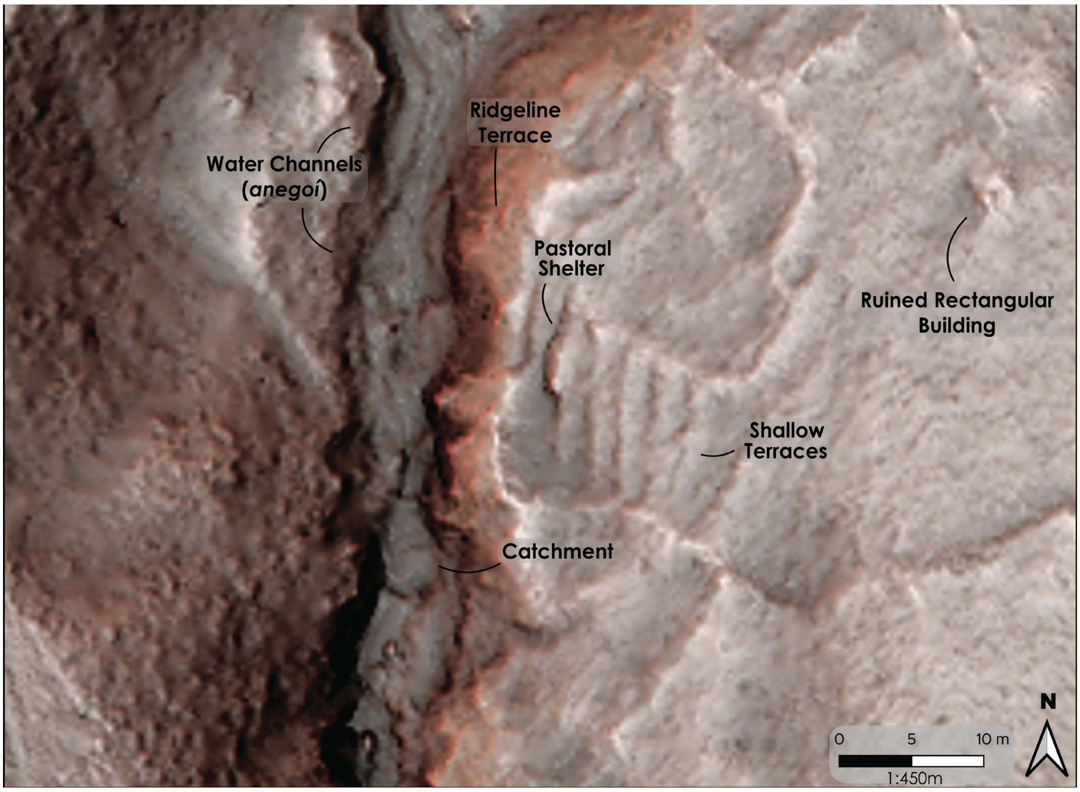

Figure 6. Inset map of archaeological features detected in the lidar survey and/or field verification in the area south of the Sanctuary of the Great Gods along the Ayia Paraskevi Stream. Features described and photographed in Figure 7 are highlighted in red. Background in the Local Dominance visualization (SaLiP).

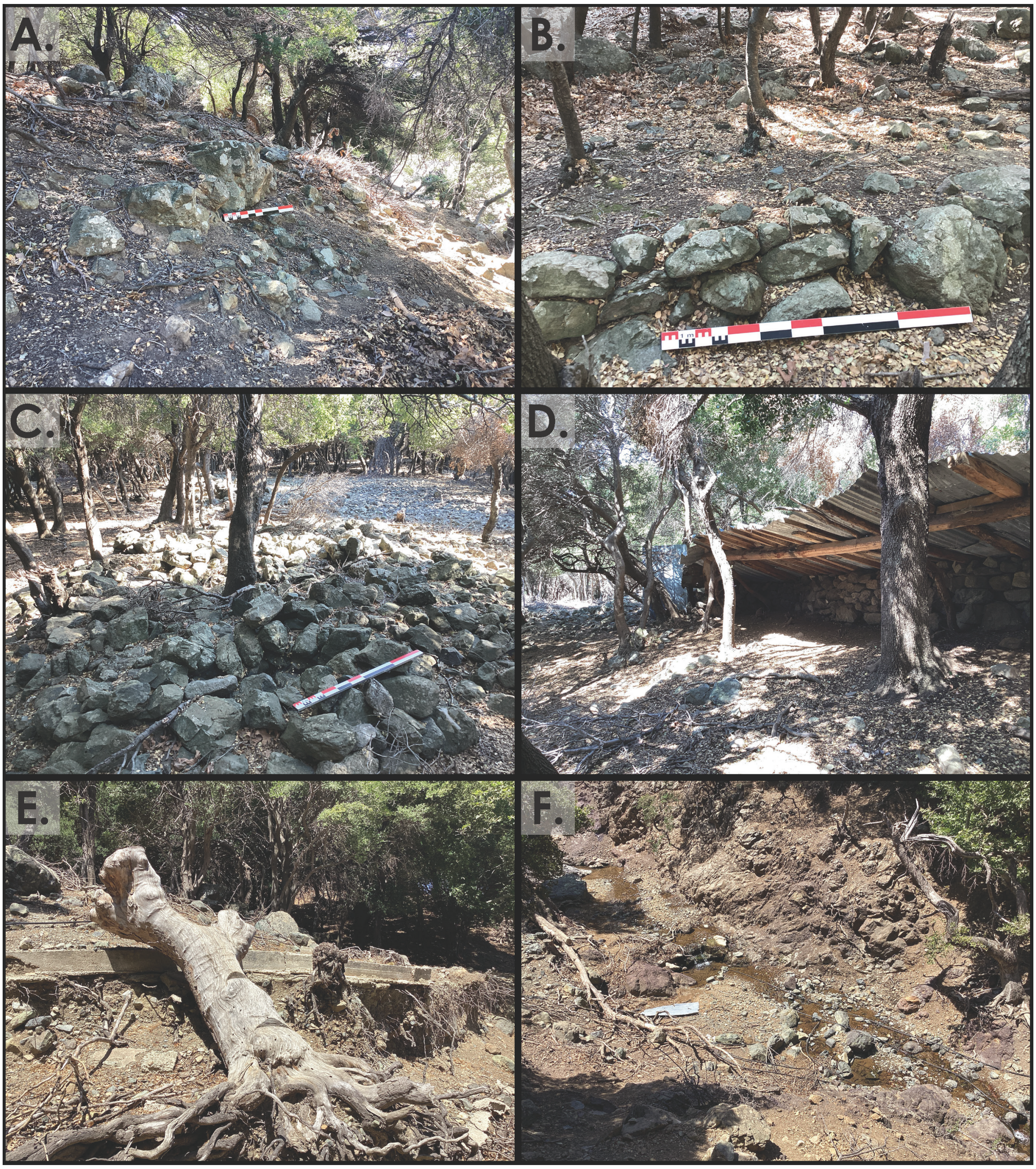

Figure 7. Photographs of select archaeological features in Figure 6 taken during field verification. (A) Terrace nested along ridge line; (B) Shallow terraces; (C) Ruined building; (D) Pastoral shelter; (E) Water channel; and (F) Water channel catchment area.

defined on the ground (Figure 4).[43] Most of these features had been located by the excavators of the site, but they have not been systematically recorded and studied thus far.

Despite their morphological differences, linear features such as fields, enclosures, rooms, stone-built walls, terraces, paths, concrete water channels, slope-cut roads, and depressions for paths stood out prominently in the lidar imagery (Figures 5-7). Size, sedimentation, and shadowing had the largest negative impact on linear feature identification, especially for the terraces. Many fragments of partially collapsed and sediment-covered terraces were originally built against the

[43] Biel and Tan 2014: 45: fig. 68.

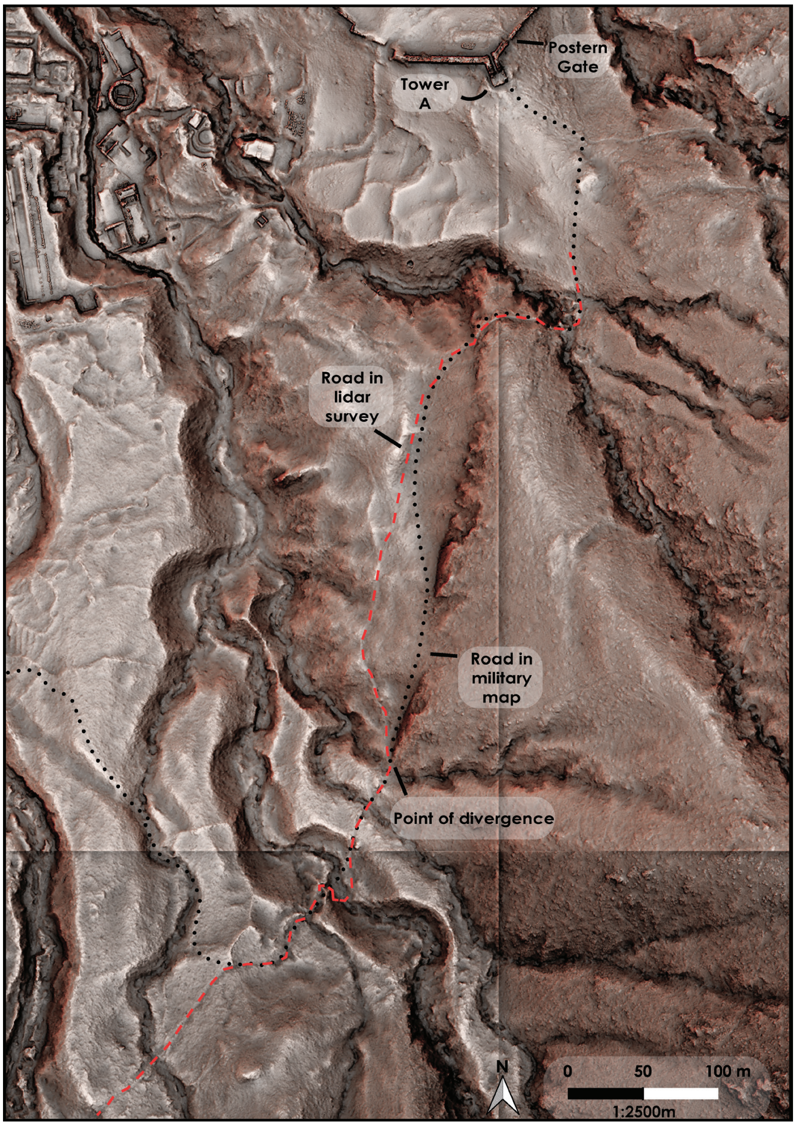

Figure 8. Ancient road as reconstructed in the lidar visualization (in red). Previously mapped section of road (in black) based on ΓΥΣ (Γεωγραφική Υπηρεσία Στρατού)1977, 4603/1, κλίμαξ 1:5,000 Σαμοθράκη (SaLiP).

steep interfluve, making them blend easily into the natural topography when viewed in the lidar visualizations. Otherwise, most terraces or enclosure wall systems on the gentle-sloped portion of the ridge stood out clearly. Stone-built walls for threshing floors were particularly distinctive, although these were most often found in the non-forested areas where higher visibility would be expected.

Buildings and other non-linear features similarly varied in visibility by location on the ridge. Most buildings in this region are rectilinear and measure roughly six to seven meters long and three to five meters wide. Several of these buildings were discovered partially collapsed on the ridge line, like the fragmentary terrace walls, and likewise they were invisible in the lidar visualizations. Other buildings appeared as anomalous protrusions on the lidar visualizations and were easily mapped, sometimes down to individual rooms. Other buildings included two animal byres and a lime kiln, all of which gave clear signals (see example of byre in Figure 7D). This area hosted several graves that were invisible to the lidar as they were either level with the topography or marked by a single large stone that was indistinguishable from the ground surface in the imagery.

One feature worthy of specific mention is an ancient road whose path is traceable in the lidar imagery from the upper gates of the ancient city south across the lower slopes of Ayios Yeoryios (Chorafi) (Figure 8). The path, which we traced to the city walls over the summer of 2024, intersects

Figure 9. Samothrace team standing on the newly documented road from the ancient city toward Chora. Note the well-preserved stretch of stone curbing just downslope of team (American Excavations Samothrace).

the main road through the ancient city to the Gattilusi Towers and strikes out east, continuing over the northern slopes of Chorafi towards Kato Kariotes. In places on the ground, the lidar directed us on the path of the road where it was otherwise indiscernible to the eye, including places where the natural contours were potentially misleading. This error seems to have happened in a previous survey, which draws parts of the road along a contour where, in the lidar, we detected the road curbs farther downslope (Figure 8). The road was suitable for carts, being wide enough (3+m) for two carts to pass in places. It is well-built with curbs on both sides and a solid metaling of hard-packed cobbles (Figure 9). This road represented a significant investment in infrastructure to connect the ancient city with Chora and other areas along the north coast. In places, holloways are formed into the road surface and breaks are built into walls that cross its route. Such details suggest that this road, or portions of it, shaped movement across the island for centuries.

Through the lidar imagery, we also have been able to identify a palaeo-channel that originally directed the western tributary of the Central Stream toward the Ayia Paraskevi Stream (Figure 5, diagonal channel immediately south of the red square). At some point, this channel was blocked with a raised berm so that the water formed a tributary of the Central Stream running through the center of the Sanctuary. This watercourse, which has been controlled within the Sanctuary since antiquity by retaining walls, has been subject to extreme weather events, most recently in 2017. The lidar data has thus proven essential to understanding the dynamics of water management in this area, their effect on the Sanctuary of the Great Gods, and the potential for remediations (i.e., reactivating the original channel to redirect excess flow away from the Sanctuary). Within the highly documented area of the Sanctuary, lidar data have now been used in combination with topographic mapping that previously was calculated using traditional total station survey methods.

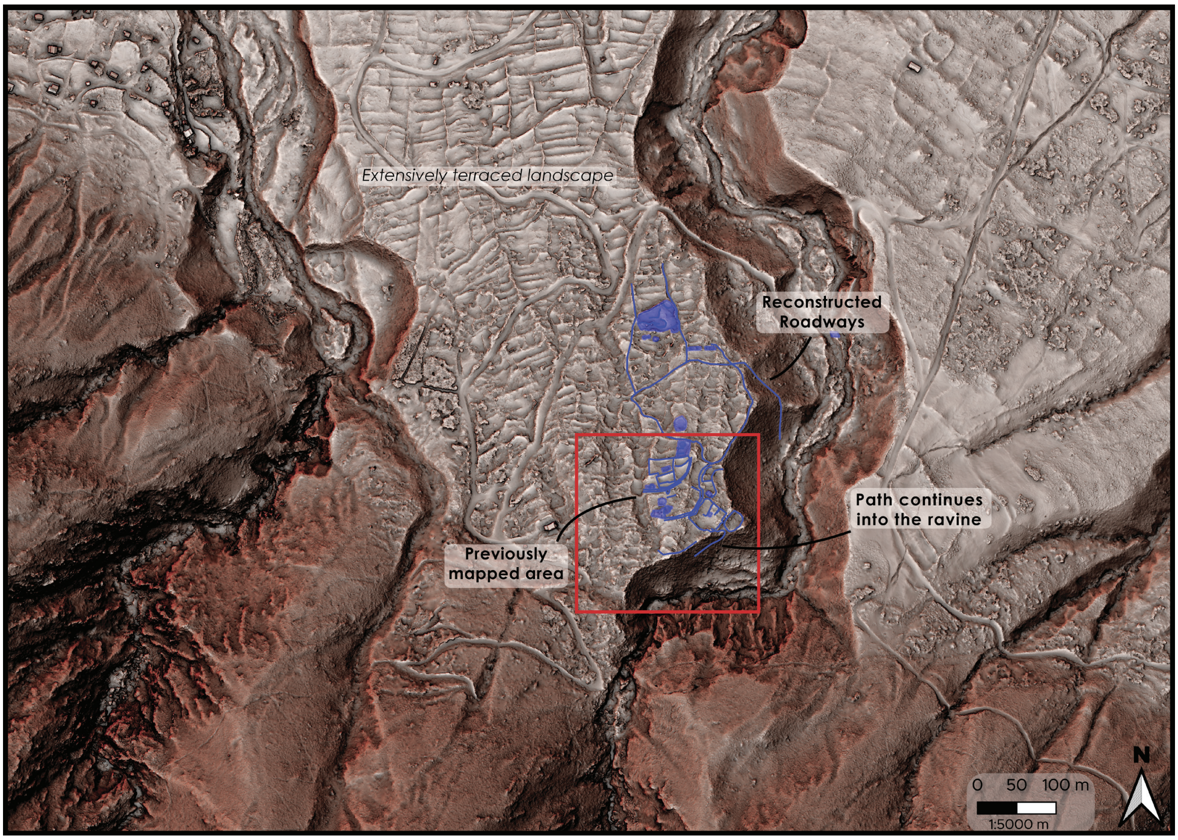

Figure 10. Site of Christos in the lidar visualization. Red square indicates the extent of the orthophoto in Figure 11. Vectors represent features drawn in lidar before and during ground-truthing (SaLiP).

Christos

Christos, an abandoned medieval settlement and associated monastery, is located on the northern coast just east of the village of Therma (Figures 10-11). Set below steepening slope on a broad platform cut by two streams, the Kardelis to the east and Platia to the west, Christos is a warren of ruins, walls, stone piles, terraces, roads, and interlocking enclosures covered in areas by low growing juniper and fern.[44] While preliminary study and mapping of a small portion of the settlement east of the Monastery has been undertaken by Evangelos Papathanasiou, the overall town plan remains obscure.[45] Today, wall collapse and thick fern cover make the site difficult and time consuming to document on the ground. However, in the lidar imagery, the layout of the site, which is composed of a series of terraces, enclosures of various sizes, buildings, streets, and chapels, is more clearly visible.

Our initial work at Christos focused on comparing Papathanasiou's plan to the lidar imagery (Figure 10). We verified structural features and enclosures in the area, and traced streets through the site. Based on this work, we determined that the accuracy of the Papathanasiou map was generally consistent with the lidar data. On the ground, Christos is a complex jumble of walls, stone piles, and ruins. Where the streets are difficult to trace because of wall collapse and fern coverage, they show up clearly on lidar. This has made the process of tracing them far less time consuming.

[44] Biel and Tan 2014: 45: fig. 68 shows garrigue with *Satureja montana* and fern.
[45] Papathanasiou 2015: 569: drawing 8; Papathanasiou 2016: 348-351, 362-363: drawings 7, 8.

Figure 11. Aerial orthophoto of Christos (SaLiP).

Feature Class	True Positive	False Negative	Recall
Wall	43	13	76.8%
Terrace	30	14	68.2%
Channel	24	1	96%
Structure	20	6	76.9%
Path/Road	14	4	77.8%
Enclosure	10	0	100.0%
Threshing Floor	10	2	91.7%

Figure 12. Recall rates for 2024 field season preliminary lidar survey. Note that no false positives are reported because systematic GIS-based survey was not conducted prior to fieldwork (SaLiP).

Water channels

For centuries, an intricate system of channels has been used to deliver water to individual plots, olive plantations, and the water-driven installations around the island.[46] This network was also tied into modern field systems that are now used mostly for fodder crops, pasture, or left fallow. We selected a number of channel systems that displayed clear lidar signals and could be explored easily on the ground. The linear channel paths are often detectable in the lidar visualizations even under dense forest cover. It is often possible to follow the trace of the channel to its catchment, although the catchment itself often is difficult to discern from the stream. Lengthy segments of these channels appear under a mixed canopy of towering planes, walnut, and oak. (Extant sections of the disused water channels (*anegoi*) in Palaiopolis are visible along the Ayia Paraskevi Stream in Figures 5 and 6).

Discussion

Approximately 77% of the 210 features recorded during our ground verification work in 2024 were identified on lidar (Figure 12). Table 1 presents the detection rates by category, omitting classes with fewer than ten instances.[47] The terrace category includes both agricultural and structural terraces. Large constructions or complexes, such as threshing floors or pastoral enclosure systems, were readily visible in the lidar imagery. The enclosure and threshing floor categories are especially exciting in their clear visibility, as these features are key indicators of past pastoral and agrarian livelihoods on the island. Furthermore, the high visibility of water channels and roads demonstrates that lidar imagery will be helpful in reconstructing large-scale patterns of movement – both of people and of water – within the establishment and maintenance of an integrated island landscape.

Categories with lower recall rates tended to have more fragmentary remains, such as the building and terrace fragments on the interfluve south of the Sanctuary or the road curb portions further east. Features on steep slopes are prone to partial burial or collapse as well as occlusion during the acquisition flight. While larger objects are visible under these circumstances, the abundance of small features that are invisible in the lidar imagery demonstrates the limitations of the technique. Similarly, low, dense vegetation like the fern cover at Christos likely lowered the recall rates for the wall and terrace categories.

Future work can adjust data processing and verification methods based on these findings. The area covered by this survey is topographically and ecologically variable, but the lidar points were interpolated into a single, half-meter resolution DFM. Fern-covered sites like Christos have different point cloud characteristics from the low-canopy forest south of the Sanctuary and may benefit from separate processing pipelines. Concerning processing, we plan to explore advanced ground point filtering methods for variable landscapes[48] and selective resolution enhancements where appropriate.[49] Integration of alternative visualization methods may also enhance detection capabilities.[50] Incorporating a systematic GIS-based classification, will allow us to use our findings to plan for a robust classification assessment strategy, such as one that targets steep ridges for higher incidents of missed classifications.[51]

[46] Matsas 2019.
[47] Compare with Manquen *et al.* this volume.
[48] See Doneus *et al.* 2020. They create a ground-filtering pipeline aimed at retaining accurate ground points for archaeology in Mediterranean regions with variable topography and vegetation density.
[49] Štular *et al.* 2021. The 'DFM Confidence Map' is a potential tool for determining the ideal resolution for a given area.
[50] Kokalj and Somrak 2019.
[51] See Garrison *et al.* 2023 for discussion of the variety of field verification strategies for lidar-based archaeology.

Conclusions

In sum, lidar imagery has enhanced our ability to record archaeological features at a larger spatial scale and better understand the built and agrarian landscape of Samothrace in the areas of long-term habitation. Among the advantages offered by lidar technology is the ability to visualize the full course of linear features such as roads, water channels, and pathways that had been obscured by tree cover. By understanding the interconnections between water sources and fields, roads and habitation zones, long-used pathways and different elevation zones, we are building toward a more granular understanding of land use history across the island as whole. We have also been able to target particular areas of interest to develop in greater specificity. While the accuracy of results on Samothrace prove the usefulness of lidar technology for archaeological detection, the preliminary survey results reinforce the necessity of field verification to systematically understand the strengths and limitations of the technology. Different strategies for processing the lidar data and additional seasons of ground reconnaissance are needed to address the challenges of identifying features with low percentage visibility on lidar. Alongside lidar, we have used a UAS to produce orthophotography. We have drawn on satellite data for understanding overall terrain and land cover. Greek Army Geographical Service maps also provide a useful comparison. Combining this suite of complementary high-resolution remote sensing methods with ground data collection has provided an effective strategy for interpreting archaeological objects and their relationships on Samothrace. Our goal is to create a common way for visualizing eight millennia of cultural history across island.

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