INTREMEDIARY REPORT 2019

UNDERWATER EXCAVATIONS ON THE SITE OF THE PHAROS

Scientific directors of the site of the Pharos : Isabelle Hairy. Operations manager: Mohamed El-Sayed.
Participants : Ismaël Awad and Cécile Shaalan (topography service); Philippe Soubias and Mohamed Abd El-Aziz (photogrammetry); Sherine El Sayed Ismail El Sayed and Aly Sayed Aly Mohamed Ahmed El Dabaa (technical managers); Philippe Soubias (photographer); Ashraf Hussein Gomaa Aly Salam, Tamer Mohamed Abdel Salam Bassiouny, Wael Mostafa Mohamed, Hassan Yasser Galal Abdel Rehim Aly (CEAlex divers); Ahmed Abdel Fattah Rashwan, Mahmoud Metwali Khalil and eight workers (land team).
The MoA was represented by Mohamed Abd El-Hamid El-Sayed and Mona El-Hadidi (from 25 September to 14 November), Marwan Fathi Gomaa and Mohamed Mahmoud Ali (from 14 November to 12 December)
The officer of the Egyptian Navy was the chief sergeant Mohamed El-Sayed Mahmoud
The underwater excavations of the CEAlex benefited from the support of the Honor Frost Foundation.

The 2019 underwater mission took place between 25 September and 12 December 2019, with very favorable weather conditions until the beginning of December: diving was possible on 52 of the 56 days of mission. The construction of a breakwater that has been taking place since 2018 to the west of the site has caused some visibility issues (clouds of sand). However, at this stage of construction, this drawback is offset by the protection gained during episodes of swell from the west-northwest direction over the western area of the archaeological site. The work programme was divided into several areas: photography for the digitization of the site, photography of fragments or pieces of architecture and statuary for their 3D modelling by automatic digital photogrammetry, the cartographic revision of a parts of zones 2, 3 and 4, mapping of new blocks in zones 2 and 3 located to the northeast of the site, surveying for areas not mapped in the northeast.

The digitisation of the underwater site

In the field, work on the digital surface model (DSM) focused on the southeast area of the site, from the stretch of dyke that protects Fort Qaitbay to the west dyke of the eastern port of Alexandria. This includes photography[1] and the setting up of reference points which are used for georeferencing the DMS. About 4023 m^2 were covered during this campaign (fig. 1). This area was a priority, not in terms of study, but because of the protection works at Fort Qaitbay that are underway.

[1] The camera used is a Nikon D700 with a 24mm lens

In order to calibrate the DSM, measurements by tacheometer were taken[2] on the 3 pivot points, then on the 30 reference points established during this campaign, as well as on a few points placed during previous campaigns in zone 2 and on the spit of sand which adjoins it to the south (fig. 1). The surveys were carried out from the quay north of Fort Qaitbay on which the tacheometer was set up, which was aimed at the prism installed on the buoy moved by the divers vertical to the points to be measured. In all, 40 support and pivot points were surveyed and positioned. Each point was subjected to 10 measurements from station 2206, in order to reduce the margin of error of the final coordinates calculated at the office from an average of the measurements retained, having excluded outliers. It should also be noted that the CEAlex topography service took advantage of the mission to update the background map of the surroundings of the underwater site at the quay located north of Fort Qaitbay.

For photography, certain areas required special devices because of their shallow depth and the poor visibility caused by the clouds of sand raised by the breakwater construction work. Wires were stretched to encircle sections of land of around 200 m^2 in which tape measures and graduated rulers were deployed to create as many visual points of reference as necessary. For the areas partially covered by the concrete blocks of the submerged dyke protecting the north flank of Fort Qaitbay, which have a complexity linked to their significant differences in height (2.50 to 7 m deep) and for the fringes between the rock and sand areas, image overlap bands of up to more than 80% have been made. In the south-eastern area, near the harbour dyke, the difference in depth varies from 1.60 m to 5 m, with large sandy areas in which it was necessary to have additional markers in the form of small stones scattered on the uniform surface of the sand. The reduced visibility at this location, especially at the end of the mission where the swell was more present, forced the team to postpone the completion of this area until the next mission.

The photogrammetry of the area covered during this mission was carried out using a total of 32,713 photographs, divided into two batches to adapt to the processing capacity of the computer (fig. 2, A & B). The average RMSD[3] after processing is around 0.085 m; it was with this average that the final orthophotograph was produced, which was inserted into the site's GIS, now managed using QGIS software (fig. 3, A & B). The GIS for the Qaitbay site was previously managed using MapInfo software. The old files are being converted to be integrated into QGIS, the software used to create the new site map.

[2] Three operations were carried out by the CEAlex topography service during this mission.

[3] Root-mean-square error or Root-mean-square deviation (RMSD) in English, is used to estimate the observed values – here the deviations of the DSM after its calibration from the support points.

The MNS now covers a total area of ca 10,250 m2, which represents approximately 65% of the archaeological site that, according to the new estimate given by the redefinition of its boundaries during this mission[4], is ca 15,910 m2 (fig. 4).

Revision and additions to the cartography

The orthophotoplan produced from the site's DSM, grouping together the material from the missions of 2014, 2015, 2016, 2018 and 2019, served as basic data for the new underwater site map developed under QGIS (fig. 5). It constitutes a very precise database, without crossfall relief, therefore without concealed area. It integrated the base layer of the Geographic Information System (GIS) on which was superimposed the old map of the site, with all its layers produced in MapInfo from 1994 by more conventional means of topography that generated a large number of small positioning errors and an approximation of the contours of the blocks and the relief.

The work in progress consists of identifying on the orthophotoplan the blocks present on the old map, so as to create, by manual vector digitalization of the analyzed data, their precise outline for a new map, linking the block represented and information about it. This method of going back and forth between orthophotoplan and old map allows us to redo the site map, to vectorize the data in detail, by defining and identifying precisely the land use and more particularly the natural relief, and locating it. It also offers the opportunity to correct cartographic oversights, and to note the transformations of the site's topography from one year to another over the past 25 years, due to erosion, exceptional climatic events, or anthropogenic damage.

New block layouts

37 new blocks were recorded and mapped during this campaign (see fig. 5), so the descriptive block database includes on 1 January 2020, 3,040 whole or fragmentary blocks, of architecture or statuary.

Photogrammetry of pieces or fragments of architecture and statuary

29 blocks belonging to six different sets were located, cleaned and photographed, first on one side, then after turning the block, on the other side. 2 numbers (CEAlex 2308 and 4318) among the processed blocks could not be turned to complete their photography; this work will be finalized during the 2020 mission. Here are the details of the numbers classified according to the major groups to which they belong:

[4] The site was estimated to be around 1.3 hectares before 2019.

Fragments of a monumental honorary column (17 components):

- Smooth fragment of a column shaft: CEAlex 2089 (fig. 6, A & B), 2139, 2385, 2924, 4220, 4235, 4267, 4284, 4500

- Pedestals: CEAlex 2090 (fig. 7, A & B), 2422,

- Base fragments of an acanthus leaf column: CEAlex 2091, 2092 (fig. 8, A & B)

- Foundation blocks: CEAlex 2308, 2428, 2443, 2789

Cornice block (1 piece): CEAlex 5126

Heart-shaped pier (3 pieces): CEAlex 1411, 4318 (fig. 9), 6500 (fig. 10)

Base blocks (4): CEAlex 507, 1600, 1700, 6058

Sarcophagus fragments (3): CEAlex 2009, 2389, 2762

Decoration fragment (1): CEAlex 9000 (Fig. 11)

Once the 29 blocks have been processed, they will join the 125 blocks (53 submerged on the underwater site and 72 salvaged) already available in 3D, in different finished states.

Salvaging a fragment of decoration

During the survey of the areas extending to the north of the current site, in order to find the limits of the site on the side of the open sea and to assess the areas remaining to be mapped, two unusual small fragments (CEAlex 9000 and 9001) have been identified: these are small blocks cut from very hard white limestone. Buried in the sand, they withstood aggressive attacks from the marine environment.

The CEAlex 9000 block (see fig. 11) is a fragment of a decorated wall (8 cm thick) with strips parallel to each other a few centimeters wide, which is undoubtedly part of a winged solar disc decoration. Its morphology suggests that certain walls could have been covered by a decorated limestone veneer. Small in size, it was extracted and moved in order to be photographed. At the end of the mission, a decision was made to salvage it, because of its decoration and its low weight (less than 20 kilos). With the agreement of the inspectors of the Alexandria Department of Underwater Archeology, it was transported to the Shalalat excavation warehouse in Alexandria where it was taken care of by the CEAlex conservation team.

Presentation of the Underwater Photogrammetry digital surface model

Mohamed el-Sayed and Mohamed Abdelaziz, both inspectors of the Ministry of Antiquities of Egypt and associate researchers at the CEAlex have presented the

methodology and aims of the Underwater Photogrammetry digital surface model of Qaitbay site at the Colloquium "Underwater 3D Recording and Modelling A Tool for Modern Applications and CH Recording", held in Limassol (Cyprus) in May 2019. Their inscriptions to this manifestation and mission costs have been supported by the HFF grant. Their contribution is available on line (https://doi.org/10.5194/isprs-archives-XLII-2-W10-1-2019) and provides step by step the methodology which was used and the difficulties that had to be faced.

Publications

Mohamed Abdelaziz, Mohamed Elsayed, « Underwater Photogrammetry digital surface model (DSM) of the submerged site of the ancient lighthouse bear Qaitbay fort in Alexandria, Egypt », in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XLII-2/W10, 2019 Underwater 3D Recording and Modelling "A Tool for Modern Applications and CH Recording", 2–3 May 2019, Limassol, Cyprus
https://doi.org/10.5194/isprs-archives-XLII-2-W10-1-2019

Jean-Yves Empereur, Isabelle Hairy, « Honor Frost and the Pharos : the Lighthouse of Alexandria », in Lucy Blue (éd.), *In the Footsteps of Honor Frost. The life and legacy of a pioneer in maritime archaeology*, Leyde, Sidestone Press, 2019, p. 183-198.

Captions:

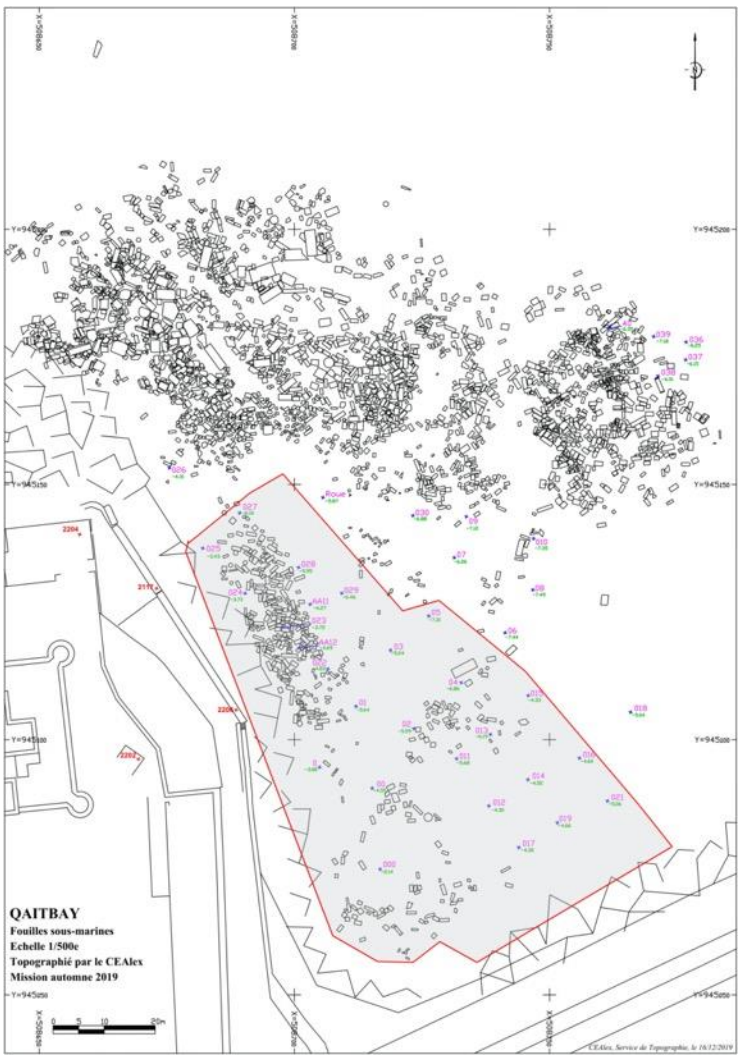
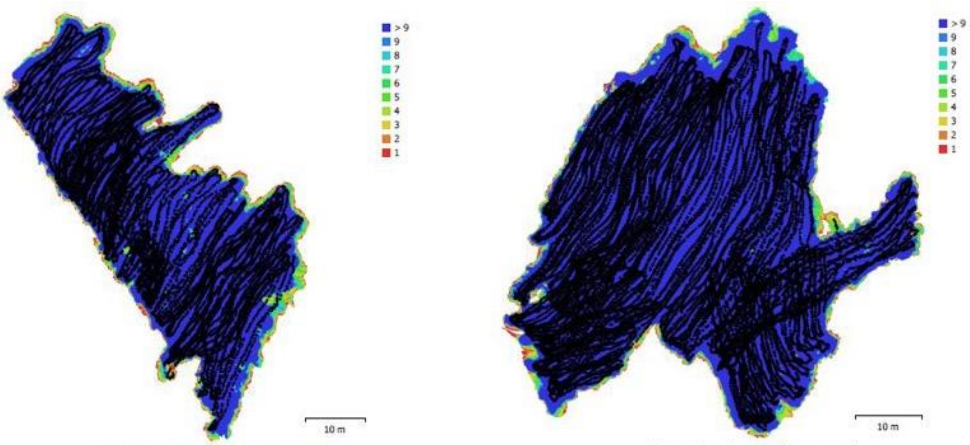
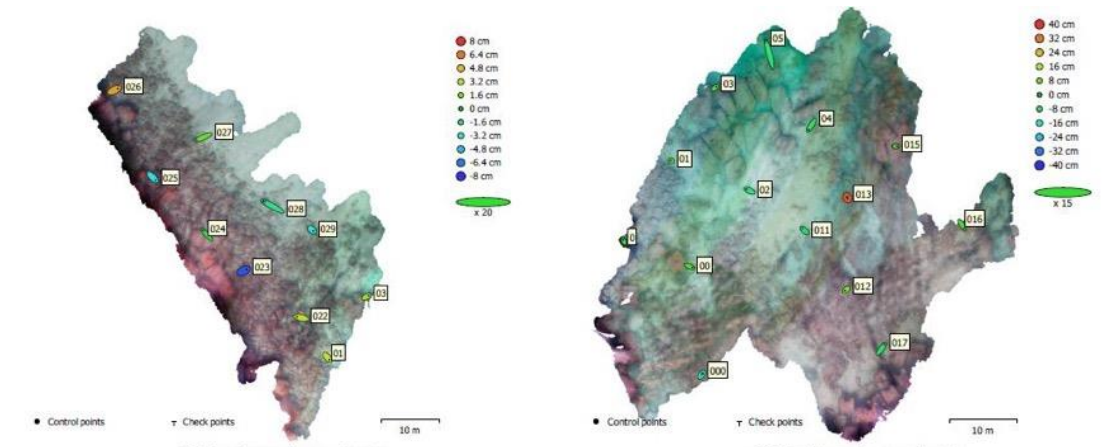


Fig. 1 - Photogrammetry area for the 2019 mission – map by I. Awad



Number of images:	11,334	Camera stations:	11,318	Number of images:	21,384	Camera stations:	21,335
Flying altitude:	1.88 m	Tie points:	27,334,599	Flying altitude:	1.74 m	Tie points:	46,374,313
Ground resolution:	0.626 mm/pix	Projections:	79,423,153	Ground resolution:	0.628 mm/pix	Projections:	127,964,325
Coverage area:	1.58e+03 m²	Reprojection error:	0.605 pix	Coverage area:	2.3e+03 m²	Reprojection error:	0.753 pix

Fig. 2 - Position of the shots on the intervention area (divided into 2 parts) – map by I. Awad and M. Abdel Aziz



GCP locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated GCP locations are marked with a dot or crossing.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
9	6.19104	3.85741	3.98756	7.29443	8.3132

Control points RMSE.
X - Easting, Y - Northing, Z - Altitude.

. GCP locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated GCP locations are marked with a dot or crossing.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
11	4.25673	4.74163	5.65956	6.37203	8.52252

Control points RMSE.
X - Easting, Y - Northing, Z - Altitude.

Fig. 3 - Position of the support points for the georeferencing of the orthophotography and display of the errors in X, Y and Z in the intervention area (divided into 2 parts) - maps by M. Abdel Aziz

Fig. 4 - Insertion of the underwater site ortophotography on the aerial view of the tip of the Pharos peninsula - map by M. Abdel Aziz

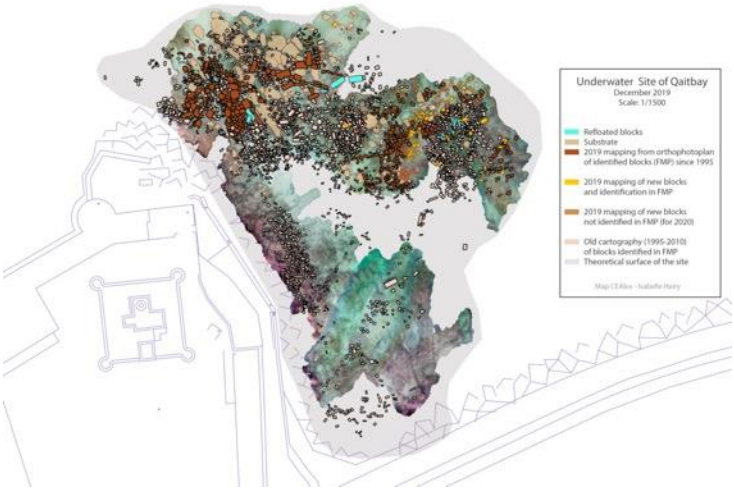


Fig. 5 - The GIS on the underwater site as of 31.12.2019 – Map by I. Hairy

Fig. 6 A & B - Fragment of the CEAlex2089 column barrel - photo and 3D by P. Soubias

Fig. 7 A & B - CEAlex 2090 white marble statue base - photo and 3D by P. Soubias

Fig. 8 A & B - Fragment of a column base with acanthus leaves in granite CEAlex 2091 - photo and 3D by P. Soubias

Fig. 9 - Fragment of the CEAlex 4318 heart-shaped pier - photo by P. Soubias

Fig. 10 - Fragment of the CEAlex 6500 heart-shaped pier - photo by P. Soubias

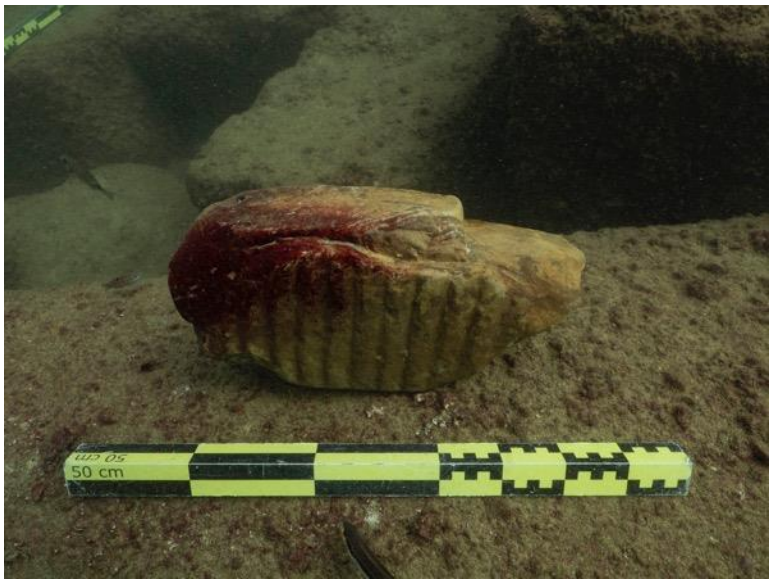


Fig. 11 - CEAlex 9000 decorated limestone fragment - photo by P. Soubias