

Reconstruction of the ancient harbours of Menorca: GIS, LiDAR, bathymetry and underwater archaeology (Ciutadella, Menorca – Spain).

1. General information

The **Sanisera Archaeology Institute for International Field Schools**, based in Menorca since 1993, trains students from all over the world in field and laboratory archaeology, with a long track record at the **Roman harbour of Sanitja** and in the underwater survey of its surroundings. This course brings that experience together with the digital tools that now make it possible to study the coast without diving.

The training consists of **reconstructing the ancient shape of several harbours and anchorages of the island** by combining **Geographic Information Systems, LiDAR, bathymetry, aerial and satellite imagery** and the data of the underwater Archaeological Chart of Menorca, and then checking on the ground, on foot and along the shore, whether the laboratory calculations match real remains.

The starting point is the GIS project applied to the underwater archaeology of Menorca carried out in 2020 by F. Contreras and A. Fernández and published in *Virtual Archaeology Review* (13, 27, 2022). That work integrated the 285 elements of the Archaeological Chart with winds, waves, currents and the seabed, classified one hundred anchorage areas according to their quality and proposed an **approximate reconstruction of the coastline around 1000 BC** based on erosion and sea-level rise.

From those results come the **four case studies of the course**. The first two are harbours whose shape has changed markedly: at **Sanitja**, the sea reached much further inland and Roman ships could anchor well beyond what can be seen today; at **Cala Pregonda**, next to the early imperial site of s'Embarcador de s'Alairó, a small harbour may have existed that is now buried or submerged. The other two are areas that the analysis identified as excellent for anchoring but which have hardly any archaeological record: **Cala Tamarells** with the anchorage of Ses Llanes, sheltered by the Illa d'en Colom, and **Ses Fontanelles**, in the Algaiairens area. Both territories offer the conditions for prehistoric, Roman and Islamic settlements that remain to be documented.

In each of the four case studies the course goes one step further and carries out its own **bathymetric survey** of the harbour, cove or stretch of coast concerned,

using a fishing echo-sounder with built-in GPS and an RTK GNSS receiver mounted on a kayak. The same method is applied at the harbour of Sanitja, Cala Pregonda, Cala Tamarells with Ses Llanes and Ses Fontanelles in Algaiarens. The result, for each site, is a digital model of the seabed with depth contours every 0.5 m, georeferenced with centimetre precision in plan and an estimated 10 to 20 cm in depth over sand and rock. This preliminary, low-resolution bathymetry is used to locate anchorages, submerged structures and wrecks, to plan future underwater survey with divers, to support drone photogrammetry in the shallow zone and to join the seabed with the LiDAR of the land in the reconstruction of the ancient coastline.

2. What you will learn

2.1. In the Laboratory

- Documenting anomalies with **LiDAR, GIS, satellite imagery and drone photography** in order to discover structures of harbour sites or sites located on the coast.
- Analysing the **transformation of the coastline**, with rises and falls in sea level and the effect of erosion, through calculations carried out in GIS.
- Building the GIS project for each of the four case studies, starting from the underwater Archaeological Chart of Menorca and adding the necessary layers: bathymetry, winds, waves, currents, historical cartography and orthophotos.
- Processing the soundings recorded at each of the four case-study sites (Sanitja, Pregonda, Tamarells and Ses Fontanelles): cleaning the data, correcting the tide and the sounder offset, and producing a **digital model of the seabed with contours every 0.5 m**, which is then joined to the LiDAR of the surrounding land to reconstruct the ancient coastline and published as a preliminary bathymetry figure.
- Producing orthophotos and 2D and 3D photogrammetric models of the harbours studied from the drone photographs.
- Handling the data with the **Claude AI** tool: organising the information of each case, cross-checking the detected anomalies against the existing documentation and assisting in the writing of the reports.
- Writing the study diary and the final report on the viability of each case, assessing whether the results of the published project have enough scope to plan future survey and excavation phases.

2.2. Theory

- Handling and fundamentals of Geographic Information Systems (**QGIS or ArcGIS**).
- Creation and processing of Digital Elevation Models (topography).

- Pre-processing of LiDAR (Light Detection and Ranging) imagery.
- Detection of archaeological anomalies with LiDAR data, thermal infrared remote sensing and artificial intelligence.
- Introduction to the use of Claude AI in archaeology: consulting bibliography and sources, support in the analysis of spatial data and preparation of documentation.
- Satellite surveying through remote sensing: thermal infrared, near infrared and integration of satellite imagery with Google Earth Engine and GIS.
- Reconstruction of the coastal palaeoenvironment around 1000 BC using LiDAR and Digital Elevation Models.
- Fundamentals of **bathymetry with an echo-sounder and RTK**: how an echo-sounder works, behaviour of the signal over sand, rock and Posidonia meadows, RTK positioning, planning of survey lines and the main sources of error.
- Introduction to seafaring and the ancient harbours of Menorca: anchorages, wrecks and anchoring conditions according to winds, waves and seabed.
- Sources for locating sites: official heritage inventories, historical cartography, online repositories and scientific publications.

2.3. In the Fieldwork

- Visual ground-truthing of the **anomalies detected with the digital techniques**, to confirm or rule out the presence of structures.
- Interpretation of the territory of each harbour or anchorage: relief, streams, sheltered points, access routes and possible associated settlements on land.
- Use of the drone to take aerial photographs and recording of coordinates with GNSS when necessary.
- **Bathymetric survey from a kayak at each of the four case-study sites: the harbour of Sanitja, Cala Pregonda, Cala Tamarells and Ses Fontanelles**, following planned survey lines with a fishing echo-sounder with built-in GPS and an RTK GNSS receiver, with the students taking turns at the paddle, the sounder and the shore control points.
- Preliminary assessment of the archaeological interest of each case with a view to planning survey projects followed by excavation.

3. Directed at

Students and graduates in archaeology, history, anthropology, geography, environmental sciences, nautical studies or related disciplines who wish to add to their training the digital heritage-documentation techniques applied to the coast

and to ancient harbours, and anyone interested in maritime and underwater archaeology who would like a first field experience in Menorca.

No prior knowledge of archaeology or of the software is required, and no diving skills are needed either, since the work takes place in the laboratory, on land walking along the coast and, for the bathymetry of the four case studies, on the surface of the water from a stable kayak in the sheltered waters of each site. Students who take part in the kayak survey must know how to swim. **It is compulsory to bring your own laptop.**

4. Field School life & language

The course takes place at the **headquarters of the Sanisera Archaeology Institute in Ciutadella de Menorca**, where the laboratory is located and where students work on their personal computers. It is a course focused above all on laboratory work. The working day is always **5.5 hours**. During the first week the training concentrates on the technology: GIS (QGIS or ArcGIS), LiDAR, Digital Elevation Models, photogrammetry, satellite imagery and Claude AI, and on the processing of the information generated for each of the four case studies: the harbour of Sanitja, Cala Pregonda, Cala Tamarells with Ses Llanes, and Ses Fontanelles in Algaiarens.

At a more advanced stage of the course the **field trips** are planned, to recognise on the ground the evidence detected in the laboratory. As the course is held in summer, these outings are short and take place first thing in the morning, always finishing by 10.30 am at the latest, before the heat becomes intense. The rest of the working day on those dates is devoted in the laboratory to analysing what was observed and writing up the results, which each student adds to their study diary and final report.

The **bathymetry of the four case studies** follows the same rule. Each site is surveyed in one or two early-morning outings on days with calm sea, starting with the harbour of Sanitja, the most sheltered of the four, and continuing with Cala Pregonda, Cala Tamarells and Ses Fontanelles when the conditions on the north coast allow it, with two students per kayak taking turns while the rest of the group records the control points from the shore. Life jackets are compulsory and the outing is cancelled if the wind or the swell make it unsafe or make the readings unreliable. The soundings are processed in the laboratory that same day and added to the GIS project of each case.

5. Certificates

At the end of the course students receive a certificate of participation stating the hours and the activities completed. Participants with outstanding performance may request a letter of recommendation from the organization.

6. Sessions & Cost

The course lasts **16 days**: the first is devoted to the formal presentation of the programme, the laboratory and the four case studies, eleven are course days and four are days off. **The course is taught in English.**

Sessions	Dates	Cost
Session #1	2027 July 14 – July 29	\$ 2600
Session #2	2027 August 01 – August 16	\$ 2600

7. Course fee includes

- Tuition and teaching.
- Transport on the field-trip days from the headquarters of the organization to the four case-study sites.
- Accident insurance for the fieldwork.
- Certificate of participation.
- Accommodation in an apartment in Ciutadella, in rooms shared by people of the same sex, with wifi, kitchen, bathroom and living room.
- [In case of needing to process a Schengen Visa](#), the mandatory letter of invitation will be written so you can travel.

Airfare not included from the student home to/from Menorca (Spain).

Meals are not included, although we will recommend some cafés and restaurants that do not exceed the average of 23 € /day in meals.

*** If you sign up for two sessions in a row that take place in Menorca, the days between sessions (2 days) you will have the accommodation for free.**

8. Spaces available

The course is limited to **6 participants per session**, according to the capacity of the laboratory and the accommodation. Reservations are only effective once payment of the registration fee is received. If for any reason the course is cancelled, the amount is refunded in accordance with the field school's refund policy.

9. Information and reservations

For more information, contact:

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