ICoD – Euro-Mediterranean Centre on Insular Coastal Dynamics / Malta

Council of Europe

European Major Hazards Agreement

Created in 1987, the European and Mediterranean Major Hazards Agreement (EUR-OPA) is a platform for co-operation between European and Southern Mediterranean countries in the field of major natural and technological disasters. Its field of action covers the knowledge of hazards, risk prevention, risk management, post-crisis analysis and rehabilitation.

Website: www.coe.int/europarisks

Abstract:
A deeper understanding of the processes acting on the coastal areas is crucial for coastal hazard assessment and mapping. To this aim, integrated geomorphological investigations of emerged and submerged areas resulting in geomorphological mapping represent an innovative way to provide the necessary knowledge for preventing hazards and reducing risks. An example is provided from the north-western coast of Malta (central Mediterranean Sea).

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Project 2014-2015

Integrated Geomorphological Mapping of Emerged and Submerged Coastal Areas based on the Coupling of Terrestrial and Marine Datasets

A research carried out in the framework of the EUR-OPA Major Hazards Agreement Project "Coupling terrestrial and marine datasets for coastal hazards assessment and risk reduction in changing environments" by:

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CNR-IRPI - Research institute for geo-hydrological protection (Italy)
CNR-ISMAR - Research institute for marine sciences (Italy)
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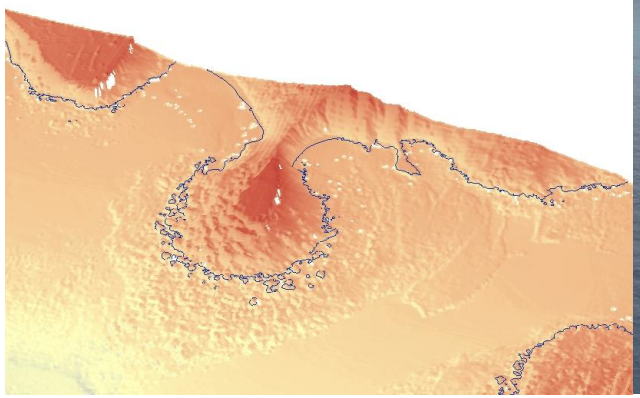
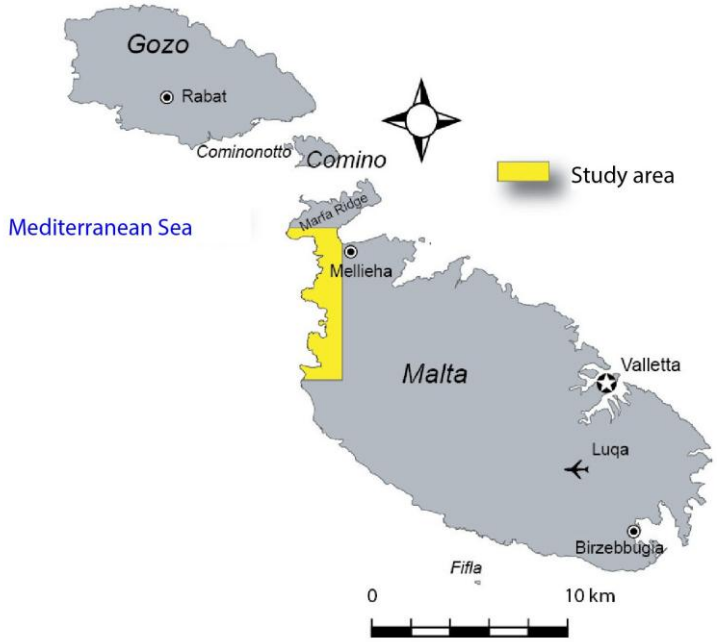


Objectives

Integrated geomorphological mapping of emerged and submerged coastal areas

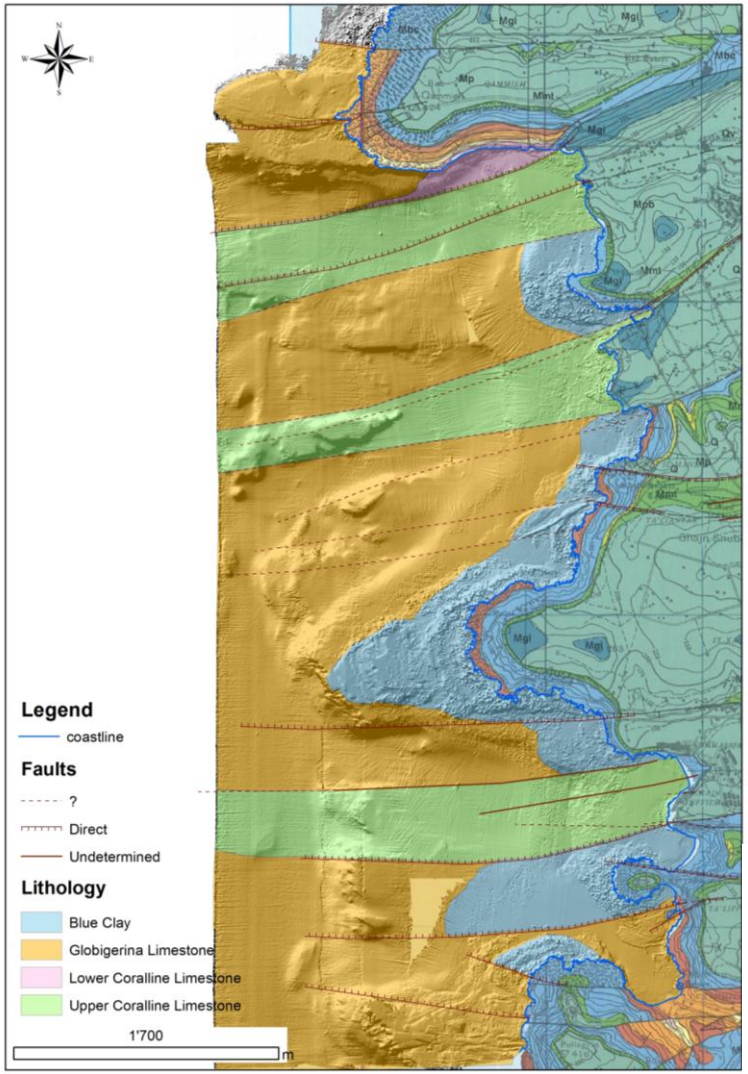


Location of the Maltese archipelago in the Europe and of the study area.

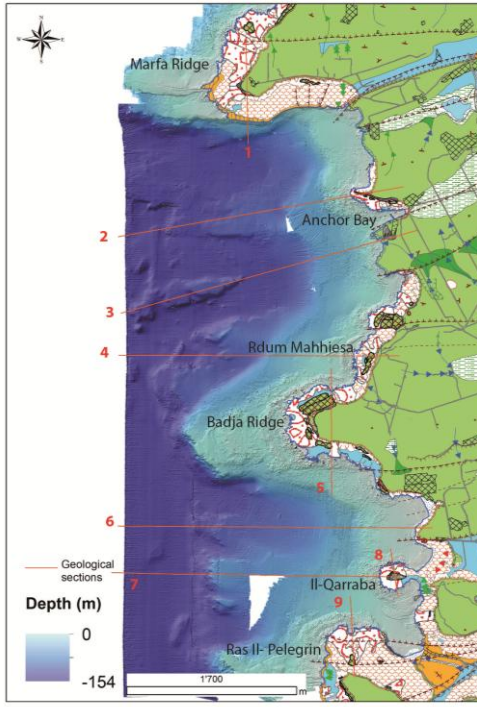
Context: The aim of the Project "Coupling terrestrial and marine datasets for coastal hazards assessment and risk reduction in changing environments" of the EUR-OPA Major Hazards Agreement is the risk reduction in coastal areas thanks to the development of coastal hazards mapping procedures including the impact of sea level rise on coastal processes as a useful basis for multi-hazard assessment.
One of the deliverables of the Project is concerned with geomorphological mapping of emerged and submerged areas along the north-western coast of Malta (central Mediterranean Sea). This stretch of coast is characterised by several types of landforms, among them the most outstanding being landslides.
Alike other European coastlines, also the Maltese ones have experienced climate changes, and related sea level rises since the Last Glacial Maximum (LGM), when the sea level was 130 m lower than the present one (Lambeck et al., 2011; Furlani et al., 2013). As pointed out by a number of authors, the ongoing and future climate changes will provide future sea level oscillations which may severely influence the evolution of coastlines in the near future (IPCC, 2007; Fitzgerald et al., 2008; Nicholls et al., 2010).
In this context, integrated studies of the geomorphological evolution of the terrestrial and marine areas can help in understanding the evolution of the processes in a framework of climatic changes. This is a key issue for further actions aiming at the development of procedures for coastal multi-hazards mapping taking into account changing environments.
A pilot study has been carried out in Malta also with the aim of testing a methodology that can be applied elsewhere in coastal areas of the Mediterranean Sea.

Integration of onshore and offshore geological data

In order to achieve a complete picture of the geological features onshore and offshore, a detailed analysis of the geological structures, rock types and sediment distribution was carried out. The data used for this purpose come from a bathymetric survey carried out in May 2012 offshore the NW coast of Malta, from field survey and available maps. The bathymetric data were elaborated by means of the software CARIS HIPS & SIPS and the maps were produced in GIS-environment.

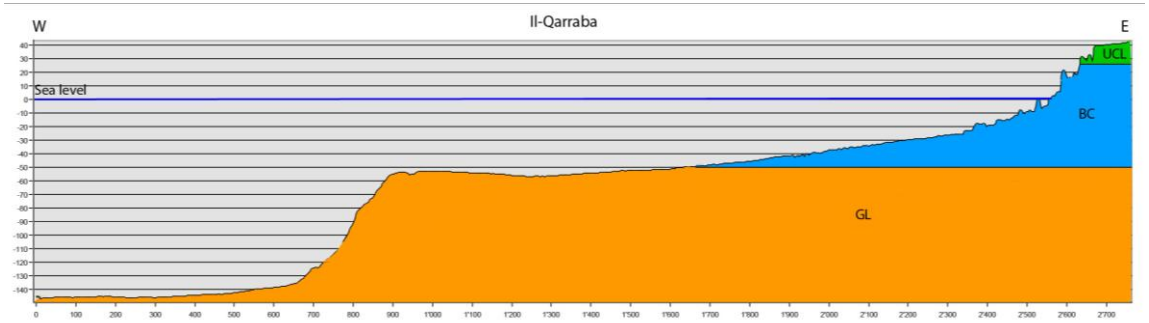


Geological map integrating onshore and offshore lithological and tectonic data (based on Oil Exploration Directorate (1993); Devoto et al. (2012); Biolchi et al. (2014)).

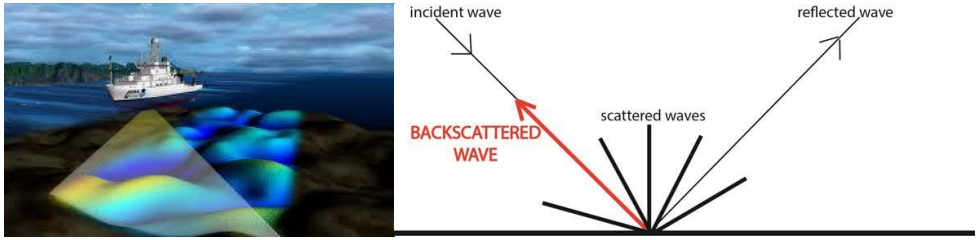


Location of the geological sections and an example of the geological section n. 7 – Il-Qarraba W-E.

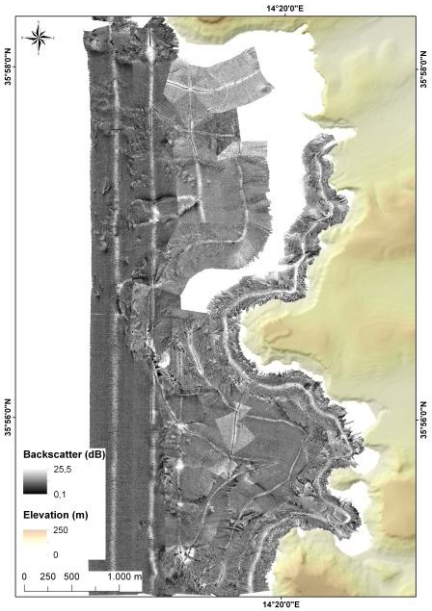
The Island of Malta is characterised by a Oligo-Miocene succession constituted by three limestone formations and a clayey formation. The tectonic setting is responsible for the *horst-and-graben* structure which characterises the north-western coast of Malta. The present alternation of hills and valleys is repeated and well recognisable also offshore. Sections have been produced to interpret the stratigraphy of the geological formations offshore. Particular attention was focused on the extension of the palaeo-shore platforms and their relationship with the isobath of 130 m which corresponds to the lower sea level during the LGM.



Seafloor sediment map



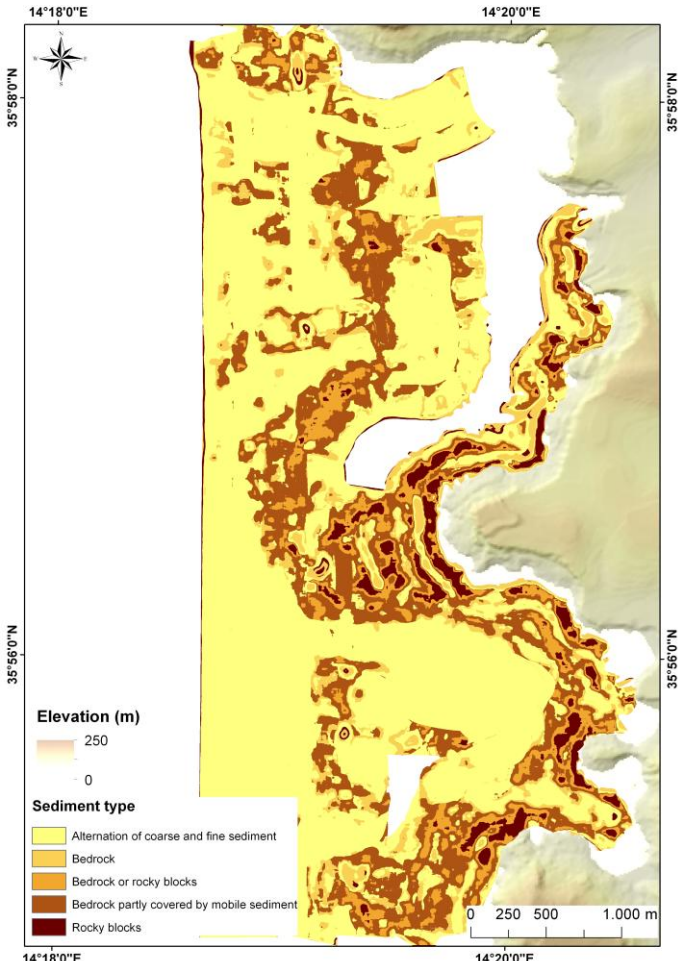
Scheme explaining which part of the acoustic wave constitutes the backscatter signal.



Map of the backscatter intensity (dB).

Beside the bathymetry, also the backscatter data of the seafloor was acquired. It gives information on the seafloor morphology (e.g. slope, roughness) and on composition and density of the surface material. These data help in identifying the type of sediment covering the seafloor, which could hide some morphological features or geological outcrops.

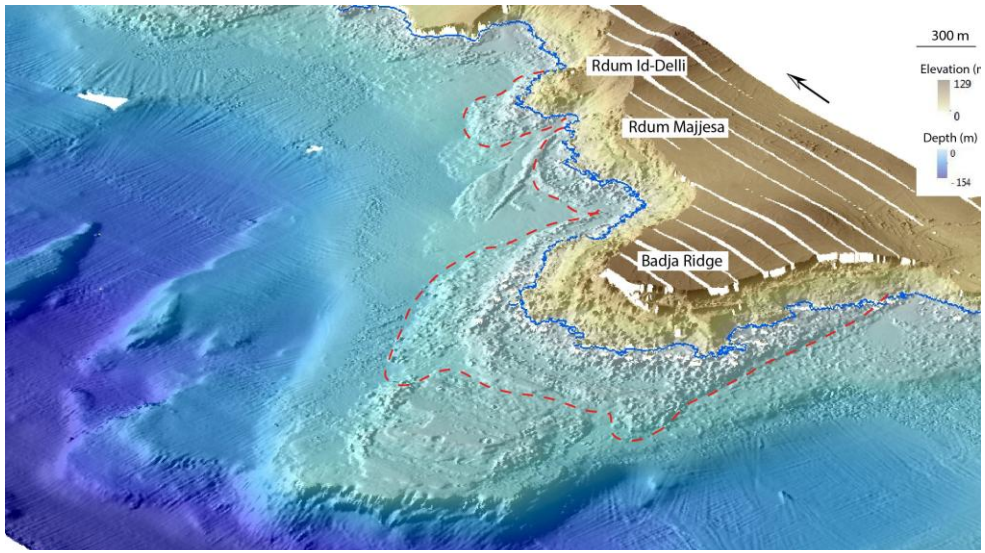
The backscatter data were analysed and classified through the software TexAn, implemented by the University of Bath (UK). This method exploits the Grey Level Co-occurrence Matrices to analyse the acoustic textures within the backscatter image. The result is a classification of the sediments covering the seafloor and it is shown in the map on the right.
The classification obtained is consistent with the inferred geology of the seabed: the deeper part is smooth and the bedrock is covered by coarse and fine sediments, while the shallower area is mostly characterised by the alternation of bedrock and blocks, the latter especially in correspondence of the coastal landslides.



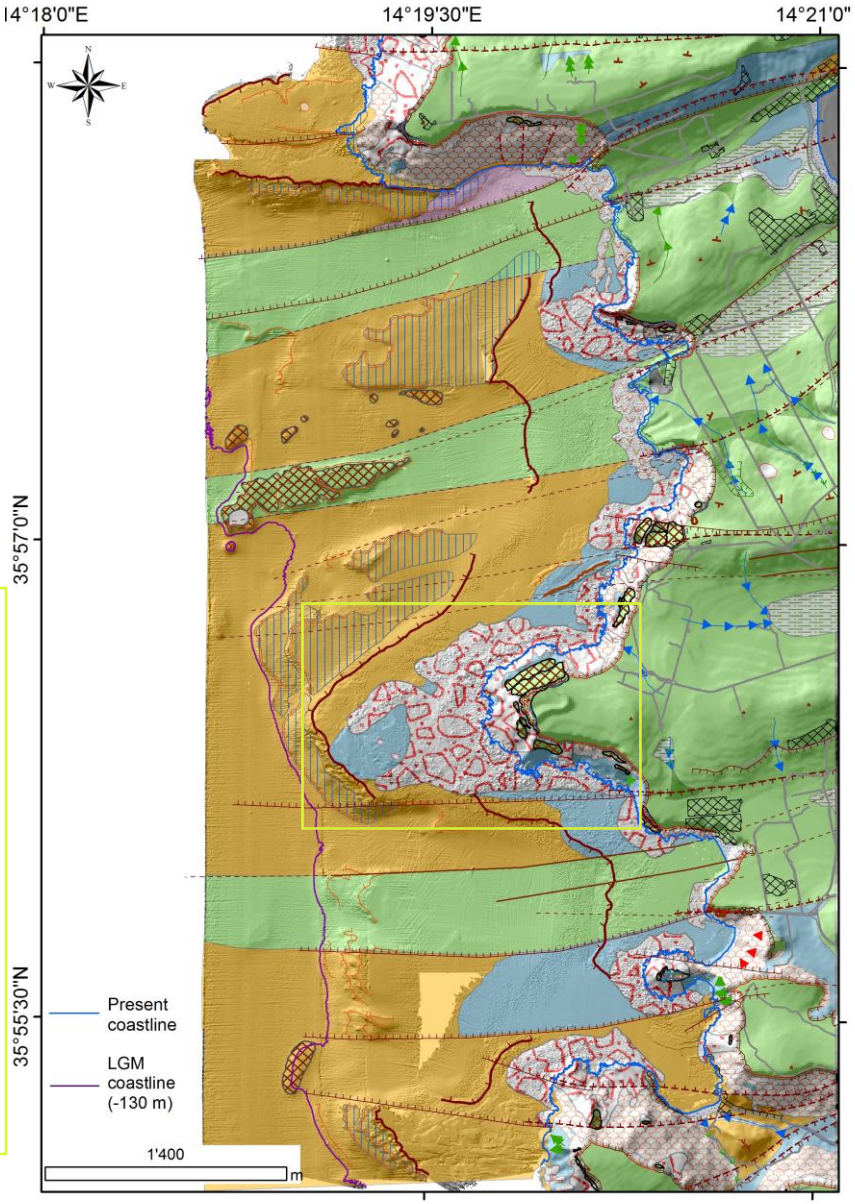
Seafloor sediments map

Integrated geomorphological map

Based on the previous steps, on the field survey and on data available in literature, an integrated geomorphological map of the land and the seafloor of the north-western coast of Malta was performed. With reference to coastal processes and landforms, the most interesting aspect is the huge submarine extension of the coastal landslides: at least 2/3 of landslide accumulations are located under the sea level, along the main promontories. They extend up to 300-550 m from the coastline and reach a depth of 20-45 m with a W-E general orientation, parallel to the fault system affecting the area.

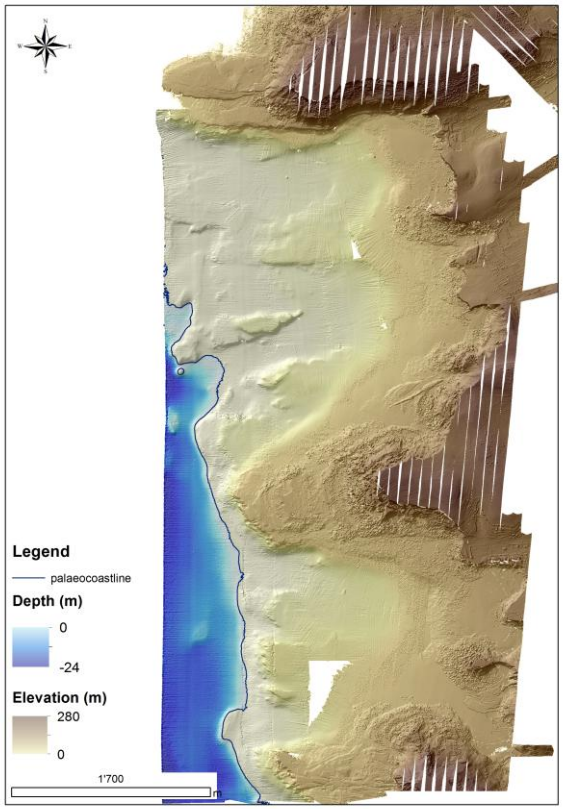


3D view of the landslide extending offshore the Badja Ridge promontory. The blue line represents the present coastline and the red dotted line corresponds to the landslide runout.

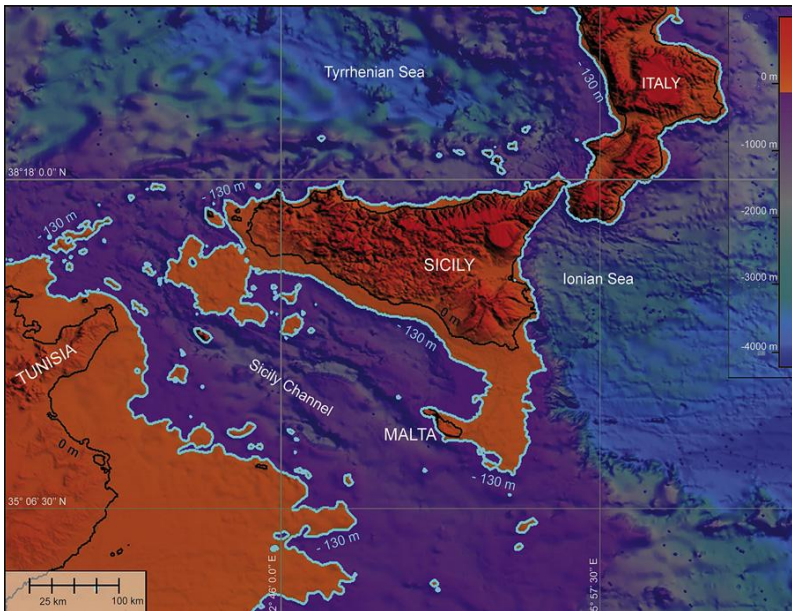


Draft of the integrated geomorphological map under elaboration of the NW area of Malta. A 3D view of the yellow frame is reported on the left.

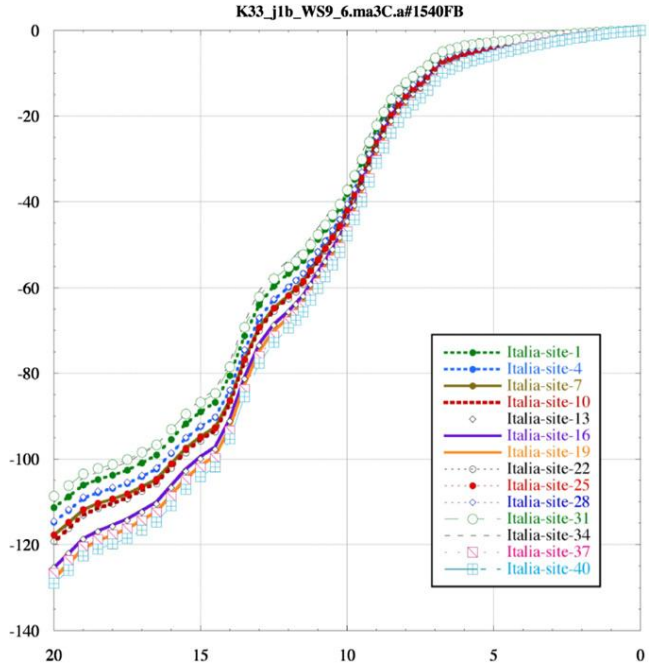
Sea level changes



During the LGM, the sea level was about 130 m lower than at present and the Maltese archipelago was a peninsula connected to the Sicily through a bridge 90 km long and 40 km wide. In particular, along the NW coast of Malta, the majority of the continental shelf investigated was emerged. On-going investigations are trying to define whether these landslides were already active during the LGM or whether they were somehow triggered during the sea level rise. The outputs of the investigations are expected to provide useful hints on the possible future behaviour of coastal slopes.

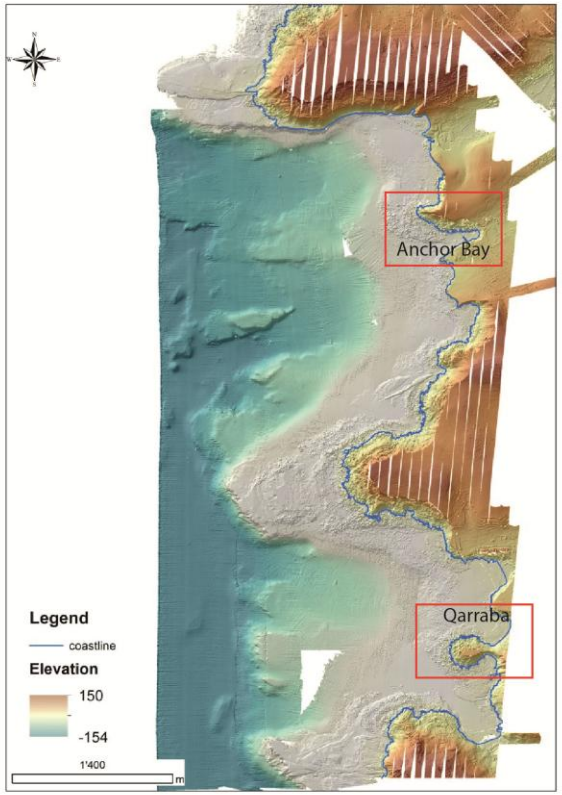


Thanks to the curve of sea level changes from 20,000 years ago untill the present elaborated by Lambeck et al. (2011) for some Italian coastal sites, it was possible to reconstruct the palaeo-geography of the the Maltese archipelago (Furlani et al., 2013) and of the NW area of Malta during the LGM.



The closest site to the Maltese archipelago cosidered by Lambeck et al. (2011) is located at Pantani Cuba and Longarini in south Sicily.

Problems and further enhancements



Sampled sites for surface exposure dating and extimated sea level rise after IPCC, 2007.

Surface exposure dating: since organic matter cannot be found within the landslide accumulations and no dating of any events has been possible so far by means of traditional methods, the next step of the research is to exploit the cosmogenic isotopes, such as ^{36}Cl for limestone, to date the exposure of landslide scarps surface. A sampling campaign was carried out during 2014 with the aim of reconstructing the evolution of large block slides along the limestone plateaus overlying clayey materials. The dating to be achieved should give a temporal frame to landslide occurrence and possibly show whether these movements were active during the LGM. In this case, landslides would have been occurring in a fully terrestrial environment since the isobaths of 130 m is well below the maximum runout of the block slides. If this is not the case, hence the dating results will be useful to understand the role of sea water on the landslide processes: erosion? support?

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best Estimate	Likely Range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [b]	0.6	0.3 - 0.9	NA
B1 scenario	1.8	1.1 - 2.9	0.18 - 0.38
A1T scenario	2.4	1.4 - 3.8	0.20 - 0.45
B2 scenario	2.4	1.4 - 3.8	0.20 - 0.43
A1B scenario	2.8	1.7 - 4.4	0.21 - 0.48
A2 scenario	3.4	2.0 - 5.4	0.23 - 0.51
A1F1 scenario	4.0	2.4 - 6.4	0.26 - 0.59

How did the sea level changes have influenced and will control the landslide kinematics?
Based on information on the spatial and temporal occurrence of landslides, it is possible to achieve important clues on the future behaviour of the coastal slopes considering the expected sea level rise.

Further actions: the approach here presented can give a complete picture of the geomorphological evolution of the investigated area from the LGM and with some insights for the future evolution.

It is clear that this type of research is crucial for a coastal multi-hazards assessment, with special attention to slope instability and impacts of sea level rise on coastal areas.

The output of this research is expected to be beneficial to develop a procedure for coastal hazard mapping to be used also in other coastal areas of the Mediterranean Sea.

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