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Searching for Neolithic sites in the Bay of Kiladha, Greece

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ABSTRACT

Since the excavations at Franchthi Cave in the 1960s and 1970s, the possibility of finding a submerged Neolithic site in the Bay of Kiladha has been discussed. Initial research, based on marine geophysical survey and core sampling, brought contrasted results. Starting in 2012, new parts of the Bay were investigated, using different techniques and improved methods, such as geological-geophysical survey, further core sampling (including the finding of artefacts and anthropogenic indicators of a given date in the cores), shallow water ERT (with an adapted methodology), and underwater excavation. The combined evidence leads to a reconsideration of previous work, to the discovery of submerged structures directly off the cave, which might well be Neolithic walls, and points to the existence of two new submerged sites, one dating to the Neolithic, in the middle of the Bay, and the other to the Final Neolithic/Early Bronze Age I, at Lambayanna. The implications of these findings are discussed as well.

1. Introduction

Pioneering marine research was undertaken in the Bay of Kiladha (southern Argolid, Greece) in the late 1970s and early 1980s, in relation to excavation at the coastal archaeological site of Franchthi Cave, which has a sequence extending from the Upper Palaeolithic to the Neolithic period. Unusually for its time, the offshore and underwater investigations were conducted alongside the excavation of the cave, to establish the nature of the submerged landscape and its archaeological settlement when sea levels were lower, and to reconstruct changes in the terrestrial and marine resources with progressive sea level rise during the occupation of the cave. This early work included geophysical survey, coring and the discovery of the remains of an underwater Neolithic settlement (Gifford, 1983, 1990; Shackleton, 1988; Shackleton and Van Andel, 1980, 1986; Van Andel and Lianos, 1983, 1984; Van Andel and Sutton, 1987).

With the current momentum of research on submerged prehistoric landscapes (the European COST Action SPLASHCOS largely contributed to this phenomenon, with regular meetings and a series of monographs devoted to the subject: see recently Flemming et al., 2017; Fischer and Pedersen, 2018; Bailey et al., 2020), a new phase of investigations took place in the Bay (and in the eastern Argolic Gulf) between 2012 and 2019 to build on the earlier work, taking advantage of an updated generation of technologies and techniques. This included more detailed mapping of the landscape, coring and shallow water geophysical measures to provide additional information about the nature and location of

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underwater prehistoric finds, and excavation of the recently discovered submerged Early Bronze Age site of Lambayanna (Beck et al., 2013; Beck and Koutsoumba, 2014, 2015, 2016, 2017, 2018, 2019, 2020; Sakellariou et al., 2015; Beck et al., 2017; Surdez et al., 2018). Offshore research was divided in the Bay between the Franchthi and Lambayanna sectors (Figs. 1 and 3).

The aim of this paper is as follows: (i) summarise the results of the 1970s/1980s work and the unanswered questions raised; (ii) set out the methods used in the new phase of work conducted between 2012 and 2019; (iii) present the results of the new work; and (iv) evaluate the wider significance of these results.

1.1. The 1970s/1980s investigations

Franchthi Cave, on the northern shore of the Bay (Fig. 1), was excavated in the 1960s and 1970s by a team from Indiana University, under the direction of T. W. Jacobsen (Jacobsen, 1976; Jacobsen, 1981 for early summaries of the results. More detailed reports have been published in the "Excavations at Franchthi Cave, Greece" volumes by Indiana University Press, and in many scientific articles). The excavation showed a long (if not always continuous) sequence of occupation, spanning the Upper Palaeolithic, Mesolithic, and Neolithic (ca. 40,000–5000 yrs BP). During most of that time (until the very end in fact), the sea level was lower, and in place of the Bay there was a small coastal plain. As the excavators developed an early interest in this and other aspects of the cave's prehistoric environment, research also involved studies in geology, geomorphology, and palaeogeography, as well as water sieving of sediments for palaeobotanical evidence, which was innovative in Greek archaeology back then (Diamant, 1979; Van Andel and Sutton, 1987; Wilkinson and Duhon, 1990; Farrand, 2000).

For the Neolithic period, excavation was not limited to the cave, but was also conducted close by in the "Paralia" area, along the present shoreline. There, cultural remains, including stone structures, were found on a short strip of land at the base of a slope, and overlooking a small pebble beach (Figs. 1 and 2). The nature of Paralia is unclear: the stone structures could be the remains of agricultural terraces or retaining walls; some may even have belonged to domestic structures (Jacobsen, 1976, 1981). In any case, much work was devoted to building them, and they had a lasting impact on the local geomorphology. They undoubtedly belonged to a sedentary occupation, and possibly to the eastern limit of a small settlement, now mostly submerged (Fig. 2: site 4).

This is the hypothesis that led to early research in the Bay, as divers sampled cores there in 1981 and 1985, following a marine geophysical survey in 1979 (Gifford, 1983, 1990; Van Andel and Lianos, 1983, 1984; Van Andel and Sutton, 1987). The coring sites (FC1-2 and OK85/1–12) covered a large area, extending up to more than 500 m from the cave. Charcoal, bone, and cultural material (potsherds, microdebitage, and plaster fragments) were eventually found at the bottom of most of the cores, at the level of the Late Pleistocene/Early Holocene surface that was exposed prior to the marine transgression. The fabric of the datable potsherds was characteristic of the Neolithic period (Gifford, 1990), a chronological indication that was confirmed by radiocarbon dating, with samples ranging from 6670 to 4850 cal BC (Jacobsen and Farrand, 1987: Plate 71).

The 1979 marine geophysical survey revealed the presence of a palaeo-riverbed and river terrace in the small coastal plain, now buried under marine sediments (Fig. 2). In his reconstruction of sea level rise in the Bay, Van Andel, referring to the 1981 and 1985 cores, mentions the discovery of a Neolithic site on the edge of the river terrace (Van Andel and Sutton, 1987). However, a discrepancy prevails, as on his oft-cited plans the site is located ca. 300 m from the cave (Fig. 2: site 1), whereas the highest concentration of charcoal, bone, and cultural material, i.e. evidence of human activity, was found in and around core OK85/1 (Gifford, 1990), ca. 100 m from the shore and 150 m from the cave (Fig. 2: site 2). This controversial issue was never discussed or

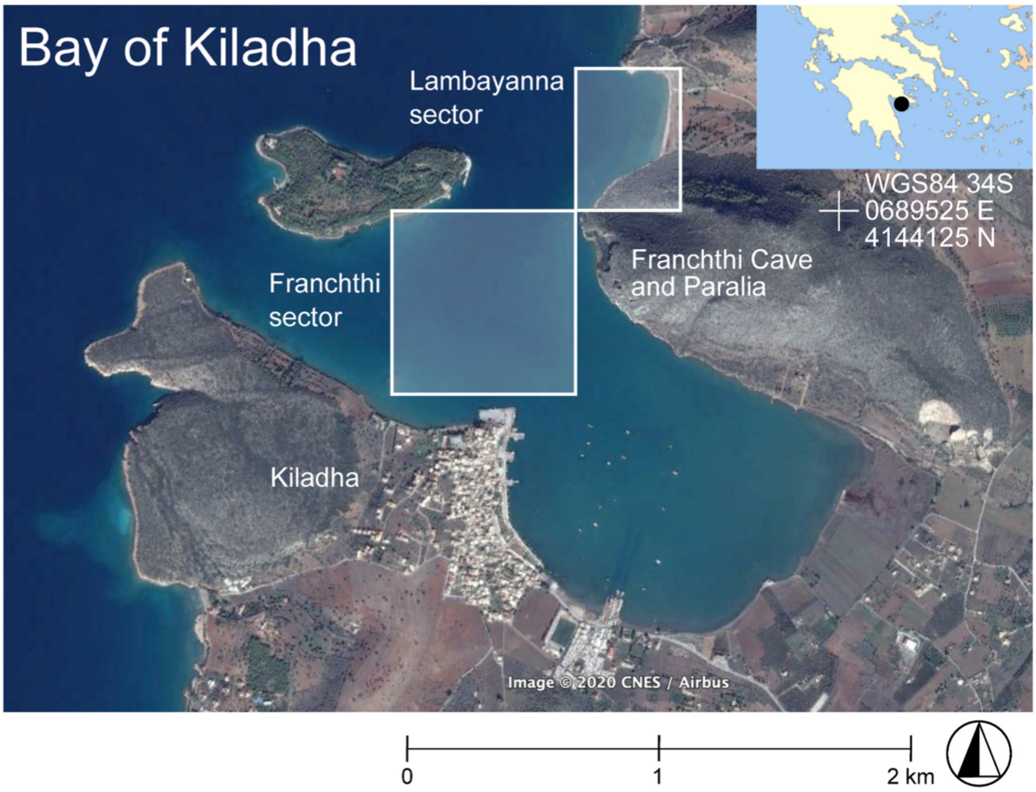

Fig. 1. General plan of the Bay of Kiladha, showing the location of Franchthi Cave and Paralia, as well as the Franchthi and Lambayanna sectors.

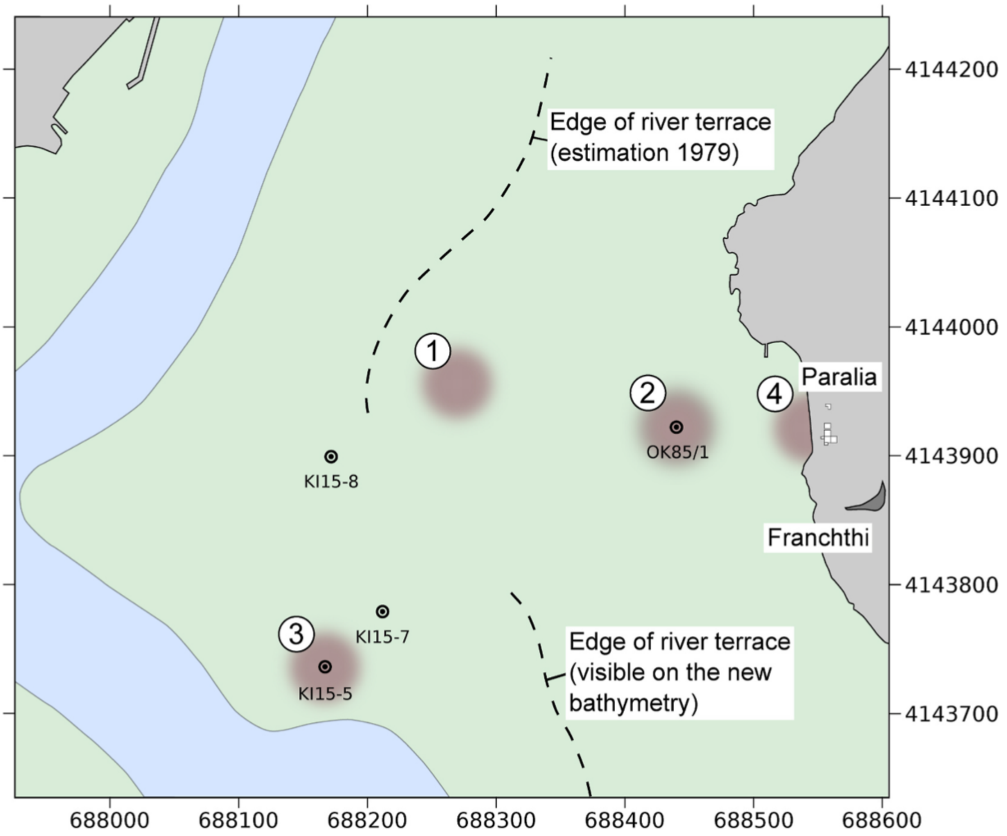

Fig. 2. Bay of Kiladha, Franchthi sector: location of palaeo-riverbed and river terrace, and possible location of submerged Neolithic sites (1 on edge of palaeo-river terrace, 2 in the vicinity of core OK85/1, 3 in the vicinity of core Kl15-5, and 4 directly off Paralia).

solved, and research stopped in the Bay after 1985.

Lastly, a forgotten chapter (the first one, in fact) of underwater research in the Bay took place in 1976, as a dredge was positioned near the cave, ca. 25 m from the shore, and a trench was dug in the marine sediments, down to the level of the Late Pleistocene/Early Holocene pre-transgression surface. Divers explored the trench, and noted the steeper slope of the pre-transgression surface, compared to the modern sea floor. This could mean that there was a small, ca. 20 m-wide shelf directly west of Paralia, now submerged (Beck and Koutsoumba, 2020). In the Neolithic period, the combined shelf and Paralia area would have been an ideal location for a small open-air site next to the cave (Fig. 2, site 4).

2. The 2012–2019 investigations: methods

2.1. Geological-geophysical survey

The survey combined sub-bottom profiling and bathymetry. Research equipment included a Geoacoustics chirp-type sub-bottom profiler (frequency 2–7 kHz) and a swath bathymetry multi beam system (Sea Bat 7125 RESON 200/400 kHz). No noteworthy change of sea level, barometric or tidal, was observed throughout the duration of the survey: measurements of the physical parameters of the water column (temperature, salinity, sound velocity) were carried out almost every day with the use of a CTD and were introduced into the swath bathymetry system to secure high accuracy of the bathymetric measurements.

2.2. Core sampling

Cores KI15-1 to KI15-9 (Fig. 4) were retrieved from a floating platform in the Bay. At each location, a short gravity core was taken first, in order to recover undisturbed surface sediment. Then, a percussion piston-coring system (UWITEC Ltd.) was used to retrieve cores in a 3 m long core barrel. In order to obtain longer sediment cores at some locations, several cores where taken with this system, overlapping by ~~50 cm. The longest core thus reached a sub-sea floor depth of 6.3 m.

Five of the cores (KI15-2, KI15-5, KI15-6, KI15-7 and KI15-8) were then longitudinally opened and photographed with the Sigma 105 mm/1:2.8 DG Macro EX line scan camera of the GEOTEK MSCL. X-ray computed tomography (CT) was performed on four of the cores (KI15-2, KI15-5, KI15-6 and KI15-7) with a Siemens Somatom Definition AS 64 CT-scanner. Finally, 14C-dating was performed on six samples of organic remains, using the accelerator mass spectrometer of the Laboratory for the Analysis of Radiocarbon with AMS of the University of Bern. The ages obtained were calibrated with the IntCal13 calibration curve (Reimer et al., 2013).

2.3. Shallow water ERT

The correct calibration of shallow water ERT (Electric Resistivity Tomography) requires a detailed bathymetric model. For this purpose, a first depth measuring campaign was undertaken off Paralia, in the Franchthi sector (Fig. 1). The absolute coordinates of three points on the coast were logged in the WGS 1984 UTM Zone 34N coordinate system using a differential GNSS (Global Navigation Satellite System) instrument, having a position accuracy of less than 2 cm. These points were used to set up the base station where the EDM (Electronic Distance Meter) was placed in order to map the bathymetry of the sector. The prism was attached to a 4-m pole that was moved along south–north tracks to cover more than 5140 square metres in the sector. Each time the pole was set on a specific point on the sea floor, the elevation

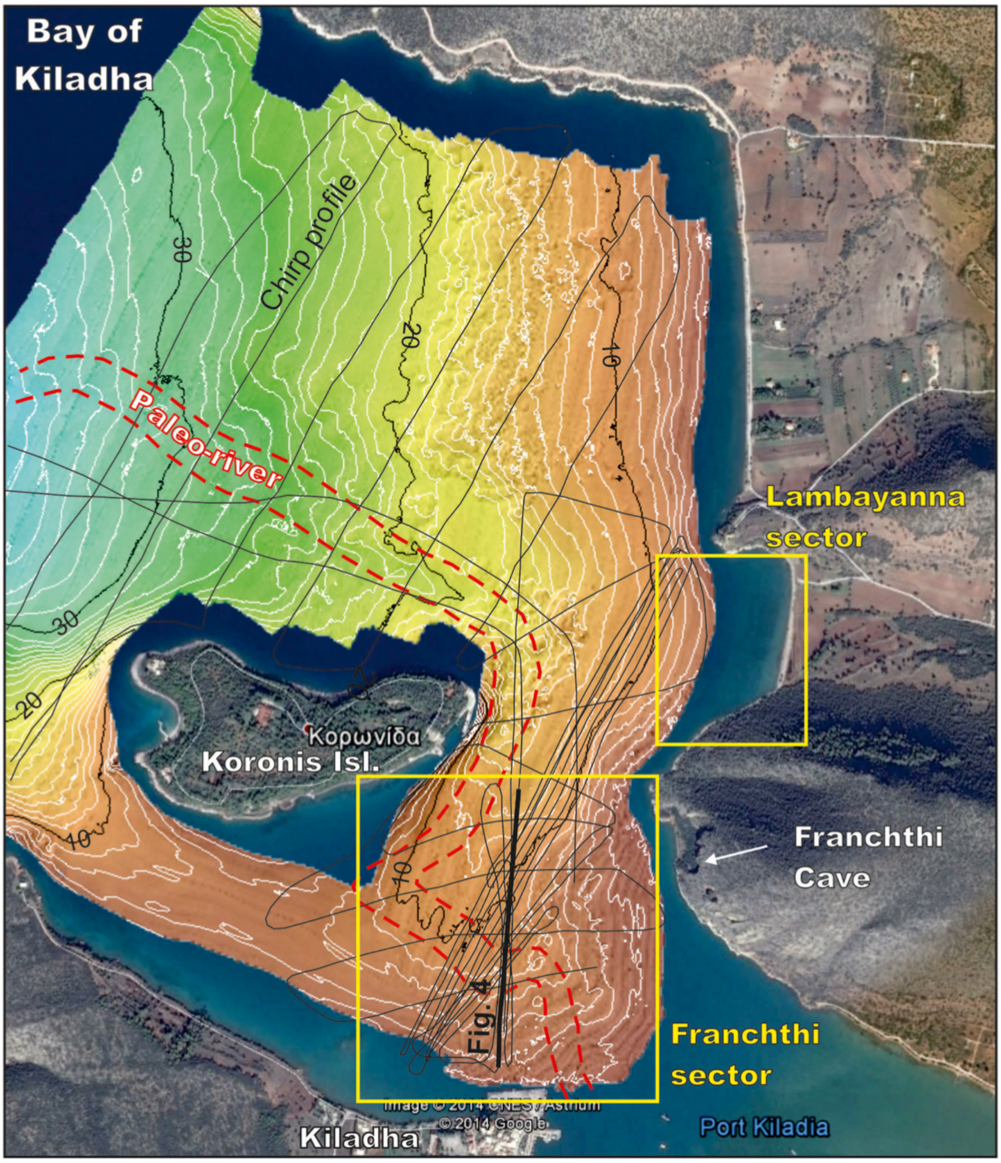

Fig. 3. Bay of Kiladha: swath bathymetry, orientation of sub-bottom (chirp) profiles, palaeo-riverbed and location of the new cores/reconstructed profile.

difference between the said point and base station was automatically mapped. The depth was thus fixed in 3D by the process. Spatial resolution was variable in relation to the actual bathymetric conditions: the shallow part of the sector was mapped with an average resolution of ~1.5–2.0 m, while the deeper part was covered with a relatively coarser step interval (~10 m) due to the difficulties for the operator of moving the pole with the prism in the sea. The bathymetry data points were interpolated using a kriging algorithm with a cell size of 0.1 m and the resulting digital bathymetry model ranged between 0 m above mean sea level (amsl) at the eastern part of the sector and 3.8 m below mean sea level (bmsl) towards the western part, with an average depth of 2.3 m (Fig. 5).

A second depth measuring campaign was later set with the goal of documenting, using new equipment, the deeper parts of the Lambayanna and Franchthi sectors (Fig. 1), where other methods could not be used. An echo-sounder (Ohmex SonarMite BTX EchoSounder v.5) was employed in connection with a differential GNSS system in Real Time Kinematic mode. The complete equipment, mounted on a small boat, allowed the recording of a total area of 217,600 square metres with about 14,000 depth points, spanning from 0 m to −12.7 m at the western edge of the larger scanned area (observed mean distance between points: 1.62 m). The density of transects and, consequently, collected points, was adapted to the expected variation of the sea floor and the specific conditions during the measurement.

These new measurements were then merged with the previously collected data and gridded with the IDW (Inverse Distance Weighted with Nearest Neighbour) algorithm to produce a uniform sea floor digital model. The result is a seamless bathymetric representation for both sectors down to a depth of about −13 m towards the west (Fig. 6).

This bathymetric model was used to correct the ERT data and includes seawater and sea floor effects in the data processing. Since the ERT data collection was completed within a limited time window (less than 3 field days), it was assumed that the effect of tides was negligible. Furthermore, numerical modelling of ERT data has shown that small variations of sea level in the order of 0.2 m have negligible effect on the ERT data corrections and processing.

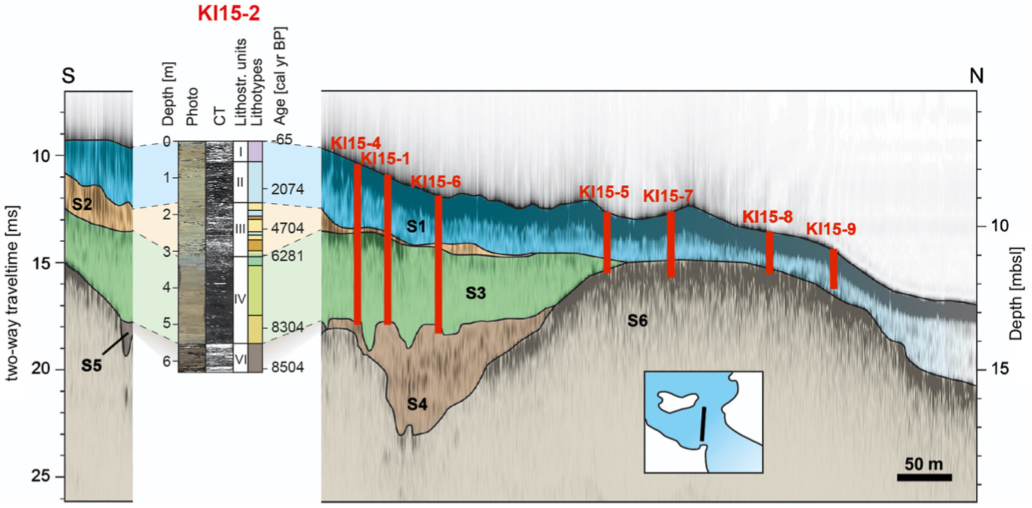

Fig. 4. Bay of Kiladha, Franchthi sector: correlation of core KI15-2 within reconstructed sub-bottom profile; the locations and lengths of the other new cores are also represented; insert shows the location of the reconstructed sub-bottom profile on the map (modified after Surdez et al., 2018 and Sakellariou et al., 2015).

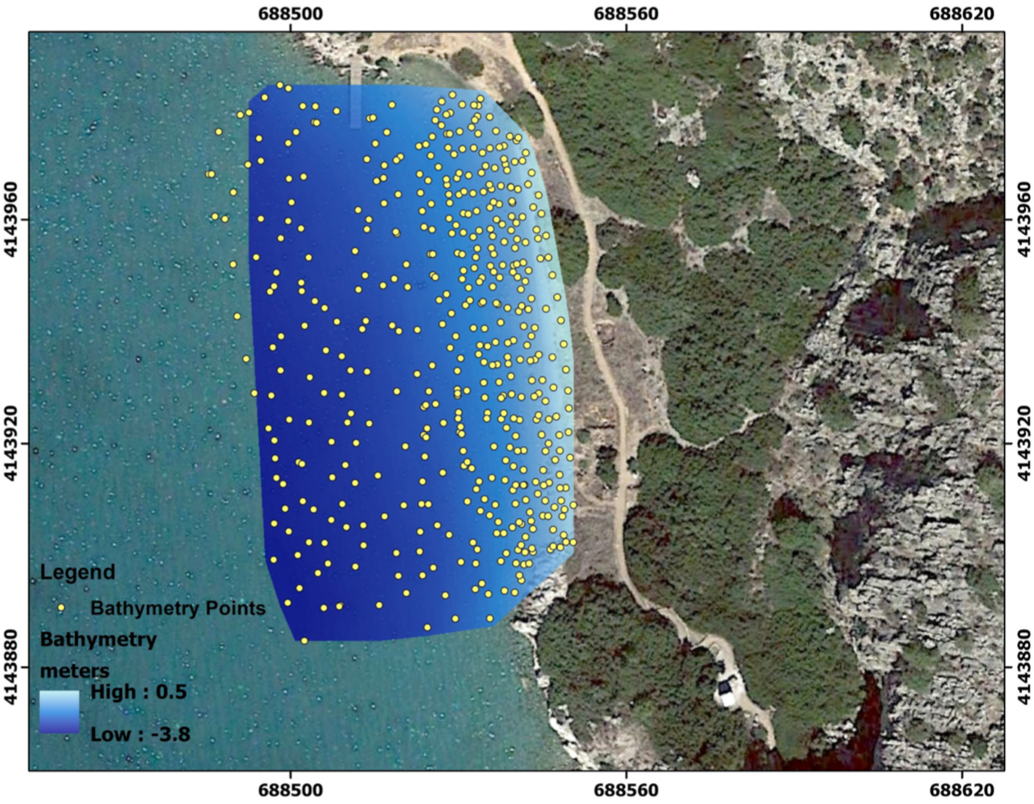

Fig. 5. Bay of Kiladha, Franchthi sector: distribution of the points logged with the total station, along with the corresponding digital bathymetry model.

As to ERT, it consists of a geophysical method capable of extracting information about both the vertical and lateral variations of the subsurface resistivity properties, thus acquiring stratigraphic images for the different soil horizons located below the sea floor. The data acquisition system along a single transect can be viewed as a series of adjacent vertical soundings, with increasing probe separation to reach greater depth. The subsequent implementation of dense parallel transects accompanied by data processing with non-linear three-dimensional (3-D) inversion algorithms can aid in the reconstruction of the submerged resistivity structure in a 3-D context (Simyrdanis et al., 2016).

The static submerged mode, as opposed to floating mode, was chosen to complete the 3-D ERT survey covering a total area of 3055 square metres in the Franchthi sector. The tomographic data were collected along 66 totally parallel 2-D lines roughly oriented in a west–east direction. The inter-line distance was 1 m, and every line was composed of 48 electrodes at an equal distance of 1 m (Fig. 7). In this case, the marine

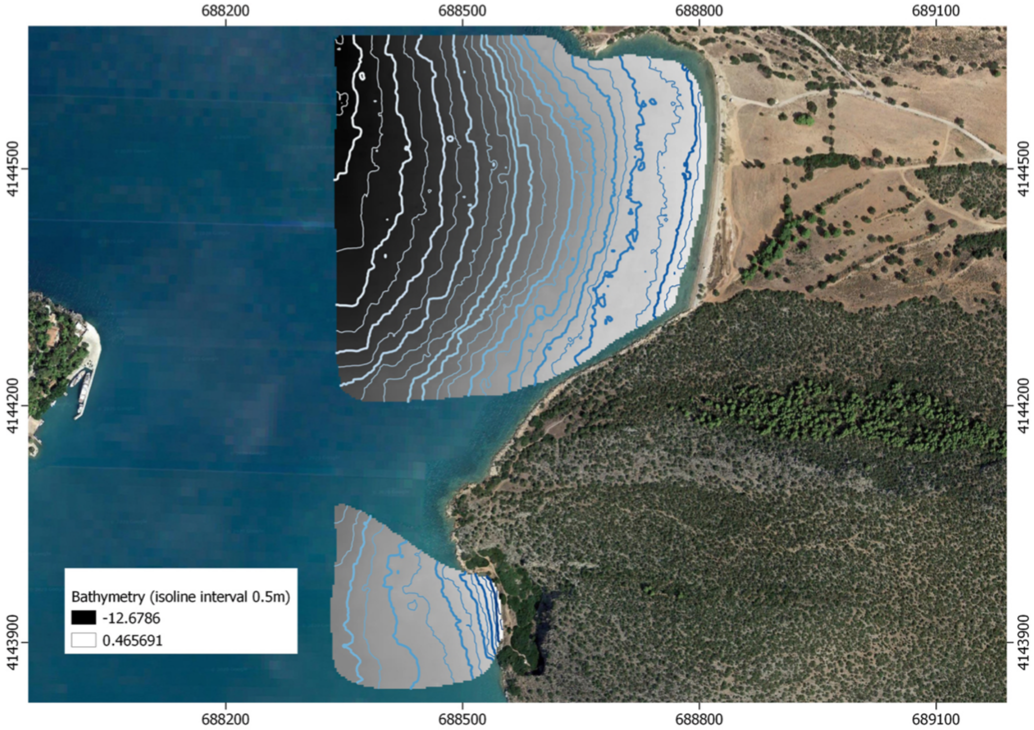

Fig. 6. Bay of Kiladha: bathymetric model (grayscale), with isoline at 0.5 m intervals, over satellite image (Franchthi and Lambayanna sectors).

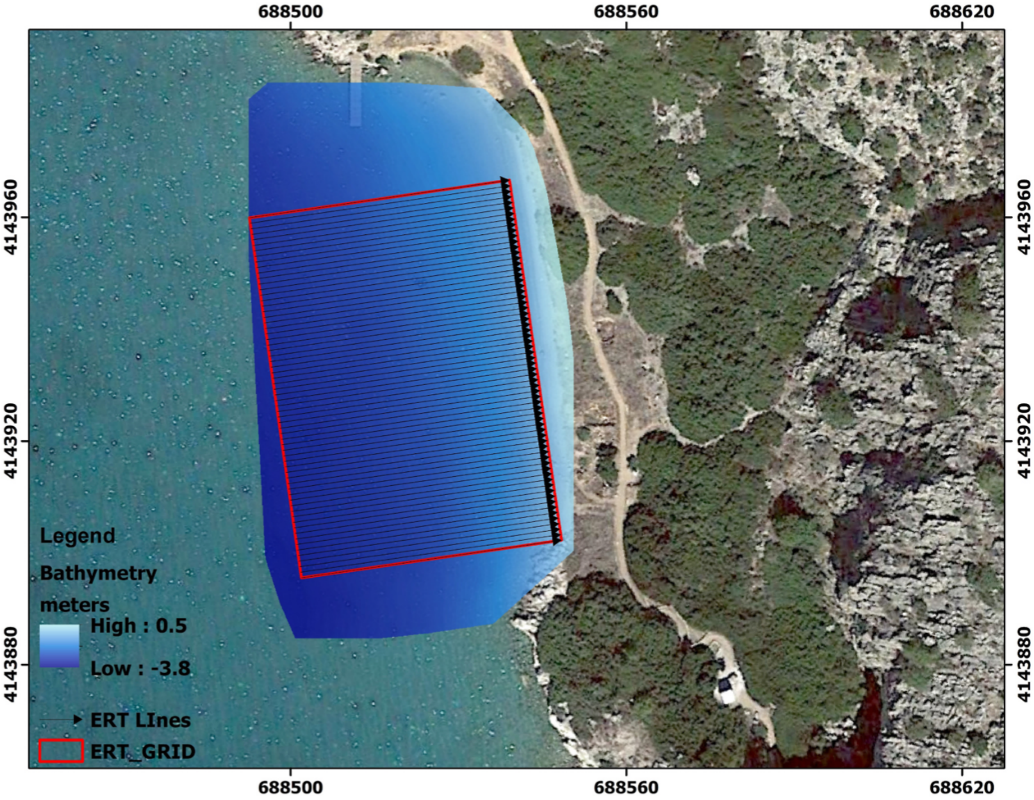

Fig. 7. Bay of Kiladha, Franchthi sector: layout of the grid where the ERT survey was completed, along with the length and direction of the individual 2-D lines.

multimode cable with the respective 48 stainless steel electrodes was attached on the sea bottom along the predefined survey transects. A dipole-dipole protocol was chosen for the collection of the tomographic apparent resistivity data, where multiple combinations of unit electrode spacing (a = 1–5 m) and N separations (distance between the current and potential dipoles N = 1a–6a) were utilized to increase the signal to noise ratio and map the deeper stratigraphy.

The pre-processing stage of the data involved the removal of outlier measurements from the original 78,144 raw data points describing the distribution of the apparent resistivity of the submerged layers in three-dimensions. The applied filters rejected the measurements collected with a current less than 2000 mA and which had a deviation of more than 5%. This resulted in keeping more than 94% (73,600) of the collected apparent resistivity values within the range of 0.17–0.91 Ohm-m. The unique depth value below the free water surface for all the electrodes was extracted from the digital bathymetry model in order to include the topographic variation of the sea floor in the subsequent data processing. The resistivity of the saline water was monitored over the entire field campaign through repeated daily measurements with a high precision and accuracy conductivity meter. The seawater resistivity value proved to be stable throughout the period and equal to 0.17 Ohm-m. Both the seawater resistivity and bathymetry variation were included in the processing procedure to account for the effect of the saline water and topography in the final resistivity images. A robust (blocky) iterative least squares inversion method (Loke et al., 2003) was applied for the deconvolution of the apparent resistivity data.

2.4. Underwater excavation

Two stratigraphic soundings were made at the submerged Early Bronze Age site of Lambayanna (Figs. 1, 8 and 9), at about 35 m from the beach, with the help of a water dredge. For the first one (2016), a 1.5 × 0.75 m trench was excavated, from an average depth of 1.85 m (sea floor) to an average depth of 2.8 m (base of trench). All the sediments from each individual excavation unit, or operation, were sieved (1.5 mm mesh), and the remaining objects directly sorted. For the second one (2017), a 2 × 2 m trench (later restricted to 2 × 1.3 m following the discovery of a wall, and finally to 1.3 × 1 m in its lowest part) was excavated nearby, from an average depth of 1.75 m (sea floor) to an average depth of 2.95 m (base of trench). All the sediments from each individual excavation unit, or operation, went through a two-tier system made of tied plastic crates with fine-meshed sieves (15 mm and 1.5 mm respectively) between them, and the remaining objects were directly sorted.

3. The 2012–2019 investigations: results

The swath bathymetry revealed that the edge of the palaeo-river terrace was still partly visible on the modern sea floor (Fig. 2). As to the sub-bottom profiles, they allow a reconstruction of the palaeo-riverbed (Fig. 3) and geomorphological evolution of the Bay. One reconstructed profile in particular, oriented roughly along a north–south axis (Figs. 3 and 4), shows the major steps of this evolution: S6 represents the palaeo-valley with the riverbed and fluvial terraces on both sides. This is the landscape of the Last Glacial Maximum and Early Holocene, when the sea level was at −120 m and began rising to its present level. The deepest point of the riverbed in this particular profile is at about 19–20 m below the present sea level. During the Last Glacial Maximum, the riverbed in the former Kiladha Valley was about 100 m higher than sea level, with a mean seaward slope of about 1–1.5 per cent as obtained from the sub-bottom profiles acquired in the Bay. This configuration indicates that the river may have been very energetic during heavy rain events and had the potential to erode its valley. When the sea level rose during the Late Pleistocene/Early Holocene and the difference in altitude between the riverbed and sea level began to reduce gradually, the river lost its energy and could no longer erode its bed. During this stage, the river valley was filled with coarse-grained, strongly reflecting fluvial deposits (S5 and S4). When the narrow palaeo-valley was completely filled in, the wider valley began to be covered gradually by fine-grained, acoustically transparent, deposits (S3), similar to the terrestrial deposits of the present-day low plain of Kiladha. By this time, the sea level was only a few metres lower than the depositional palaeo-landscape shown on the sub-bottom profile, probably at about 15–20 m below the present sea level. Note that episodic, abrupt uplift/subsidence events caused by earthquakes and tectonic activity superimposed on eustatic, gradual sea level rise, might alter significantly the “normal” sea level rise curve. S2 represents a strongly reflecting layer, which (a) truncates the S3 reflectors below, indicating subaerial erosion, and (b) marks the deposition of coarse-grained material. The latter may be beach deposits such as beach rock, coarse sand, or even cultural remains. The right end of the layer may correspond to the beach (land to the left, sea to the right), when the sea level was about

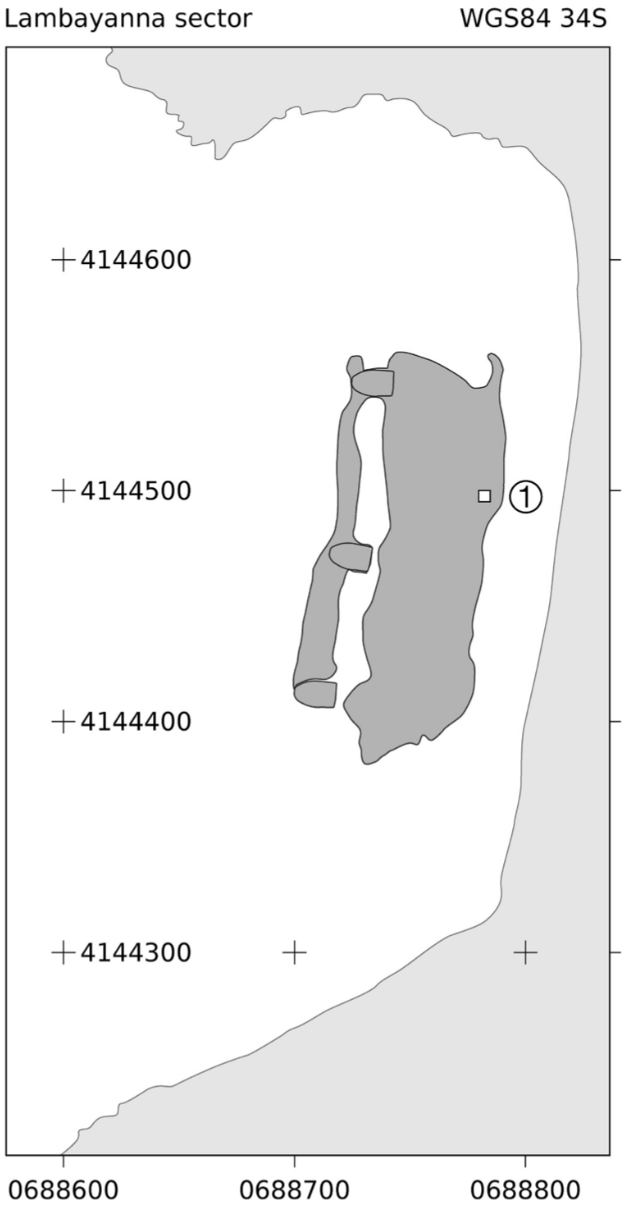

Fig. 8. Bay of Kiladha, Lambayanna sector: extent of visible Early Bronze Age remains on the sea floor, and location of stratigraphic soundings (1).

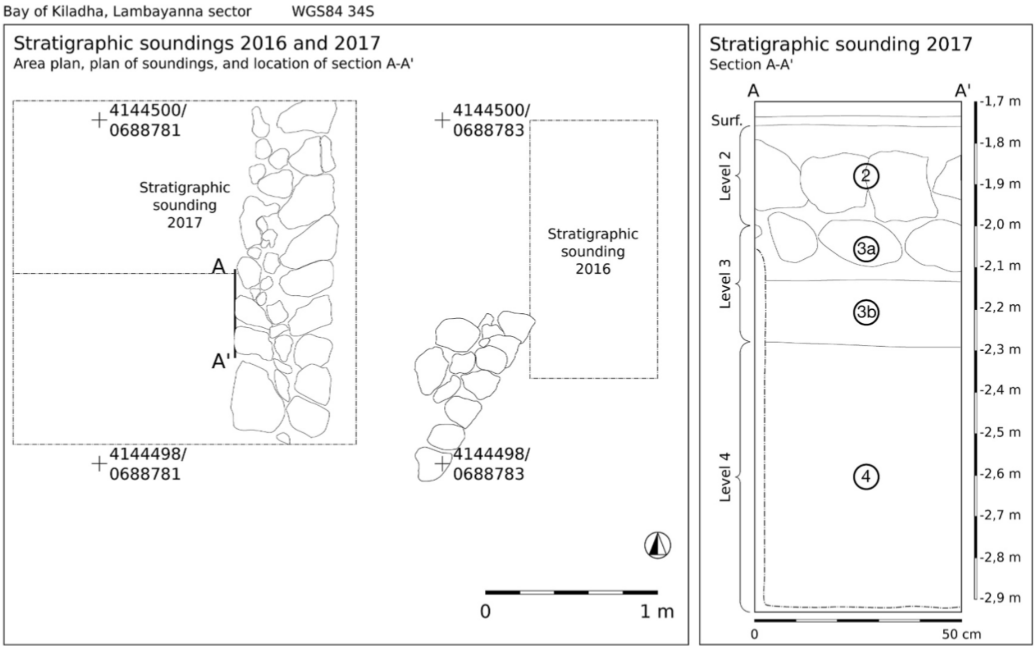

Fig. 9. Bay of Kiladha, Lambayanna sector: stratigraphic soundings 2016 and 2017. Area plan, plan of soundings, and section A-A'.

11 m lower than today. The time range for this level varies from about 10 to 12 to 7 ka, depending on the source used (sea level curve or coring in the Bay, see Van Andel and Sutton, 1987; Gifford 1990; Surdez et al., 2018). S1 indicates the surface that was subsequently covered by marine transgressive deposits, meaning that the former valley was inundated by the sea at about this time.

Based on the analysis of the cores, several lithostratigraphic units (I–VII) could be defined. In combination with the sub-bottom profile units (S1 to S6), they were used to illustrate the evolution of the coastal sedimentary system through time (Fig. 4). The sub-bottom profiles show a buried valley with a terrace (S6) on its northern side. The top of S6 was recovered in cores KI15-5, KI15-7 and KI15-8. It consists mostly of angular limestones (up to 5 cm) with some shells and charcoal pieces in a fine-sand matrix. It can be interpreted as the Late Pleistocene/Early Holocene exposure surface. A small filled depression appears at the southern edge of the valley (S5). The presence of carbonate rubble and gravels of varied lithologies as well as terrestrial plants in a fine dark matrix suggests that this unit was formed in a terrestrial environment with weathering processes. The valley fill was sampled in cores KI15-1, KI15-2, KI15-4 and KI15-6. Two sub-bottom profile units can be distinguished. The lower one (S4) is composed of very stiff clay with coarse sand and is overlain by the silty mud of S3. These sediments were deposited in an estuarine environment. Unit S2, dated at ~6300 cal BP, corresponds to a shell-rich layer and can be interpreted as a marine transgression, caused by sea-level rise. The topmost unit (S1), composed of clayey silt with sand and some marine shells, corresponds to shallow marine sediments, such as are deposited today on the sea floor of the Bay of Kiladha.

Cultural material was found in all the cores that included deposits from the Late Pleistocene/Early Holocene pre-transgression surface (KI15-5, KI15-7, and KI15-8, Fig. 4). In the case of Core KI15-5, a decorated potsherd (dating to the transition between Early and Middle Neolithic, personal communication, K. D. Vitelli) was discovered directly on the platform, at the bottom of the core in the lowermost core-catcher sample. A potsherd was later found at the bottom of Core KI15-8, as well as an obsidian blade fragment in Core KI15-7. The core-catcher sample at the bottom of Core KI15-5 contained more than the decorated potsherd: it was immediately sieved on the platform, revealing limestone flakes, a few pebbles, a small shell and shell fragments, and a smaller, very worn potsherd. The flakes are made of very fine-grained Upper Cretaceous pelagic limestone. At least two of them were involved in knapping activities (personal communication, C. Perlès). This concentration of cultural material (the potsherds and limestone flakes, Fig. 10), so far away from the cave and Paralia (Fig. 2: site 3), cannot be accidental.

For the ERT, the static submerged 2-D inversion resistivity models exhibited an average RMS (Root Mean Square) error of 5.1%, implying a relatively high data quality and increased confidence in the interpreted submerged 2-D resistivity distribution. The combined interpretation of all the 2-D ERT lines from the Franchthi sector (Fig. 11a) resulted in a simplified conceptual model describing the main submerged lithological units there. The area closer to the coastline is characterized by a resistive layer just below the sea floor showing lateral variations registered with resistivity values in the range of 0.7–2.5 Ohm-m. This layer occupies the entire length of the section, and after a horizontal distance of about 27 m, dips to the west with a gentle slope of about 2.5°. As it is closely related to the archaeological deposits in Paralia, any potential archaeological features should be imaged within this layer as more resistive geophysical targets. A more conductive layer, having resistivity values in the range 0.17–0.5 Ohm-m, is correlated with clay material and overlies the aforementioned layer. This conductive layer is visible in the ERT tomographic images after a horizontal distance of ~27 m from the coast (Fig. 11b).

In a second processing stage, the individual 2-D lines were collated to a single group describing the 3-D subsurface resistivity variation and a respective inversion algorithm was used for the deconvolution of the data and the reconstruction of the 3-D resistivity model below the sea floor. The bathymetry information for each one of the 3168 electrodes was extracted from the digital bathymetry model and incorporated within the modelling and inversion procedure. The finite element method was used to solve the forward resistivity problem and a homogeneous half-space was used as an initial model to start the inversion procedure. The submerged subsurface was divided in 6 layers of increasing depth, thus reaching to a depth of ~3 m below the sea floor. The seawater layer was also part of the modelling procedure by constraining the inversion model with its value (0.17 Ohm-m), and its effect

Fig. 10. Bay of Kiladha, Franchthi sector: cultural material (potsherds and limestone flakes) found at the base of core KI15-5.

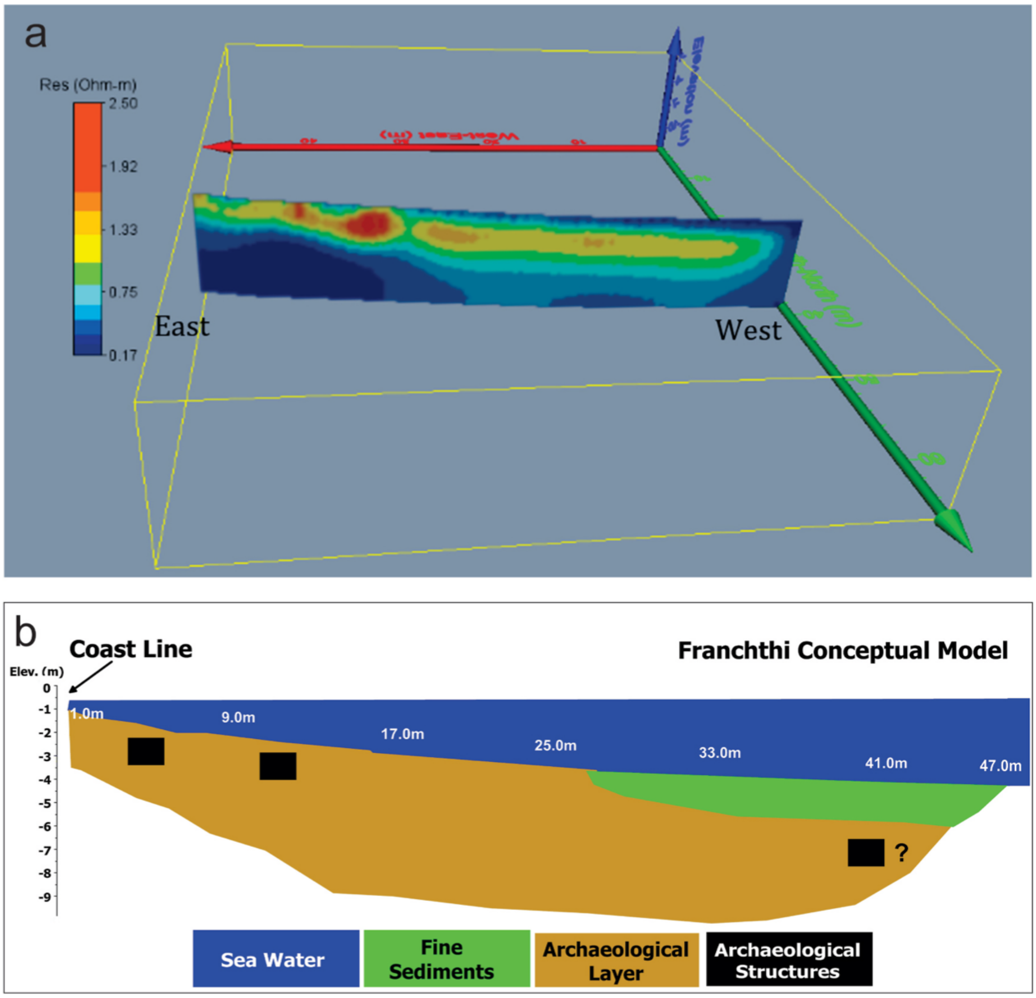

Fig. 11. Bay of Kiladha, Franchthi sector: a) 2-D resistivity distribution along a single ERT line; b) simplified conceptual model of the main stratigraphic units interpreted through the 2-D ERT models (direction east–west). The direction of the profiles is from east to west and the axis scale represents the distance and depth in metres.

was taken into account based on the difference between the free water surface (0 m) and the bathymetry variation below the water surface. The RMS error of the final 3-D inverted resistivity model was 4.0% after four iterations showing the high quality of the collected data.

The horizontal depth slices of 0.25 m, 0.75 m and 1.25 m, with the respective integrated diagrammatic interpretation, were extracted from the 3-D resistivity inversion and registered on the Google satellite image of the Franchthi sector (Fig. 12). The northern part of the area outlines a

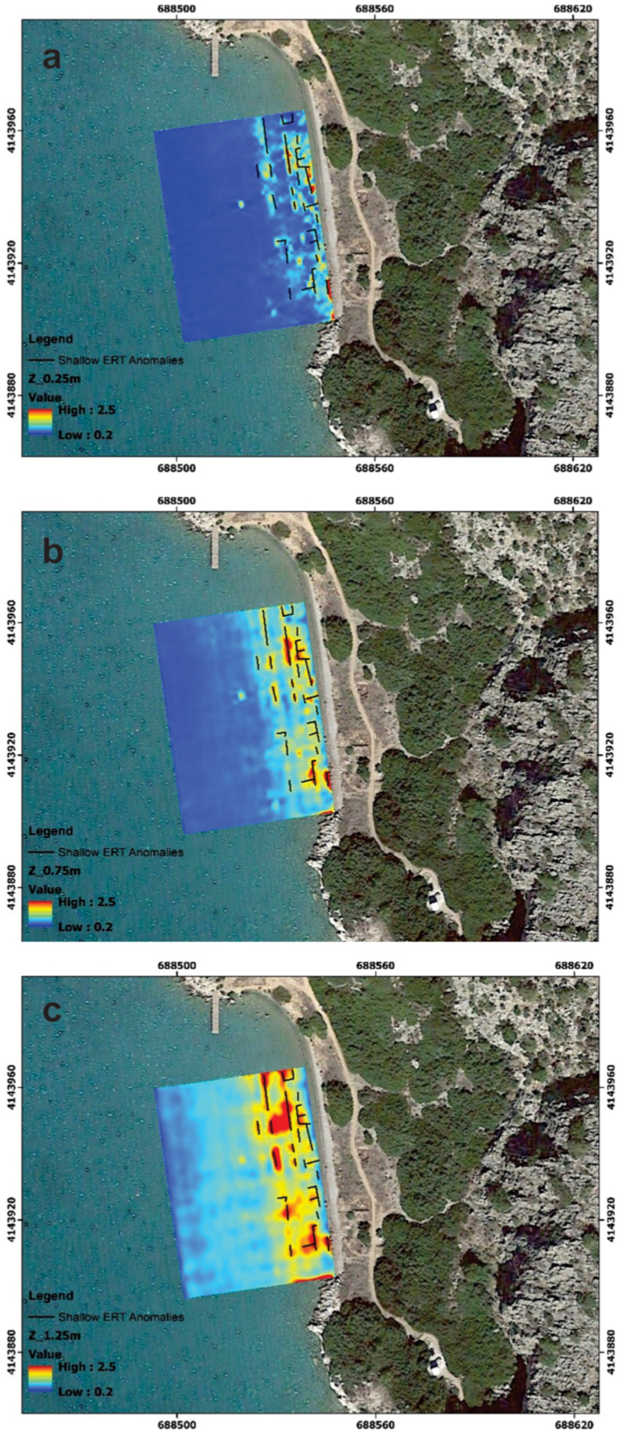

Fig. 12. Bay of Kiladha, Franchthi sector: ERT depth slices registered on satellite image along with the respective diagrammatic interpretation (a: horizontal depth slice of 0.25 m, b: horizontal depth slice of 0.75 m, c: horizontal depth slice of 1.25 m).

significant number of strong linear, rectilinear and rectangular resistive features related to remains of structures or foundation walls. The ERT images also have the resolving capability to discriminate internal divisions within specific features. Furthermore, the density of the possible archaeological targets seems to decrease as we move further to the south. All the resistivity anomalies share a common orientation along a south–north direction, which gives a strong indication of their archaeological origin. The resistivity depth slices down to ~1.5 m below the sea floor show an active resistivity zone related to the archaeological layer, covering the area between the coast and up to a distance of about 20 m to the west in the sea, thus defining the western limit of the Neolithic open-air site that had already been excavated at Paralia.

Concerning the excavation, a careful study of the finds (potsherds, obsidian, flint, seashells, etc.), architecture and sediments is still under way, but judging from a preliminary, integrated and multi-level analysis of the pottery, encompassing macroscopic, petrographic and chemical examination, four stratigraphic levels (Fig. 9, see section A-A') can be identified. Level 1, which appears only in the first sounding, is linked to pit-digging activity that post-dates the Early Bronze Age settlement. Level 2 is correlated with the stone structures (mainly the foundations of walls or buildings) visible on the sea floor, dated to the Early Bronze Age II. Level 3 has two sub-phases, 3a and 3b (3a being linked to the construction of the wall that was discovered in the second sounding, see 3.4 above). Both are dated to the Early Bronze Age I. Level 4 is more ambiguous, as potsherds from its bottommost layers show no sign of incised decorations, a common trait of the local Early Bronze Age I pottery. Their fabric is more homogeneous, and they rather belong to coarse or semicoarse wares, with many, usually large (1–3 mm) nonplastic inclusions. This, and the fact that brown flint was associated with them (whereas there is only obsidian elsewhere), might point to a Final Neolithic date, to be confirmed by further investigations. Interestingly, D. Pullen, in the Southern Argolid Survey (Runnels et al., 1995), mentions that Final Neolithic material is very often found with Early Bronze Age I material.

Due to the relatively low concentration of finds in level 4, it is impossible to know if there is a Final Neolithic/Early Bronze Age I site directly under the Early Bronze Age I-II settlement (levels 2 and 3), or if the site is further away, but in any case it cannot be far.

4. Discussion

The new bathymetry confirms, and gives a more precise location of, the submerged landscape's main features, i.e. the palaeo-riverbed and adjacent terrace (Figs. 2 and 3). The new sub-bottom profiles and cores enable us to better understand and date the dynamics of change in the coastal plain until the marine transgression (Fig. 4), and to suggest a new reconstruction of the evolution of the landscape there (Surdez et al., 2018). In this specific setting, one must start by emphasizing the large quantity of evidence of human activity on the Late Pleistocene/Early Holocene pre-transgression surface. Charcoal, bone, and cultural material was found at the base of most of the 1981 and 1985 cores, and all the related new cores. It is particularly surprising in the latter case, as the probability of finding such evidence in a 6 cm diameter core is very low, and these new cores are located tens or hundreds of metres from each other (Fig. 2). What do these chance finds mean? Obviously, the majority of them could be the product of erosion from the cave or Paralia, or even from a submerged site or sites, whether before or because of the marine transgression, which would almost certainly have a detrimental effect on archaeological deposits, depending on its speed and other factors, as Gifford (1990) discussed at length.

But erosion cannot account for all cases. When there is a high concentration of cultural material at the base of a core, such as in the vicinity of OK85/1 (see above), or in KI15-5 (Fig. 5), we must be on, or close, to a site – a settlement or special activity area.

There are thus at least two submerged Neolithic sites in the Bay, judging from these two cores: one ca. 150 m from the cave, and the other ca. 430 m (Fig. 2: sites 2 and 3). It is impossible at present to know what type of site they were, what was their size, function, and precise date, and therefore if they were contemporaneous or not: we could be dealing with a succession of sites, following the sea level rise in the Bay, for instance.

But archaeological evidence does not only come from cores: the presence of walls up to 20 m offshore of the small pebble beach below Paralia (Fig. 2: site 4), revealed by the shallow water ERT, should it be confirmed, would be perfectly consistent with the existence of a small shelf there. It would also imply an extension of Paralia to the west: what would be, then, its relation to the site in the vicinity of core OK85/1 (Fig. 2: site 2), provided that they were contemporaneous? Was it just one site, sloping downwards from Paralia and the shelf to a distance of at least 100 m westwards?

As to Franchthi Cave, careful study of the finds, notably the pottery (Vitelli, 1993, 1999), led to stimulating questions that remain to be answered pertaining to the occupation of the cave and Paralia during the different phases of the Neolithic, until the abandonment of the site at the very end of the period.

In this context, more research will be needed at Lambayanna to locate the Final Neolithic/Early Bronze Age I site apparently buried directly under (or not far away from) the Early Bronze Age I-II layers. With the sea level rising to its present day position, a shift of occupation from the cave and Paralia, where the space remaining between the slope and the Bay was becoming limited, to better conditions at Lambayanna, would not be surprising. It would be interesting to find out if the Early Bronze Age settlement there is a direct continuation of previous Neolithic occupation.

The new cores also indicate significant subsidence in the Bay, due to tectonic processes in the eastern Argolic Gulf (Surdez et al., 2018), which explains why Lambayanna is now (partially) submerged at a depth of 1–5 m bmsl, whereas eustatic sea level rise should have more or less ceased at the transition from Final Neolithic to Early Bronze Age in Greece, around 5000 yrs BP (Lambeck et al., 2014). Local subsidence could also explain why Salanti, another Early Bronze Age site just a few hundred metres north of Lambayanna, is submerged too, but what about other sites from the same period that are further away, such as Pavlopetri in the southern Peloponnese or Platiyali in Aetoloakarnania (western Greece)? One can think of the long-term subsidence trend in the Aegean Basin as a whole (Lykousis, 2009), and of the resulting submergence of coastlines in the area in recent millennia (Galanidou et al., 2020), as a possible answer (for Pavlopetri at least). In any case, there are potentially many Early Bronze Age coastal sites, and older ones such as Agios Petros (dating back to the transition between the Early and Middle Neolithic), in the Northern Sporades (Flemming, 1983), that are now submerged, and therefore unknown or not easily accessible to research. This could have far-reaching implications for our understanding of Greek prehistory, if one considers the importance of seafaring and coastal sites in early periods, be it for the dispersal of farming and herding at the beginning of the Neolithic, or in the Early Bronze Age context of expanding maritime trade. Such an issue even belongs to the extensive discussion of early seafaring in the Mediterranean, where coastal sites would have been especially important for maritime communities, if the most informative part of the archaeological record for these societies is now under water (see for instance Ammerman and Davis, 2013–2014).

The Bay of Kiladha exemplifies this situation well, with at least four submerged sites belonging to the Neolithic, Final Neolithic/Early Bronze Age I, and Early Bronze Age I-II, as new radiocarbon dating currently makes Franchthi Cave one of the earliest Neolithic sites in Greece (Perlès et al., 2013), and Lambayanna is confirmed as an important Early Bronze Age coastal site.

5. Conclusion

There is currently no evidence for the presence of a submerged Neolithic site on the edge of the palaeo-river terrace in the Bay of Kiladha, contrary to what was previously thought. Conversely, there is substantial evidence, linked to cores, for the presence of two submerged Neolithic sites (settlement or special activity area), one ca. 150 m from Franchthi cave, and the other ca. 430 m, below the palaeo-river terrace. Geophysical measurements also show submerged structures, possibly Neolithic walls, directly off Paralia, close to the cave, and there is potential evidence for a Final Neolithic/Early Bronze Age I site close to or at Lambayanna, with the eventuality that the Early Bronze Age I-II settlement there is in fact its continuation.

These results can only highlight the importance of underwater investigations in prehistoric coastal settings, without which key elements remain unknown. Future research will seek to confirm what was recently found, and continue to focus on the environmental and cultural dynamics at work in the Bay of Kiladha, as well as their interactions.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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