

Sea level changes and vertical land movements in the Mediterranean inferred from fish tanks, harbours and quarries



13:10 • Marco Anzidei

Zoom link:
https://us06web.zoom.us/webinar/register/WN_lti_aNvJSyCjOTb4NLeV7A



Key points of this talk

- **Brief history of archaeological of RSLC in the Mediterranean**
- **The roman harbor of Lipari and the pier of Basiluzzo (Aeolian islands)**
- **Comparison between RSL from from nearby fish tanks, harbors and quarries: results from Ventotene and Torre Astura**
- **conclusions**



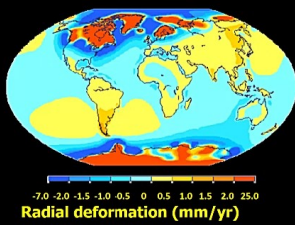
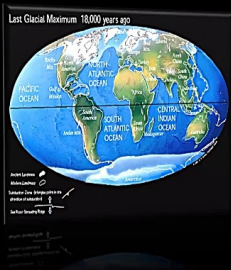
RELATIVE SEA LEVEL CHANGE

$$\Delta\zeta_{rsl} = \Delta\zeta_e + \Delta\zeta_I + \Delta\zeta_T$$

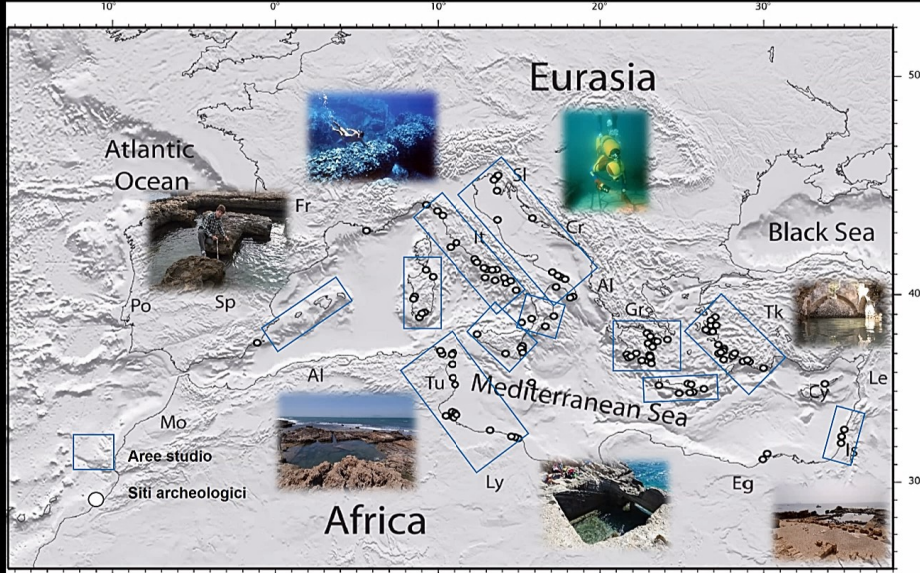
Global ice volume

Isostatic response

tectonics



Harbors, fish tanks and quarries in the Mediterranean





The harbors



The harbor of Leptis Magna, Libya



The harbor of Leptis Magna, Libya



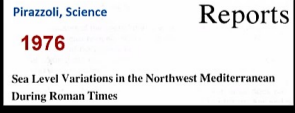
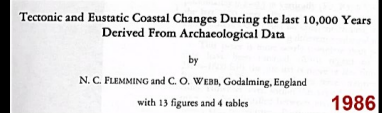
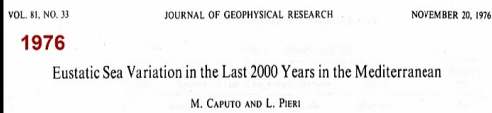
The harbor of Miseno (Italy)



The slipways of Carthage, Tunisia



Brief historical papers on archaeological RSLC in the Mediterranean





THE FISH TANKS: the crepido



AKTES
Archaeology for the Study of Ancient Civilizations



Le Grottacce



Ponza



Ponza

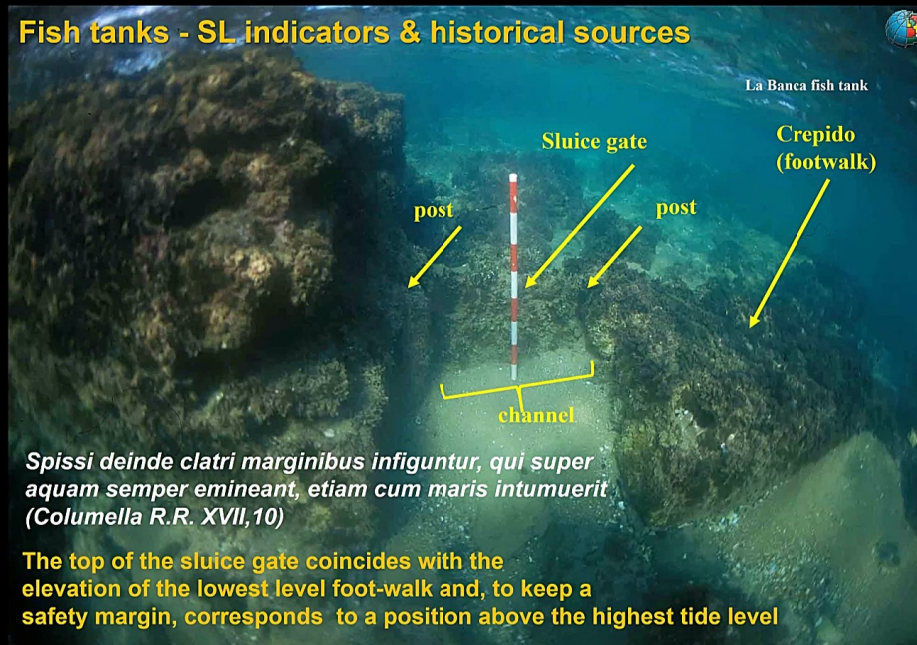


Torre Astura

Fish tanks - SL indicators & historical sources



AKTES
Archaeology for the Study of Ancient Civilizations



Spissi deinde clatri marginibus infiguntur, qui super aquam semper emineant, etiam cum maris intumuerit (Columella R.R. XVII,10)

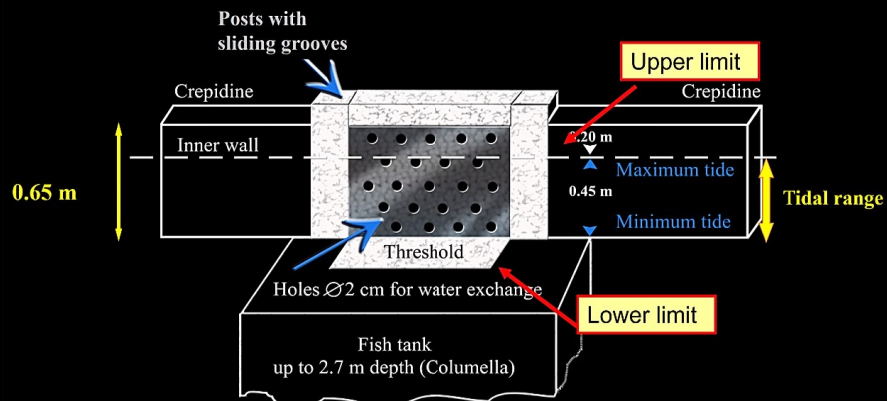
The top of the sluice gate coincides with the elevation of the lowest level foot-walk and, to keep a safety margin, corresponds to a position above the highest tide level



Fish tanks - SL indicators: channels with sluice gates



Sketch of a sluice gate for the water exchange in a Roman Fish tank



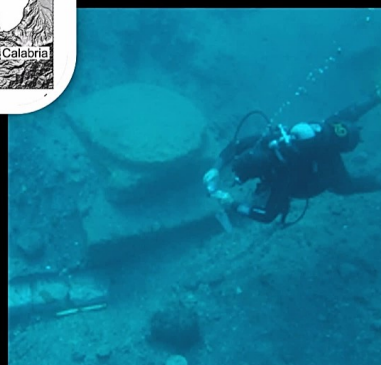
The top of the sluice gate coincides with the elevation of the lowest level foot-walk (crepido), to a position above the highest tide level.

Anzidei et al., 2005
Lambeck et al., 2004b

Enregistrement



The roman harbor of Lipari Marina Lunga





The roman harbor of Lipari Marina Lunga



Sebastiano Tusa

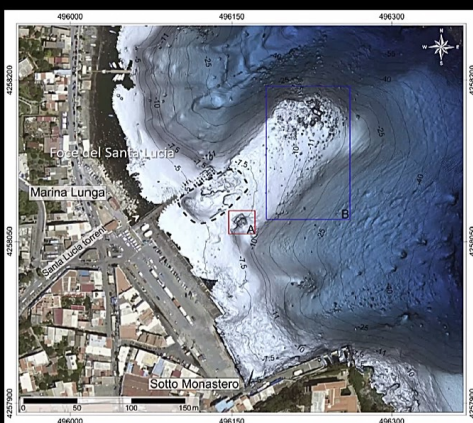


Marco Anzidei

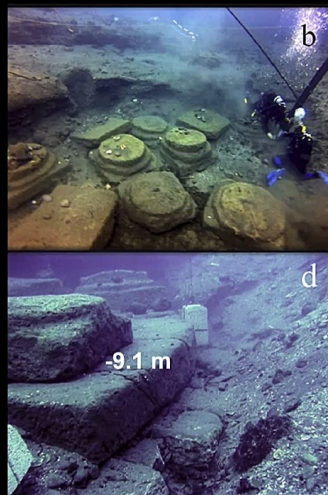


The roman harbor of Lipari Marina Lunga

High resolution topography, multibeam bathymetry and direct surveys



Red square: the columns area
Blue square: the lighthouse area
Length: 140 m
width: 40 m
area: 10.000 m²



b) Panoramic view;
d) The basement of the pier



Marco Anzidei



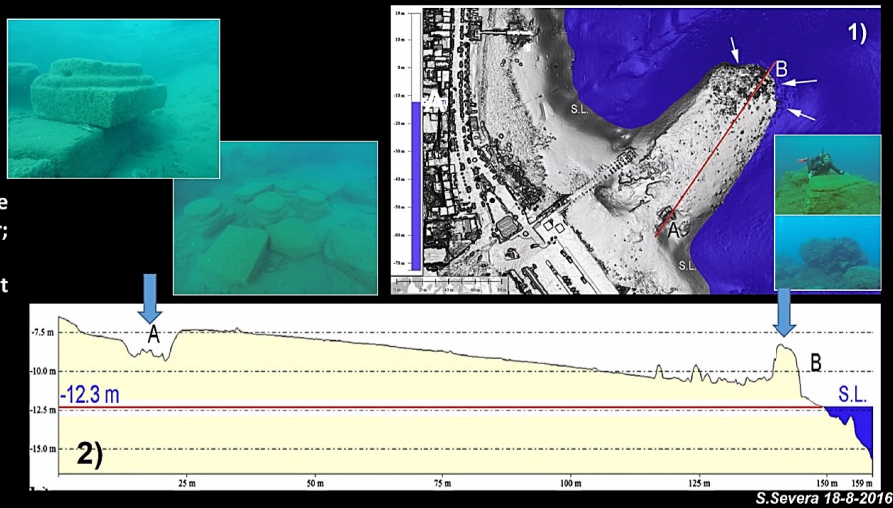


RLSC at Lipari in the last 2100 years

1) DTM; 2) cross section of the pier from A to B.

With arrows: SL position in roman time at -12.30 ± 0.7 m.

Violet horizontal line (in 2): mean SL position at -12.30 ± 0.7 m when the harbor was operational (2100 \pm 100 BP)



Land subsidence up to 12 mm/yr;

Vertical gradient -0.4 mm/km/yr

S.Severa 18-8-2016

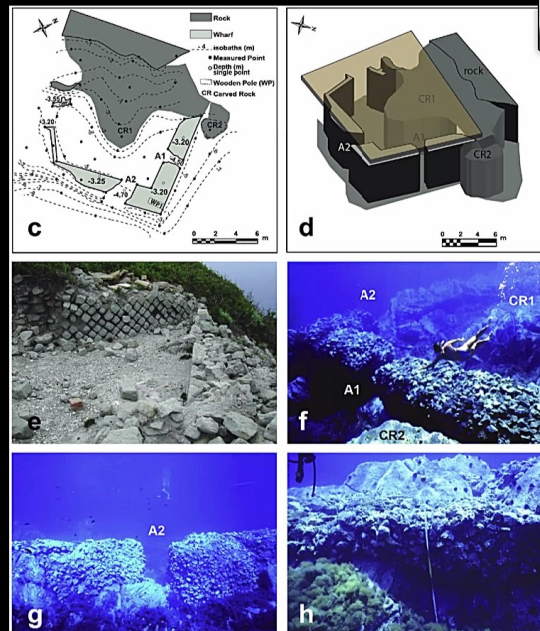


AKTES



The pier of Basiluzzo island

c) Map of the pier. CR1 & CR2: excavated rocks. A1 & A2: opening along the external wall. WP1 & WP2: inprints of wooden walls. Black dots: topo points; d) 3D map; e) remains of the roman villa; f) submerged walls; g) opening A2; h) inner side of the basin. Walls made of rhyolithe and hydraulic mortar.



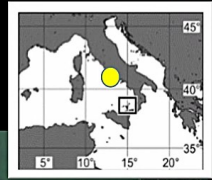
RSLC 4.23 ± 0.2 m



AKTES



The roman fish tank complex and the harbor of Torre Astura (Italy)

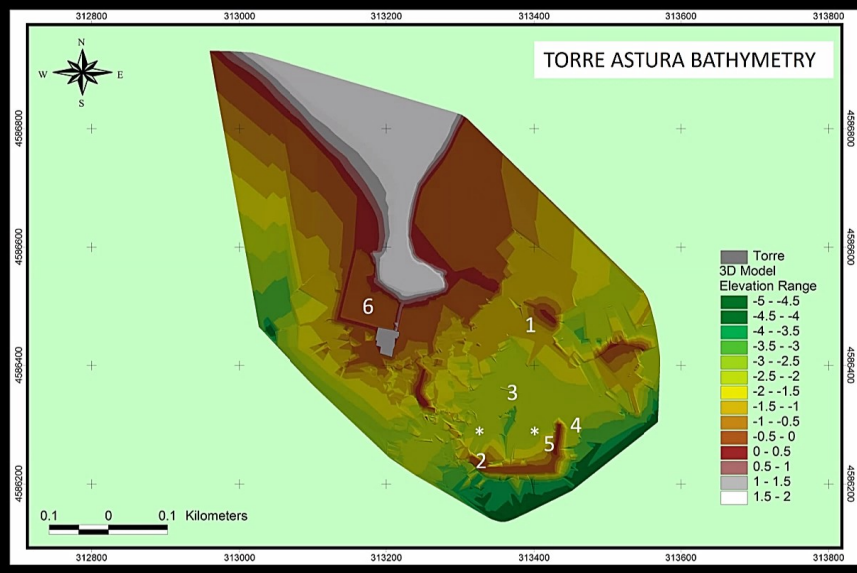


The harbor of Torre Astura (Italy)



Single beam bathymetry of the harbor of Torre Astura (Italy).

- 1- northern pier
- 2- southern pier
- 3- basin
- 4- lighthouse
- 5- wooden tables
- 6- fish tank
- * - shipwrecks



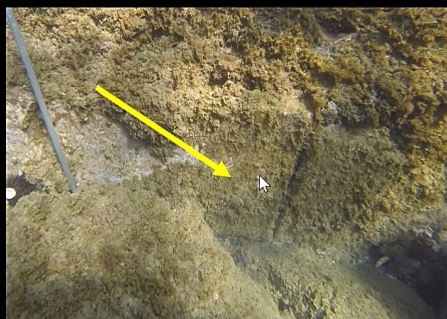


The harbor of Torre Astura (Italy)



the basement of the lighthouse

the pier



the wooden boards of the caissons



Dating the harbor of Torre Astura (Italy)

Poznań Radiocarbon Laboratory



<i>Sample name</i>	<i>Lab. no.</i>	<i>Age 14C</i>	<i>Remark</i>
TABLE AST	Poz-62846	1865 ± 30 BP	(Torre Astura: table from the main harbor)
WRECK AST	Poz-62692	1860 ± 30 BP	(Torre Astura: wood from shipwreck)
POLE AST	Poz-62694	2000 ± 30 BP	(Torre Astura: pole from a small pier between fish tanks)

Age comparison with the fish tank of Pirgy

POLE PIRGY	Poz-62695	1885 ± 35 BP	(Pirgy pole from the fish tank)
------------	-----------	--------------	---------------------------------

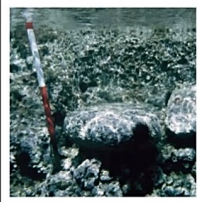




Ventotene



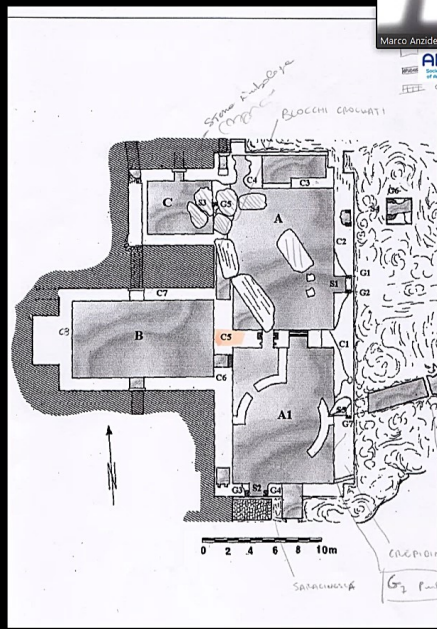
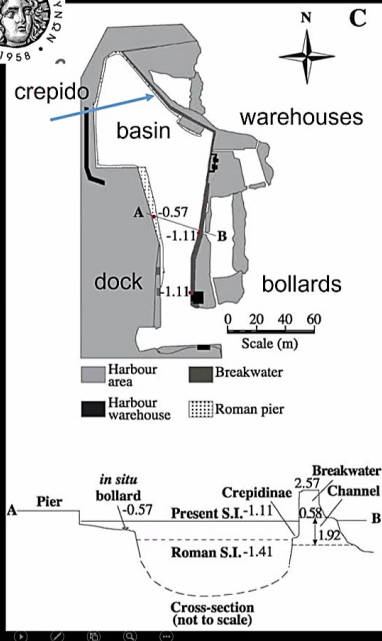
AKTES



AKTES

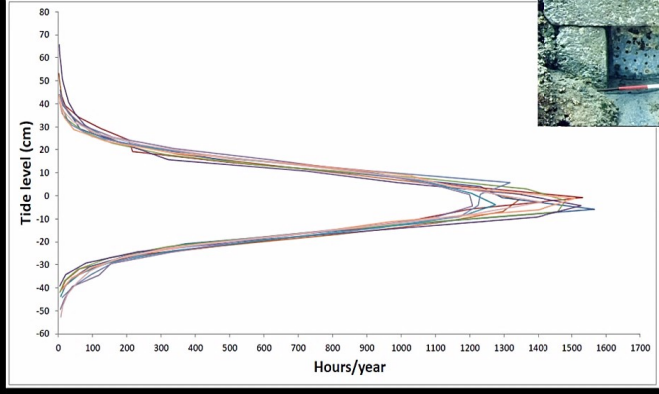
Ventotene

harbour and fish tank excavated in tuff





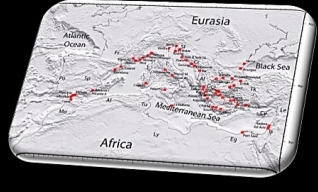
Tides and fish tanks: calibrating surveys and functional elevation



Italian tidal network



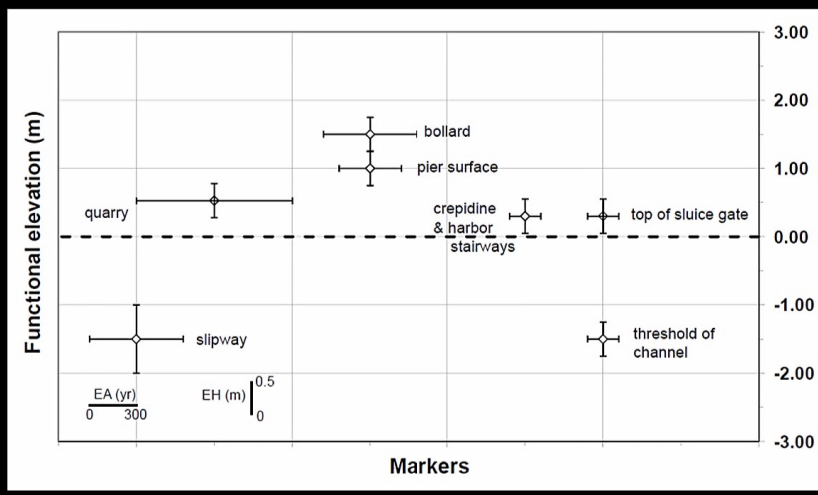
PSMSL tidal stations



Tide levels in hour/year for 10 stations in the Tyrrhenian Sea (1998-2013). Mean tidal range is ± 30 cm in agreement with the height of the sluice gates of the fish tanks and the functional elevation of quarries, piers and bollards of harbors.



The functional elevations: a proposed calibration



Uncertainties of functional elevation for different archaeological markers. Maximum values are for slipways and quarries. The fish tanks are the most precise markers.

Anzidei et al., in prep,



Archaeological RSLC in the Mediterranean

During the '80s

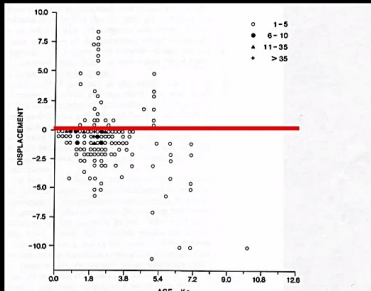
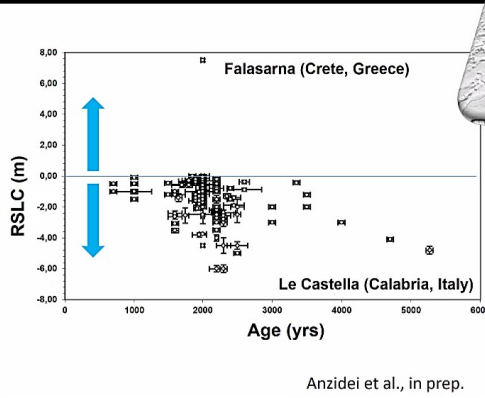


Fig. 6. Scatter plot showing the relationship between vertical displacement (Z) and age (T) for all valid records. Note the massive concentration of data trending slightly below the axis up to 3 ka, and the bifurcation of the scatter into relatively uplifted and submerged site records.

Revised data



Anzidei et al., in prep.

Elevation plot of about 150 investigated sites located in different tectonic environments of the Mediterranean

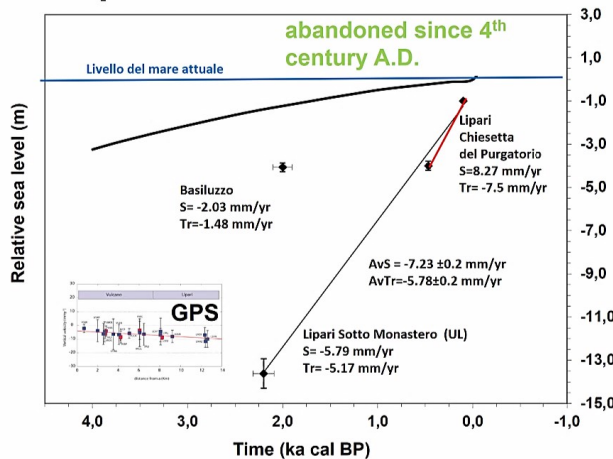
Tectonic and Eustatic Coastal Changes During the last 10,000 Years Derived From Archaeological Data

by
N. C. FLEMING and C. O. WEBB, Godalming, England
with 13 figures and 4 tables

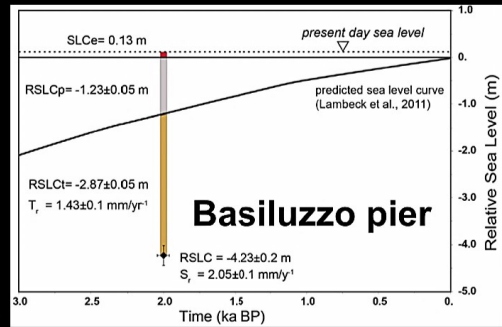


The role of VLM for RSLC

Lipari harbor



Blue line: current SL
Black curve: SL prediction for the last 4000 years (model K33_j1b_WS9_6, Lambeck et al., 2011)
Black dots with error bars: depth and age of SL indicators
Tr: estimated tectonic rate



SL prediction for the last 3000 years.
The RSLC at 2000±50 years BP is at -4.23 ± 0.2 m exceeding -2.87 ± 0.05 m with respect to prediction (RSLCp).
Sr: land subsidence at 2.05 ± 0.1 mm/yr;
Tr: vertical tectonics at 1.43 ± 0.1 mm/yr
SLCe: recent eustatic change (Lambeck et al., 2004b).



Comparison between RSLC from from nearby fish tanks, harbors and quarries: results from Ventotene, Torre Astura and Lipari.

Site	RSLC harbor (m)	RSLC Fish tank (m)	RSLC Quarry (m)	Δ_{RSLC} (m)	Tr (mm/yr)
Ventotene	1.5 ± 0.2	1.54 ± 0.2	1.22 ± 0.4	0.32 ± 0.26	0.0 ± 0.05
Torre Astura	1.32 ± 0.3	0.97 ± 0.2	-	0.35 ± 0.25	0.02 ± 0.05
Lipari	12.3 ± 0.7	4.23 ± 0.2 (Basiluzzo)	-	8.07 ± 0.45	-5.17 ± 0.1 -1.48 ± 0.1