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HYDROGRAPHIC SURVEYS AS AN ART OF DELINEATING THE IMPACT OF CLIMATE CHANGE ON THE COASTAL ENVIRONMENT

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Towards a SUSTAINABLE BLUE ECONOMY

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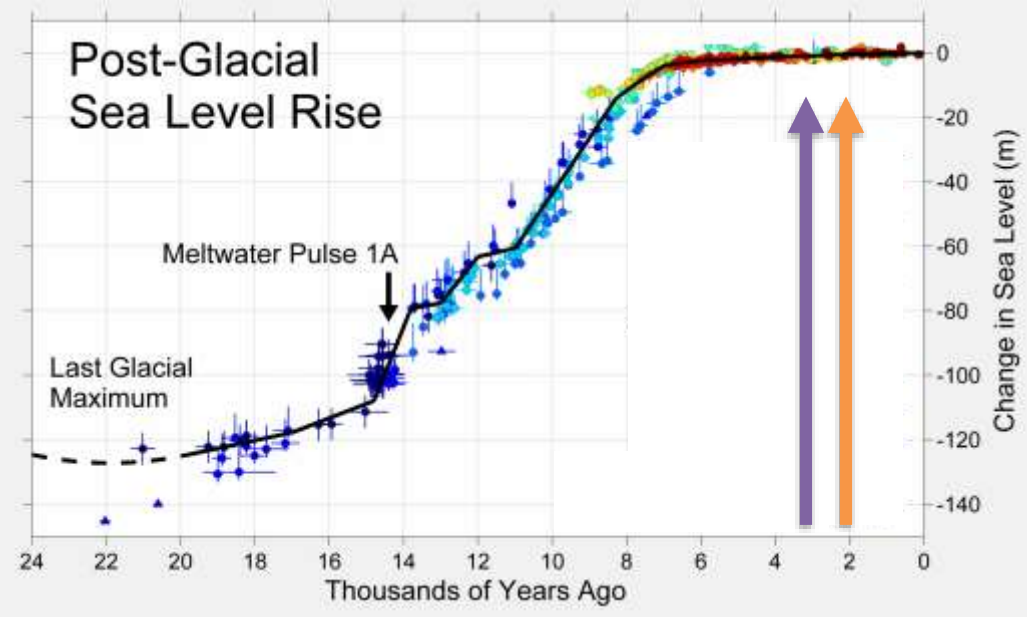
Climate change

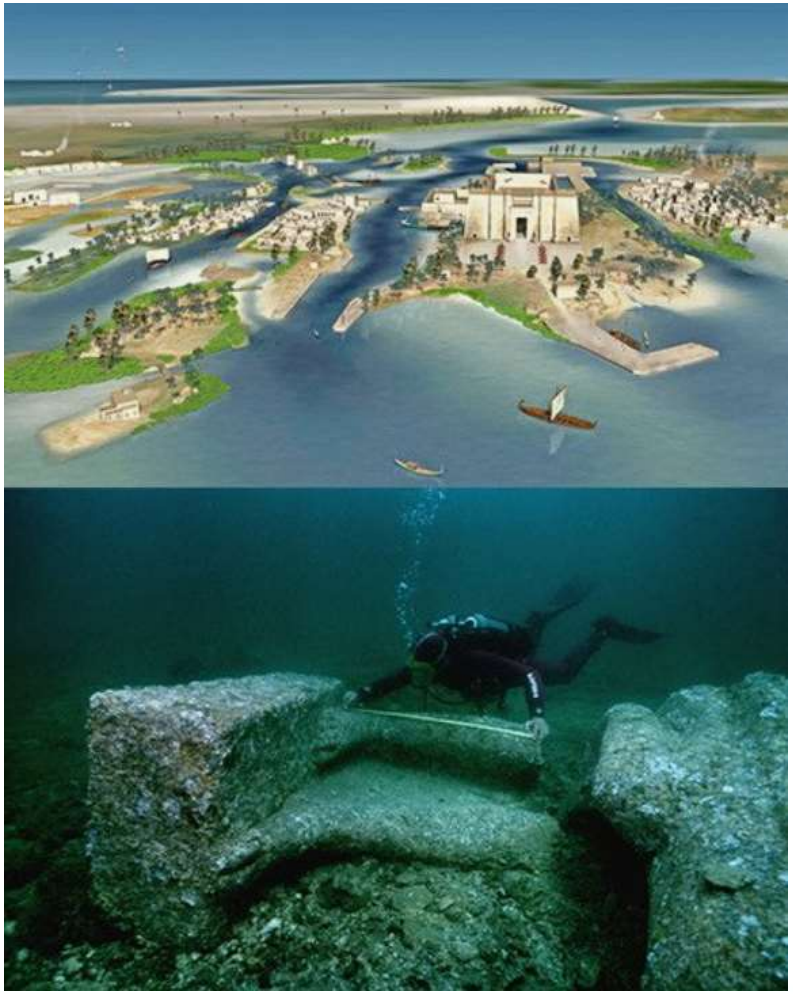
Climatic change is considered as the forcing factor for the eustatic sea-level-rise along the Mediterranean coast.



2K-3K ya : Not exceeding 0.5 mm/yr

- During these periods, the majority of the coastal installations of ancient Alexandria were totally submerged under the sea level and the shorelines were eroded.

- These observations indicated that the sea level rise occurred due to climatic and non-climatic factors, or combination of both factors.



Recently, waves of violent weather hit the coast of Alexandria on October 2015 and reoccurred on November 2021.

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Materials & Methods

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Hydrographic and marine geophysical surveys were carried out to delineate the coastal geomorphological changes associated with sea level rises and natural hazards along the coast of Alexandria (Eastern harbor) during the last two millennia.

Local Historical Evidences

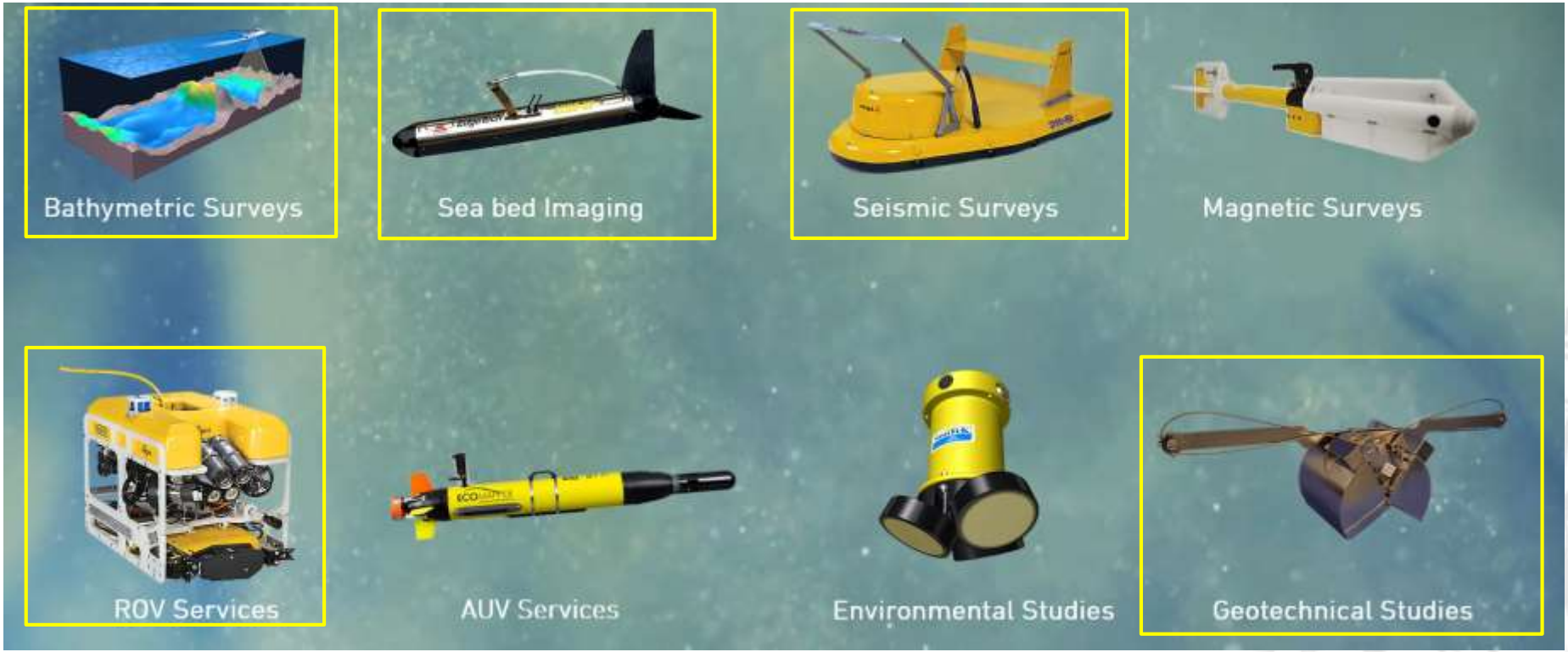
- Tsunamigenic hazardous event on 21 July 365 AD (Hamouda, 2010).

- Coastal slumping as a result of land sliding followed by the retreat of the seawaters (Stiros, 2020).

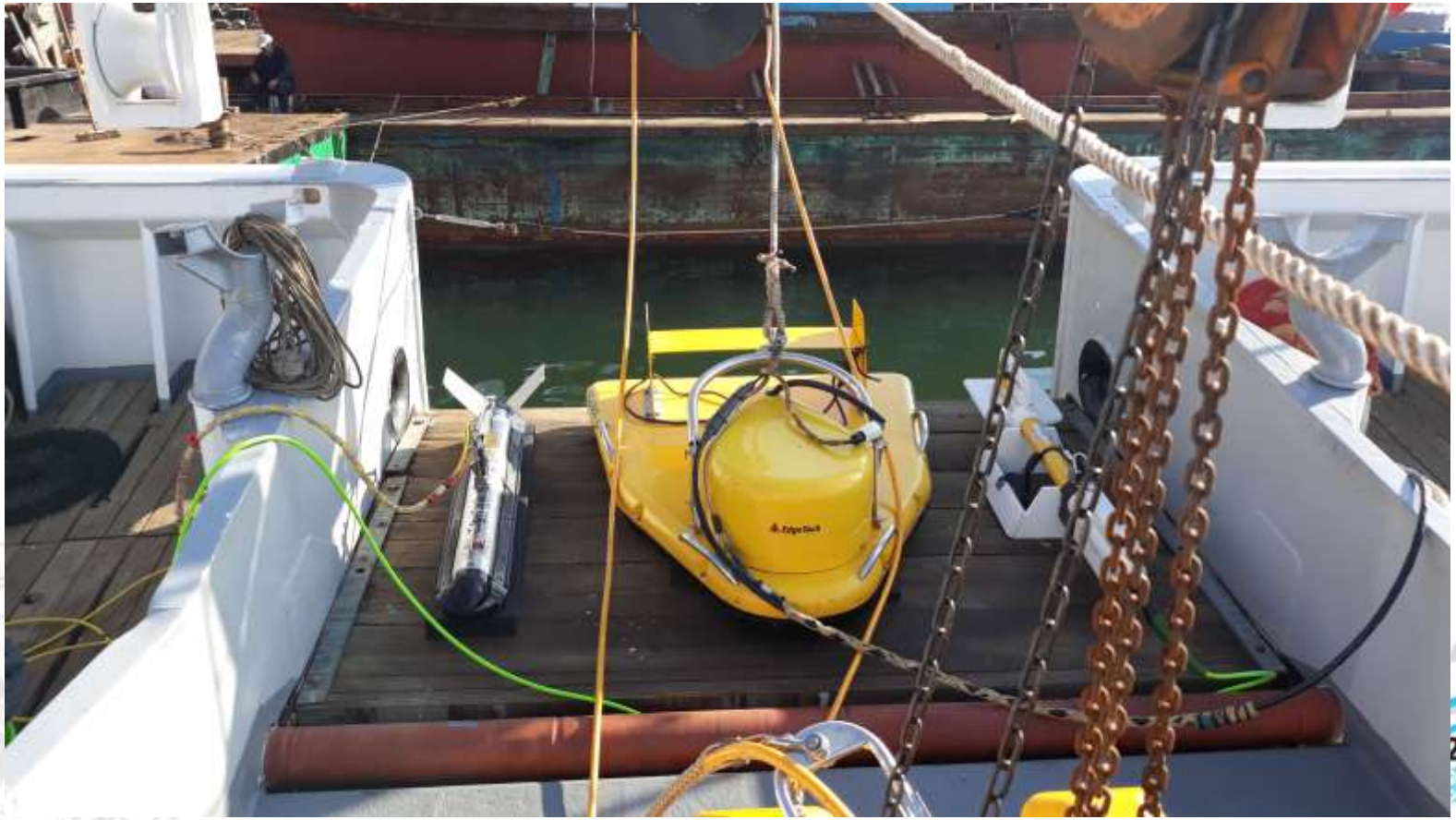
- The ancient royal ports and structures were collapsed and sunk by the action of the destroying waves and the following tectonic activities (Guidoboni, 1994).

Salsabil Research Vessel

Geophysical techniques



Geophysical techniques



Salsabil laboratory

Shallow seismic survey

- **Sub-bottom profiler**

- **Sub-bottom profiler installation**

Seabed Imaging survey

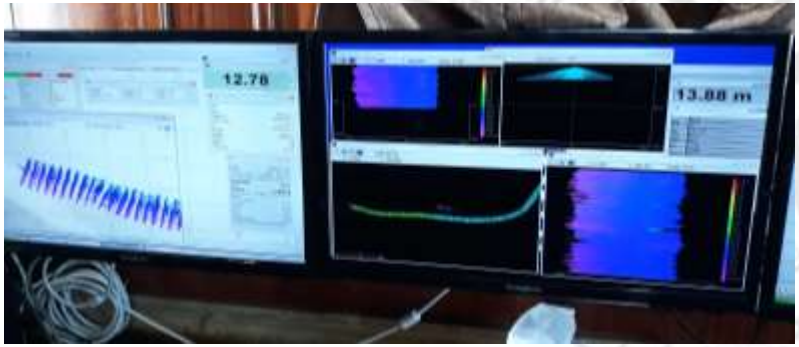
- **Side Scan Sonar SSS**

Bathymetric Survey

- Multi-beam system

Bathymetric Survey

- Multi-beam system



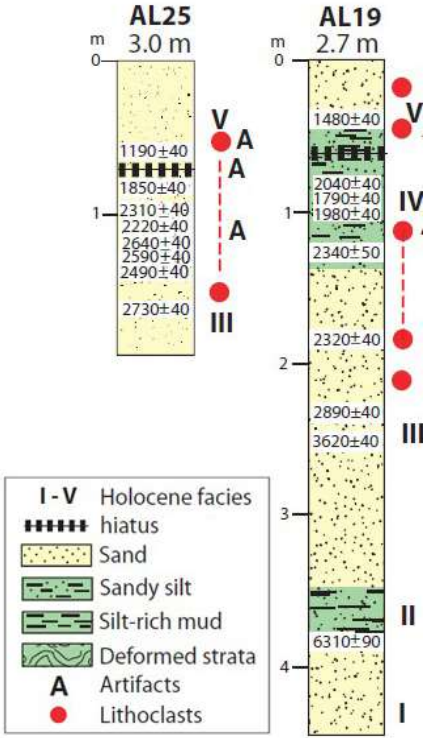
Non-Acoustic techniques

- ROV camera dives

Non-Acoustic techniques

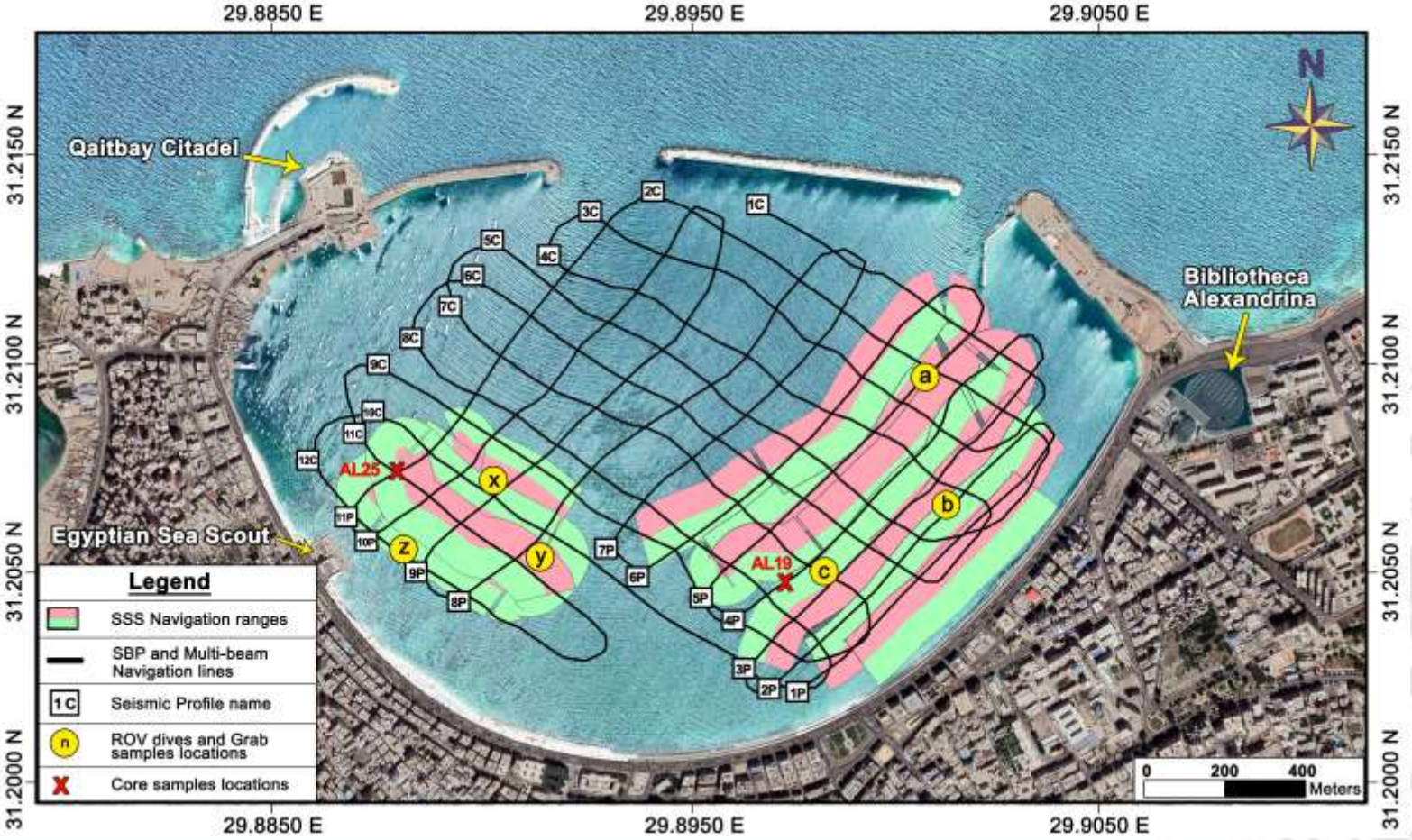
- **Sediment grab sampler**

Correlation with previously published core samples "dated"



Modified after Stanley et al., 2007

Survey plans



- Using multi-beam system, the Bathymetric survey was performed to measure the depth of the seafloor and determine the submerged borders of the ancient port.

- Side scan sonar survey was carried out to obtain clear seafloor images and detect the submerged artifacts.

- Sub-bottom profiler was utilized to detect the subsurface discontinuities across the high resolution vertical images.

RESULTS & DISCUSSION

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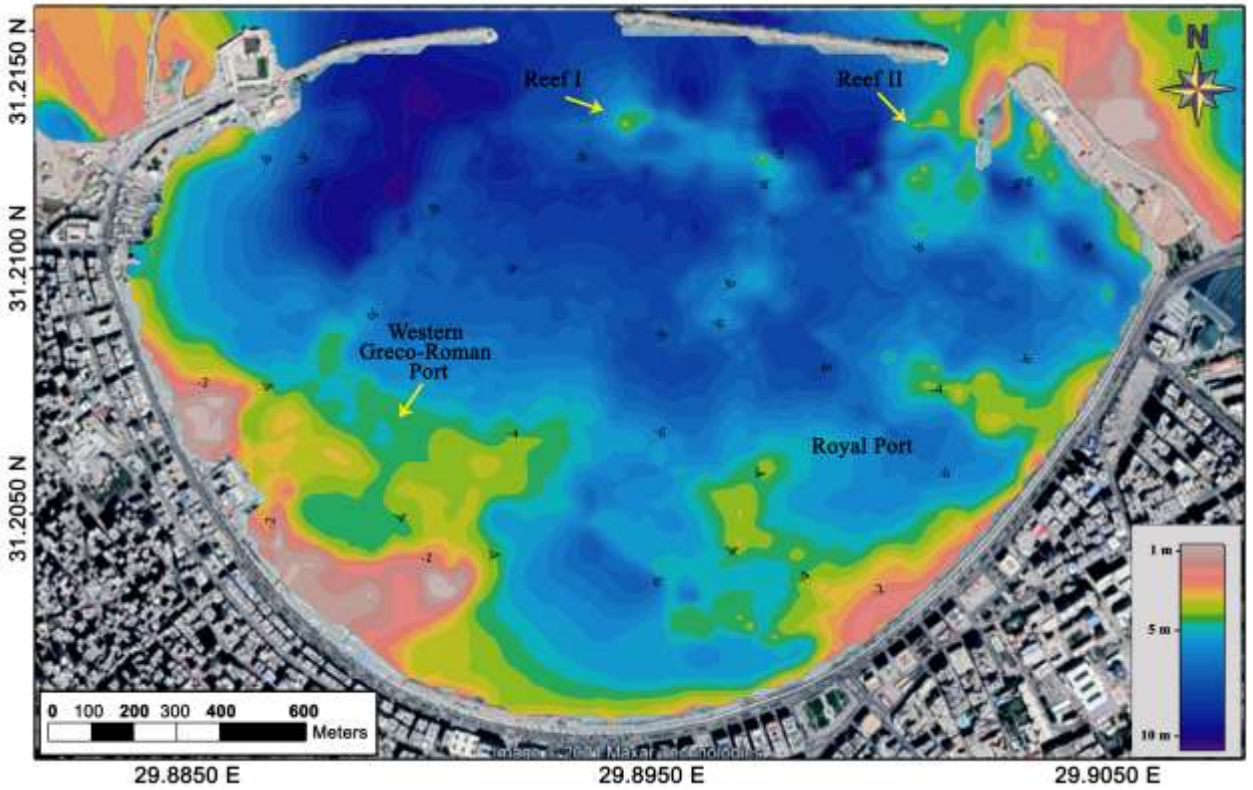
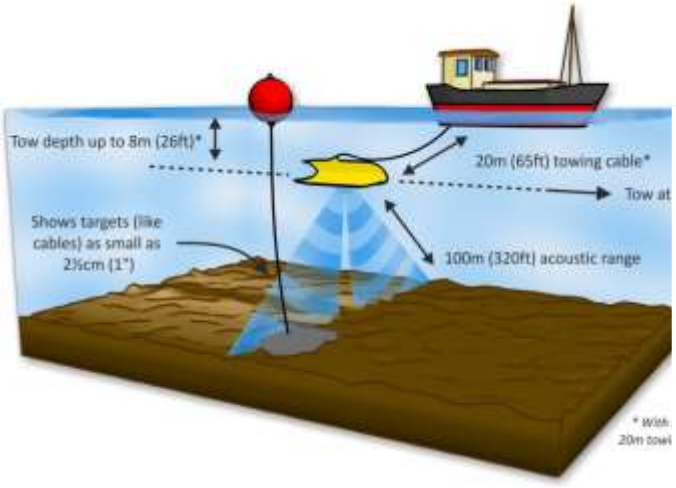
1. Bathymetry

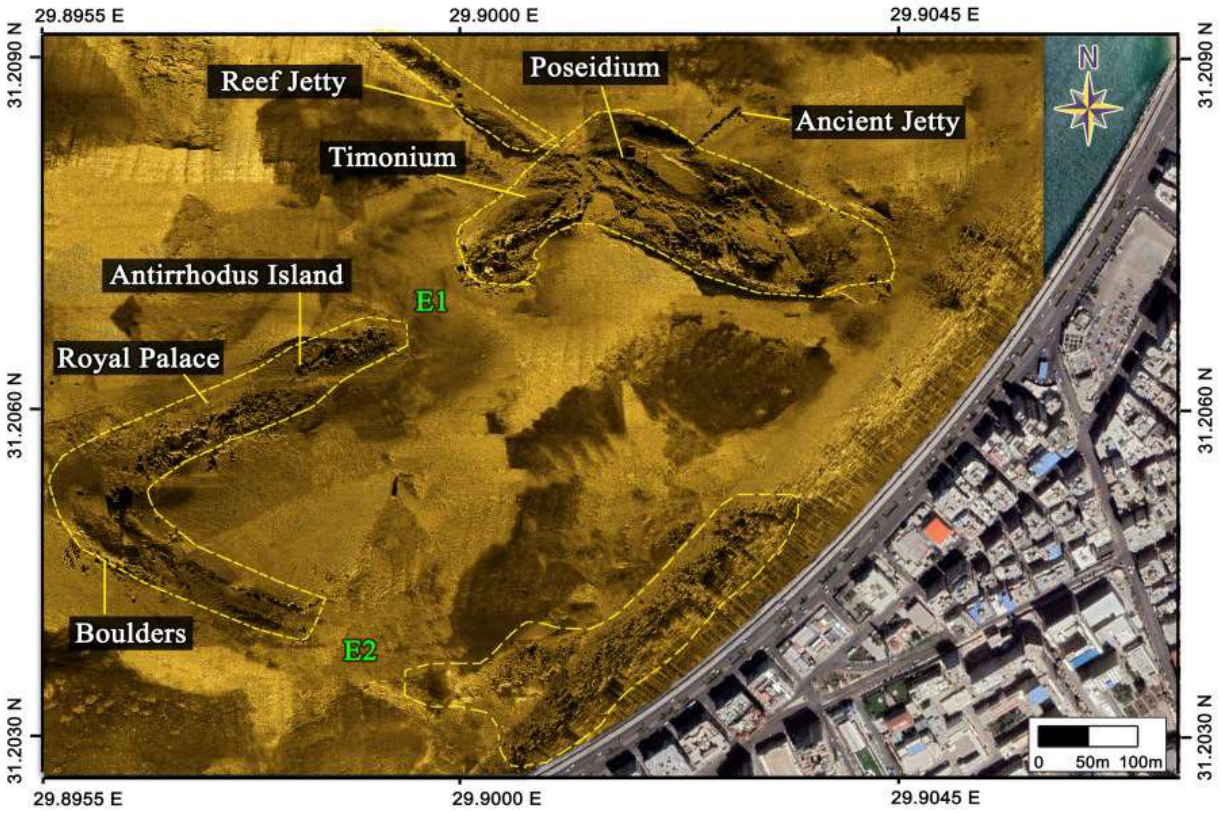
- Eastern Royal Port and western Greco-Roman port.
- Depth values ranged from 1m (shore) to around 10 m (El-Boughaz).
- Irregular contour patterns around the submerged borders of the ancient ports (~4m).
- Outcropping reef or ridges (~3.5m).



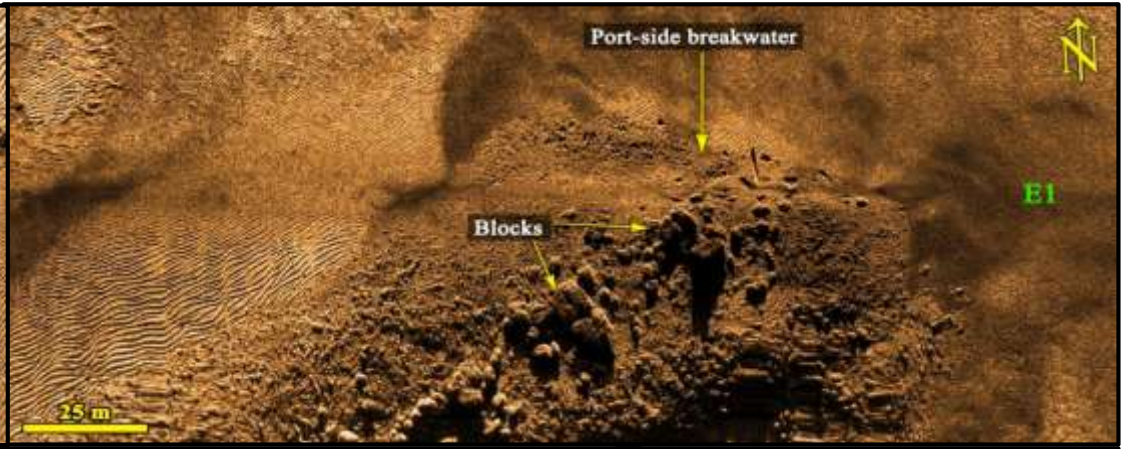
2. Sea-bed imaging

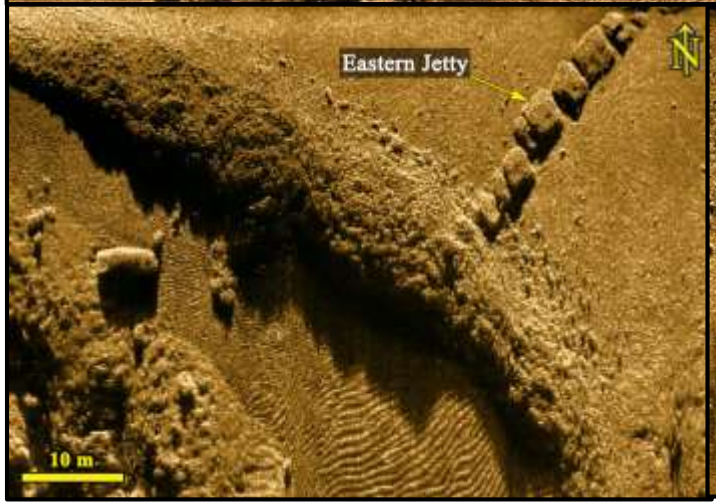


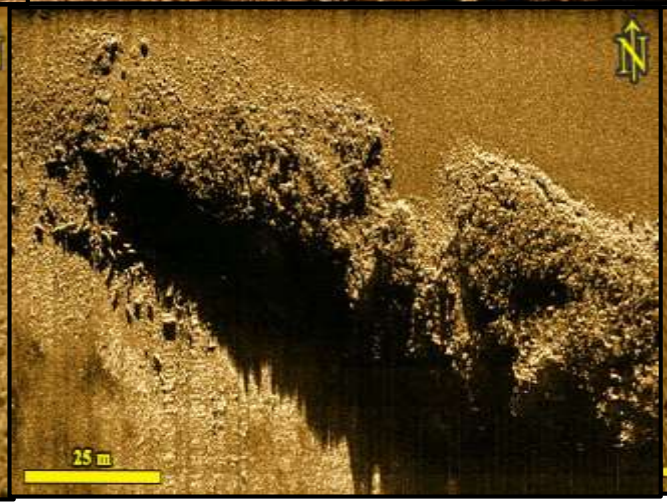
- **Light tone**: Strong backscatter strength (rock, coarse sediments)
- **Dark tone**: weak backscatter strength (fine sediments)




Deformed blocks
E1
25 m


Port-side breakwater
Blocks
E1
25 m


Eastern Jetty
10 m


25 m

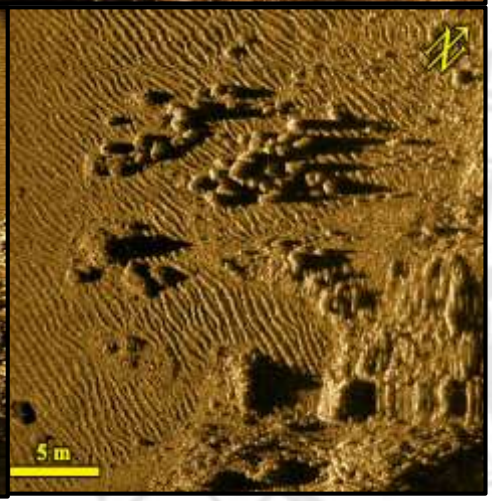
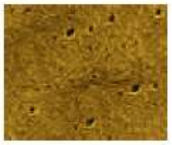
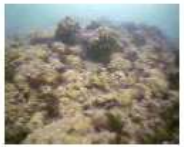
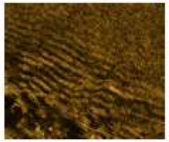
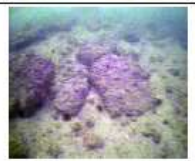
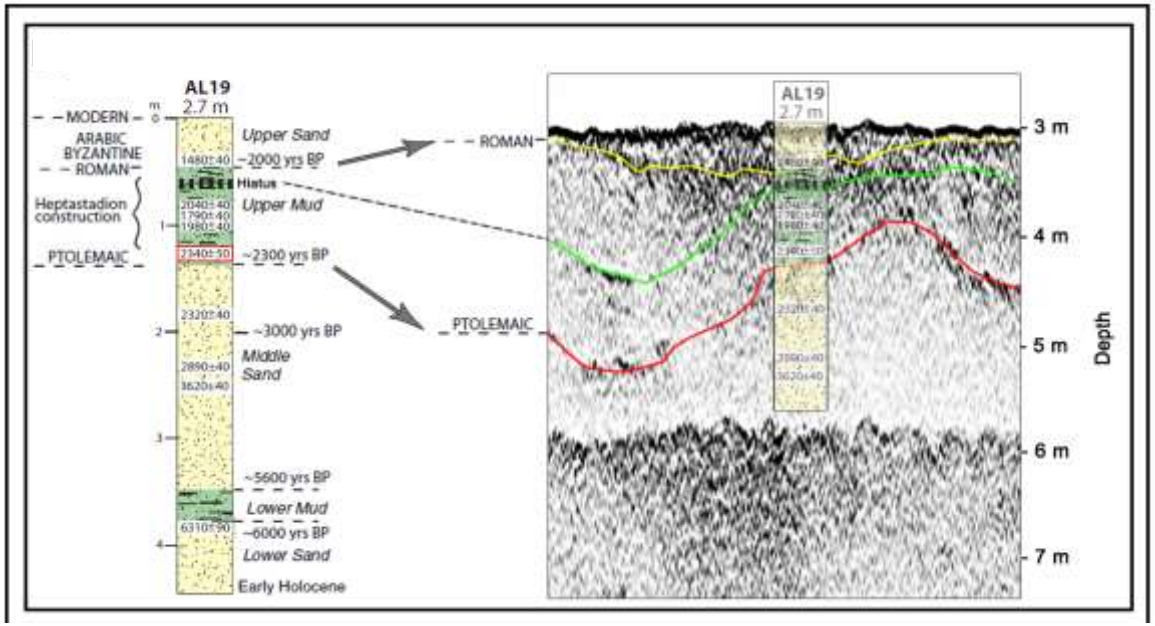

5 m

Table 1. Sediment analysis results corresponding to acoustic classes and ROV images in the study area.

Sample no.	*Acoustic response*	*ROV image*	*Sediment type/ Mean size*	*Sediment sorting*
a			Fine sand	Poorly sorted
b			Very Fine sand	Moderately well sorted
c			Medium sand	Moderately sorted
x			Coarse sand	Poorly sorted
y			Medium sand	Poorly sorted
z			Very Fine sand	Moderately well sorted

3. Seismic profiling interpretation

Core (AL 19) tie with profile (4P).

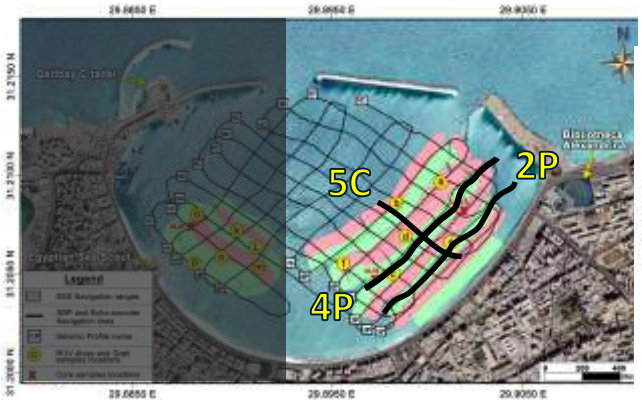


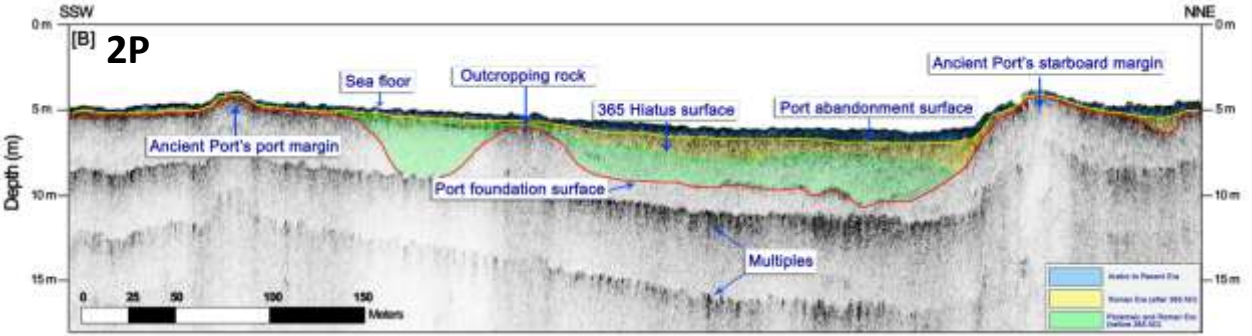
3 top surfaces were identified

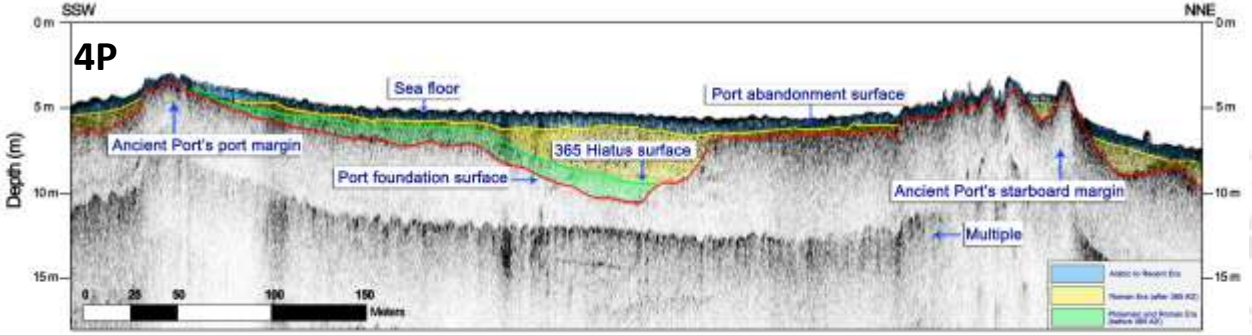
A) Top Ptolemaic

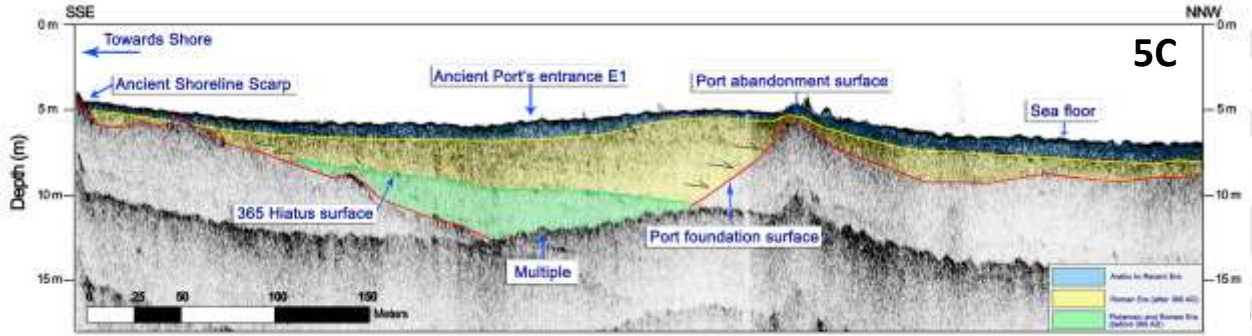
B) Top Hiatus

C) Top Roman

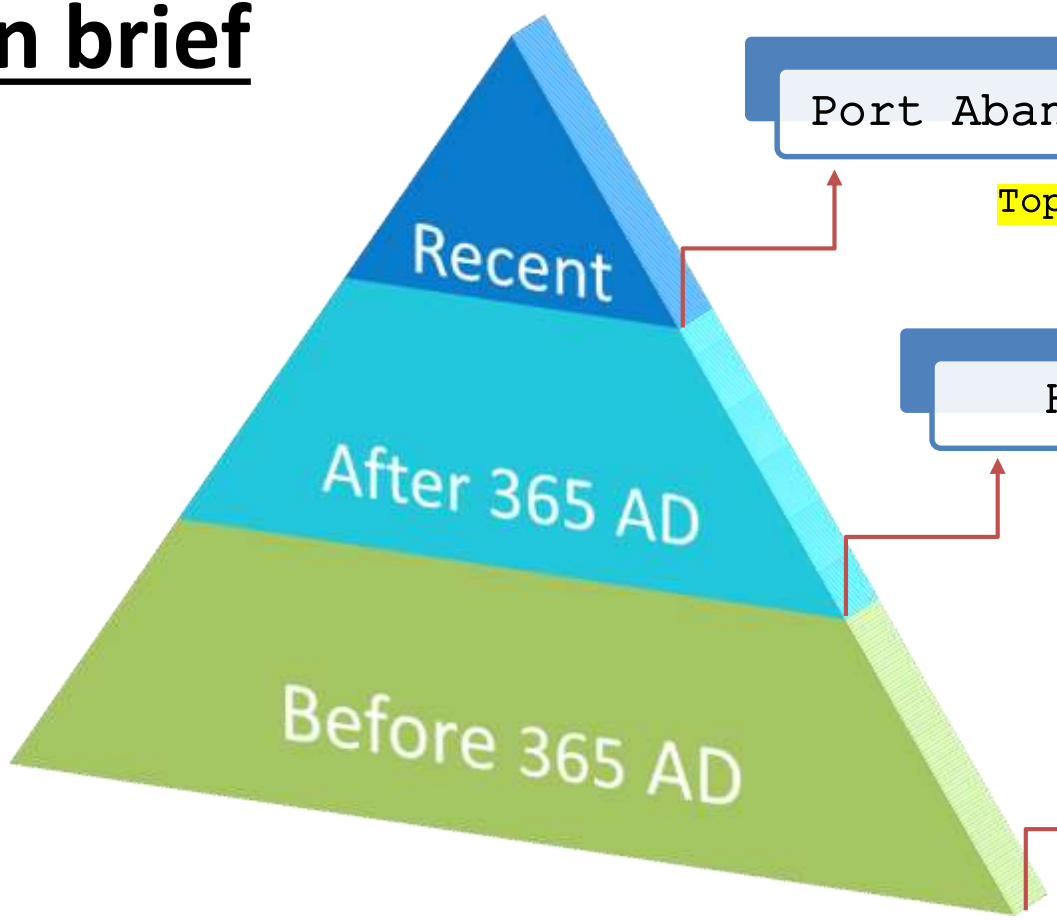

5C
2P
4P
Legend


SSW
NNE
[B] 2P
Sea floor
Outcropping rock
Ancient Port's starboard margin
365 Hiatus surface
Port abandonment surface
Ancient Port's port margin
Port foundation surface
Multiples
Depth (m)
0 25 50 100 150 Meters


SSW
NNE
4P
Sea floor
Port abandonment surface
Ancient Port's port margin
365 Hiatus surface
Port foundation surface
Ancient Port's starboard margin
Multiple
Depth (m)
0 25 50 100 150 Meters


SSE
NNW
5C
Towards Shore
Ancient Shoreline Scarp
Ancient Port's entrance E1
Port abandonment surface
Sea floor
365 Hiatus surface
Port foundation surface
Multiple
Depth (m)
0 25 50 100 150 Meters

In brief



Port Abandonment surface

Top Roman

Hiatus surface

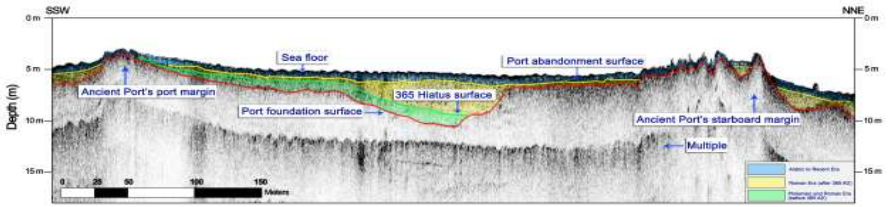
Top Hiatus

Port Foundation surface

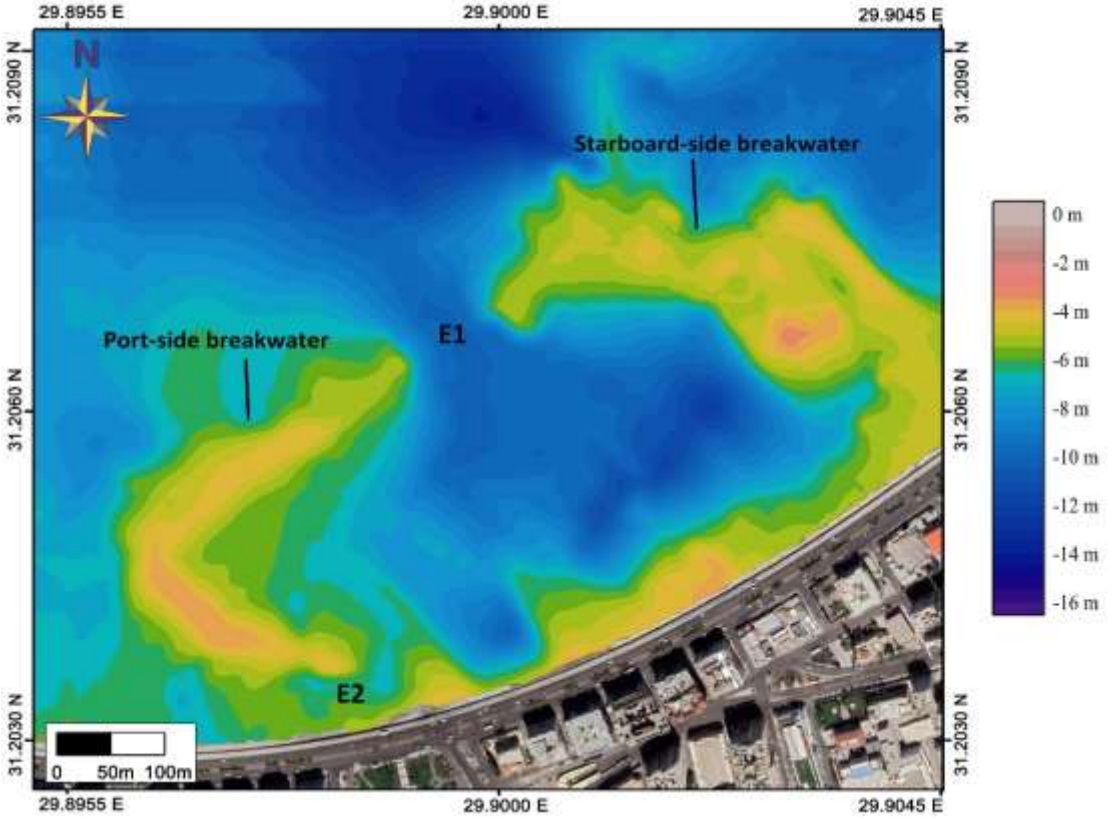
Top Ptolemaic

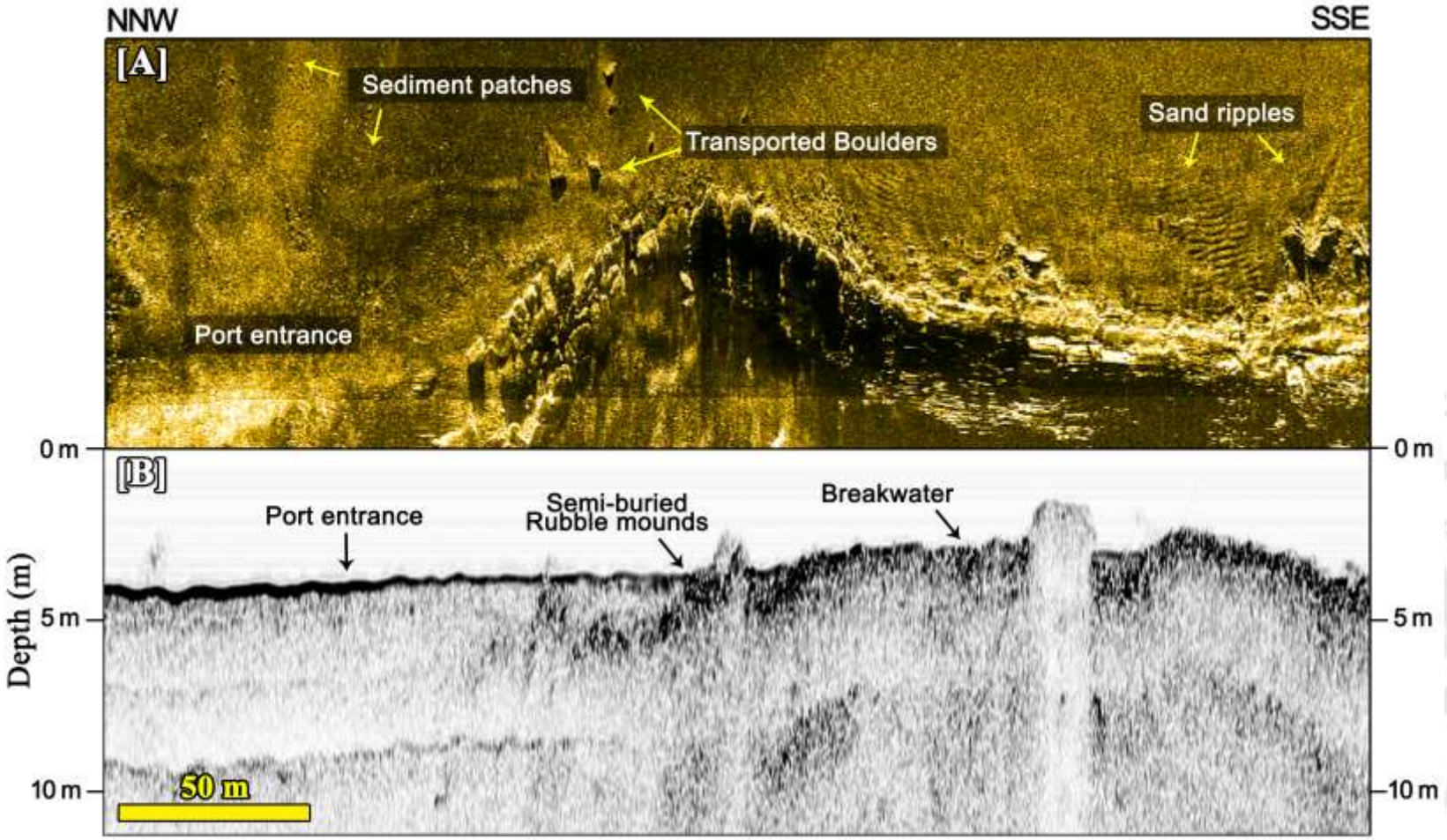
Structure contour maps

A. Ancient port foundation surface "Red Picking"

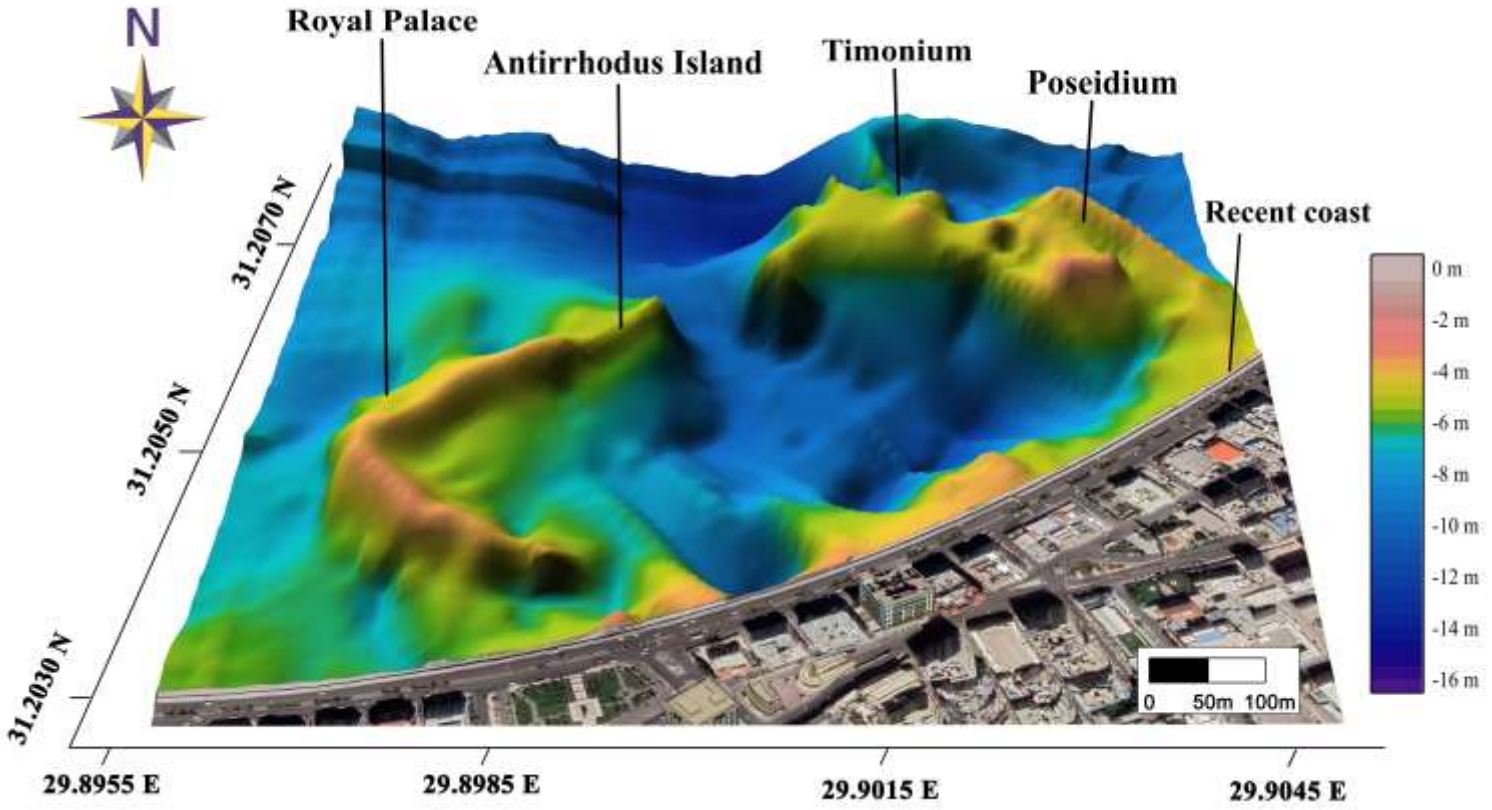


- **Depth values**
  - Generally, 2.5 m to 13 m
  - Royal Port margins, 2.5 m to 5.5 m
  - Port basin, 6 m to 11 m
  - E1: 9 m, E2: 6.5 m

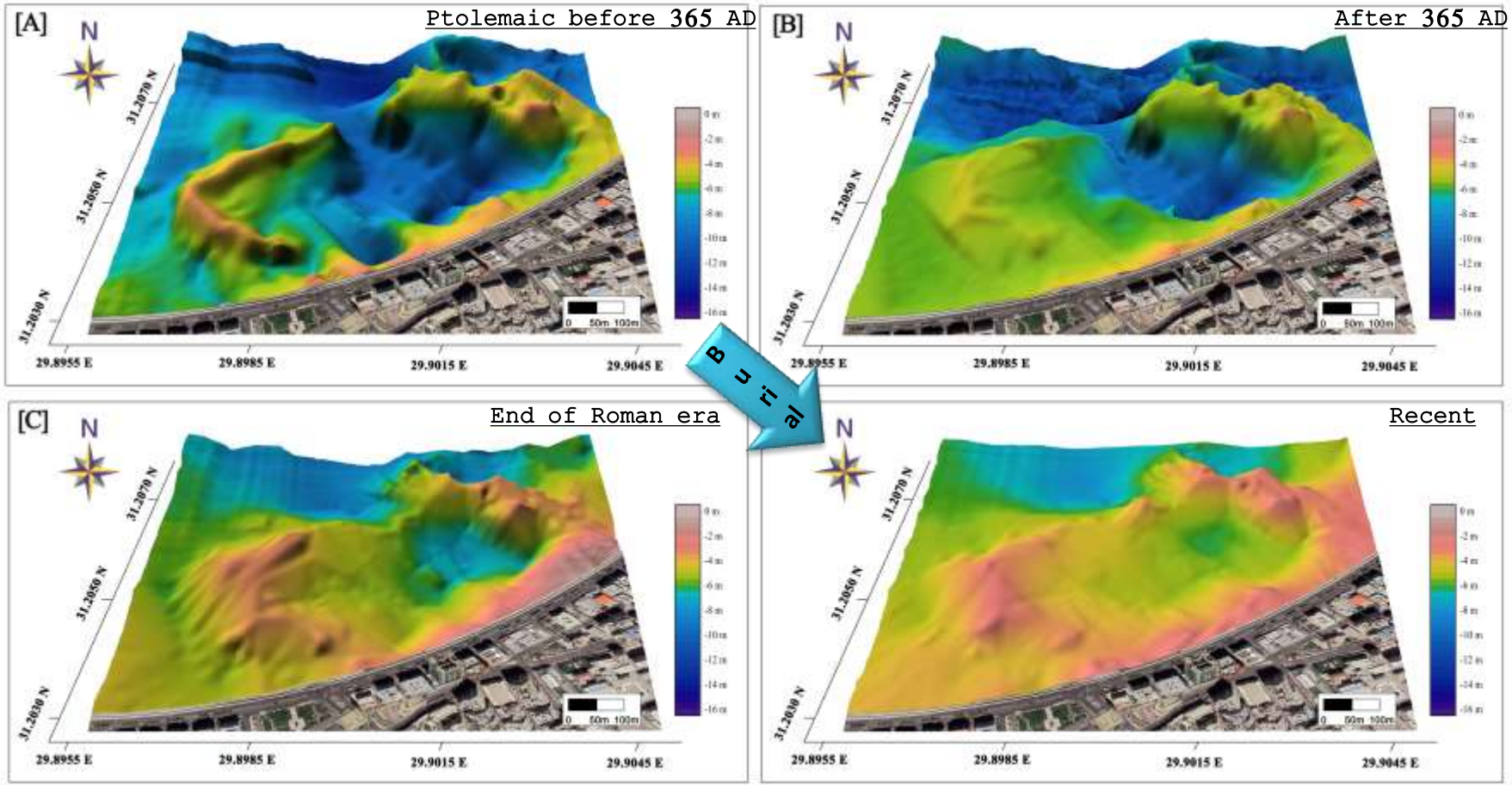



NNW
SSE
[A]
Sediment patches
Transported Boulders
Sand ripples
Port entrance
0 m
[B]
Port entrance
Semi-buried
Rubble mounds
Breakwater
Depth (m)
5 m
10 m
50 m
0 m
5 m
10 m

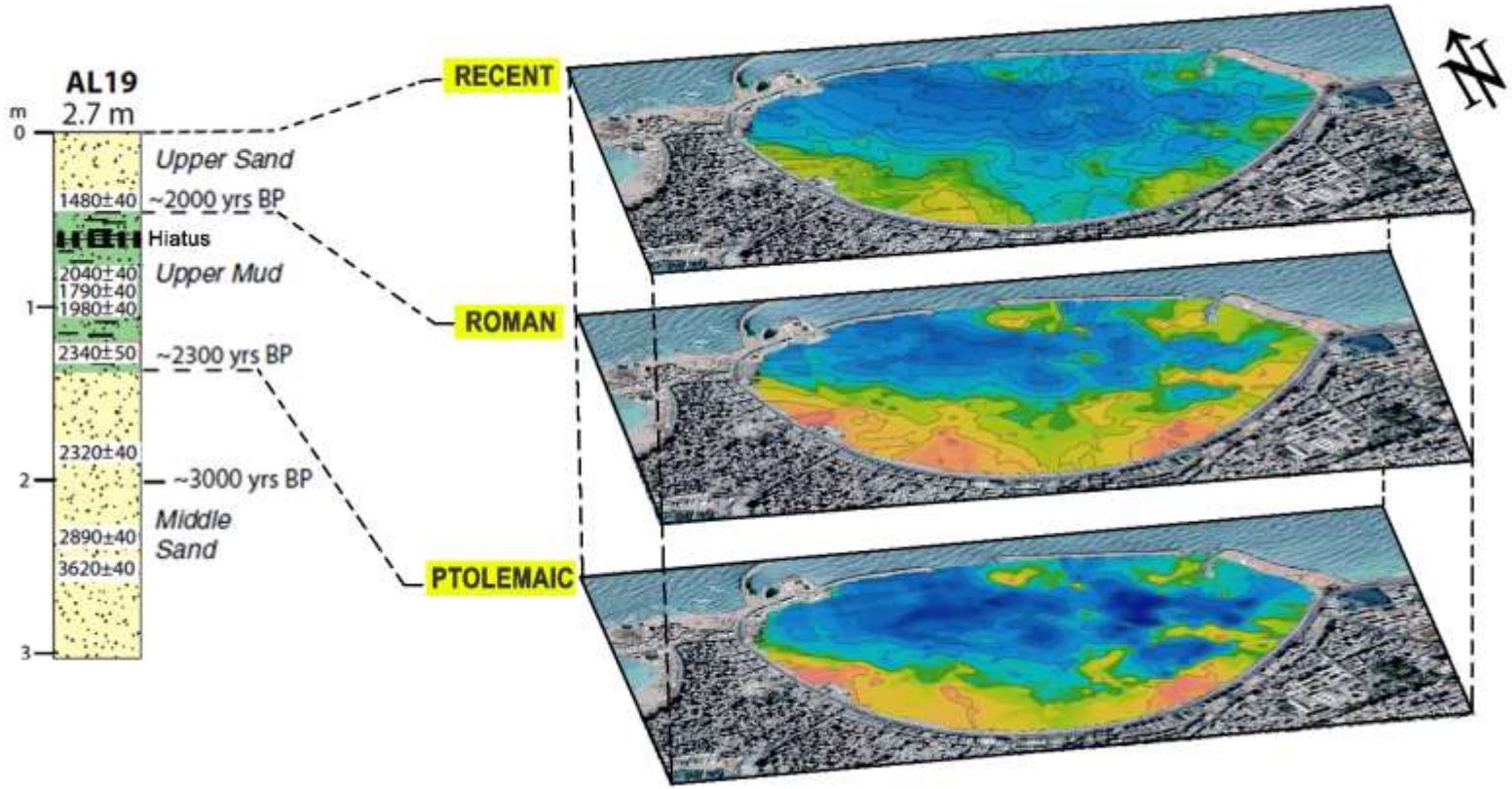
3D model


N
Royal Palace
Antirrhodus Island
Timonium
Poseidium
Recent coast
31.2070 N
31.2050 N
31.2030 N
29.8955 E
29.8985 E
29.9015 E
29.9045 E
0 m
-2 m
-4 m
-6 m
-8 m
-10 m
-12 m
-14 m
-16 m
0 50m 100m

Implications of the ancient site evaluation



Shoreline variation



- **The results strongly confirm the submergence and subsidence of several coastal settlements of ancient Alexandria as a result of:**

  Relative sea level rises and geo-hazards including, earthquakes, tsunami waves, coastal slumping and sediments mass failure.

- **As the subsurface sediment thicknesses typically matched with the previous records of sea-level rise and land subsidence (± 2 m) during the last 2000 years.**

Recommendations

1. Pay responsible attention for the recent sea level fluctuations along the littoral of Alexandria.
2. Expand the usage of the marine geophysical methods in the underwater geoarchaeological investigations and harbors monitoring.
3. Increase funds for research projects dealing with the challenges facing a sustainable blue economy such as monitoring of the seafloor of ports and harbors to facilitate a safe navigation.
4. Expand the scope of cooperation between various authorities.
5. Establish virtual museums for the underwater heritage sites of ancient Alexandria using (VR) technology.

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Thank YOU

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