Geostatistical study of Italian submarine landslides

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How the project start?

What are the risks due to geological events such as landslides, earthquakes, volcanic eruptions? Are we exposed in the area where we live?

To answer questions, the MUR (Italian Ministry of University and Research) under the PNNR (National Recovery and Resilience Plan) has launched a national project called *"Geosciences IR"* that aims to create a new research infrastructure for the Italian geological services network, involving 13 universities and 3 research institutions (more detail in https://geosciences-ir.it).

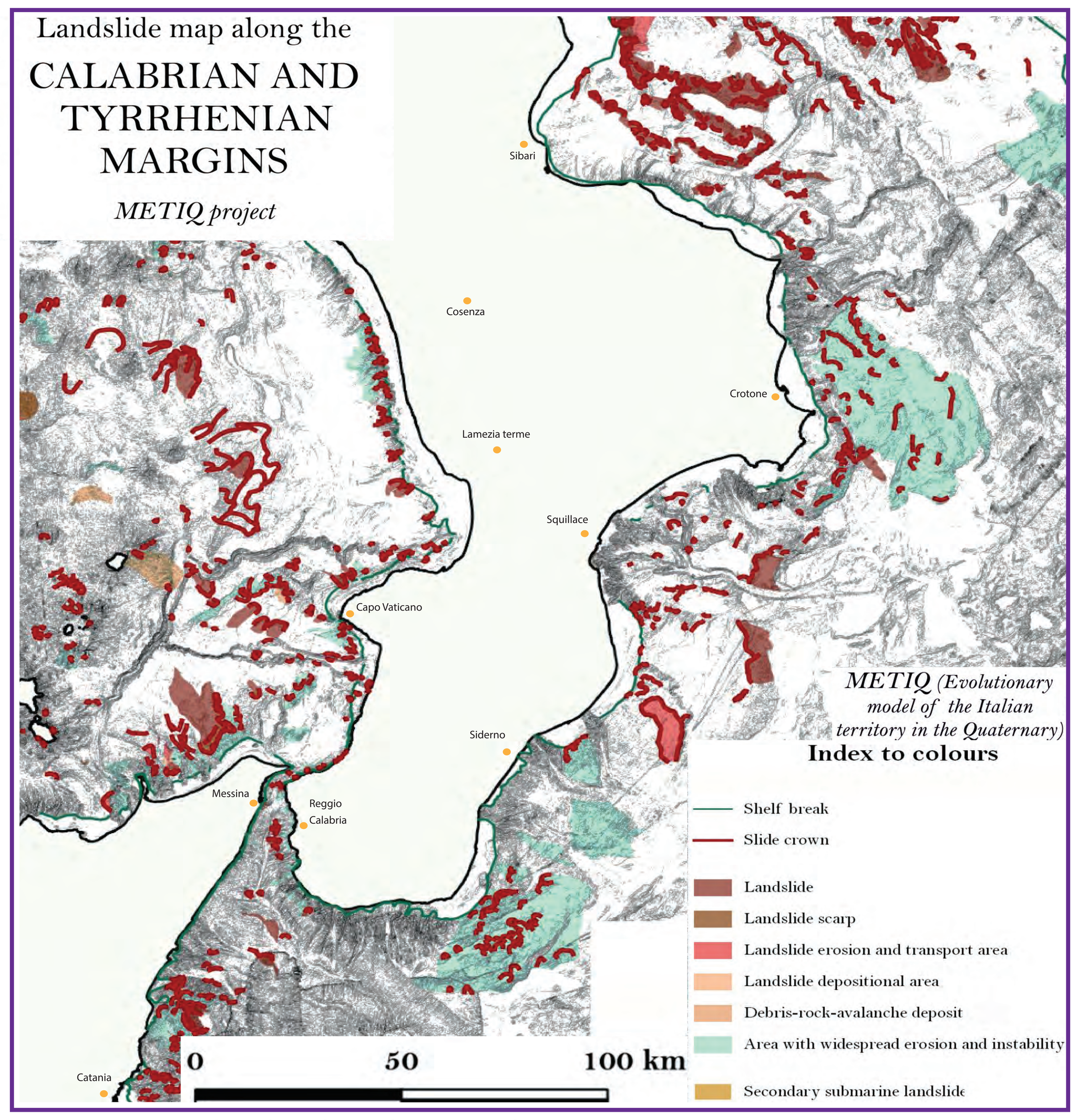
The PhD project is funded by the National Institute of Oceanography and Applied Geophysics **(OGS)** in the framework of the National Recovery and Resilience Plan **(PNNR)**.

Objective

The aim of this PhD project is to advance knowledge about submarine landslides by using a geostatistical approach.

Geomorphological features will be collected in a geodatabase and analyzed to obtain a tool useful for the geohazards assessment in coastal areas and in marine infrastructures.

Key words : ***Submarine landslide, Statistical approach, Geomorphological analysis, Geohazard assessment, Reasearch infrastructure***



Distribution map of the landslides along the Calabrian Tirrhenian and Ionian margins (source: Metiq Project - Modello evolutivo del terrirorio italiano nel Quaternario).

Geological setting

Calabrian Tyrrhenian and Ionian continental margins are an excellent laboratory for studying marine geohazard elements. They are part of a wider active geodynamic region and important spots for the seismicity in Italy (Polonia et al. 2011).

The Tyrrhenian Sea is the youngest backarc basin of the western Mediterranean linked to the Ionian plate subduction. It is characterized by the opening of sedimentary basins as well as by widespread extentional fault systems, with E-W trends orthogonal to Appennine foredeep and coherent with the eastward migration of the Adria-Appennine trench (Carminati & Doglioni 2012).

The complex seafloor topography of the Ionian Calabrian margin reflects the interplay between the south-eastward migration of the Calabrian accretion prism active since the mid-Miocene and the rapid uplift affecting the onshore and shallow shelf areas since mid-Pleistocene (Minelli & Faccenna 2010; Praeg et al. 2009)

Tirrhenian and Ionian continental margins are characterized by narrow and steep shelves that are scored by a series of a wide canyon systems (Ceramicola et al. 2015; Morelli et al. 2022). These canyon systems are often located very close to the coastline (less than 1 km).

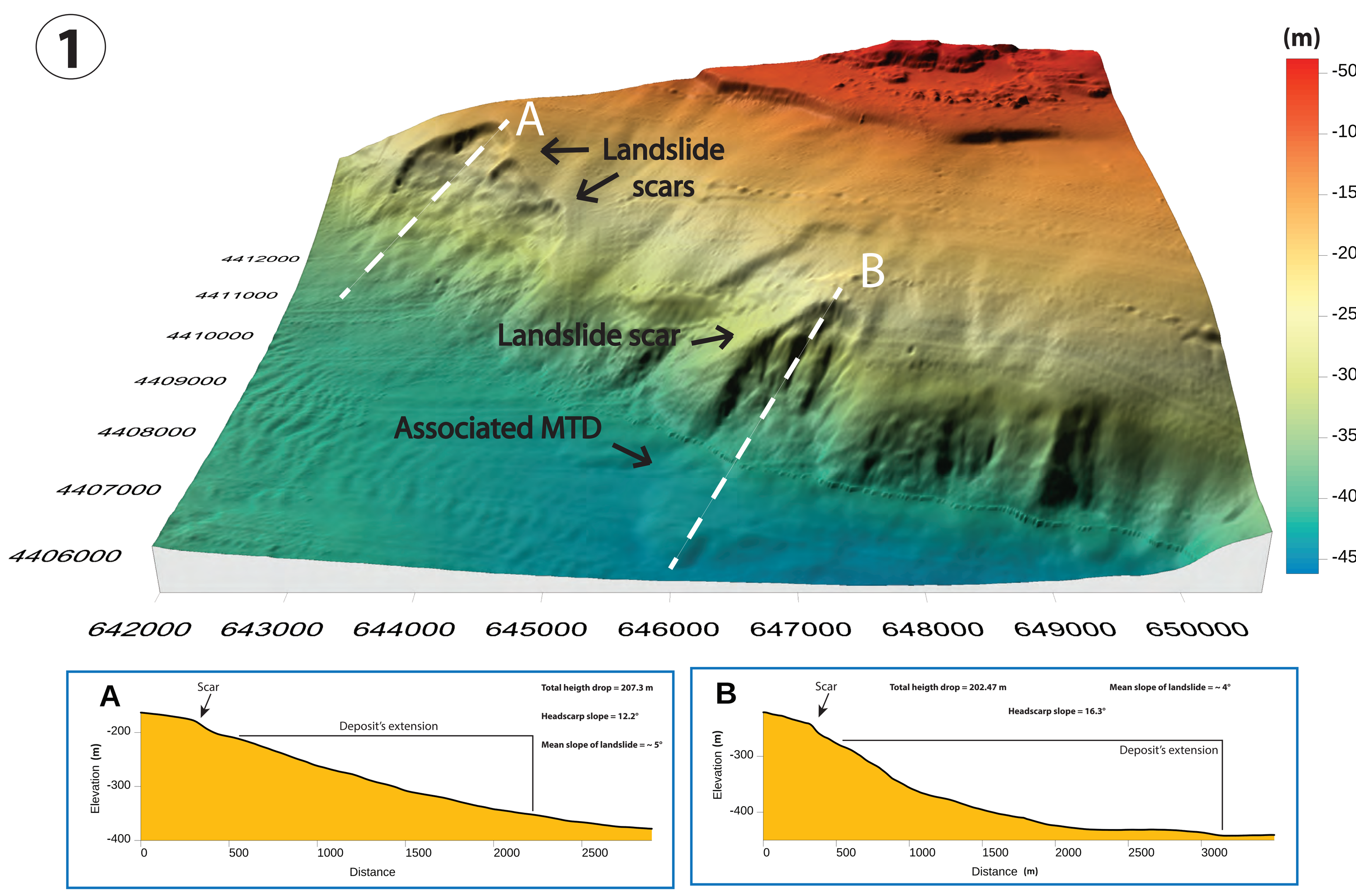


Fig. 1 (I) 3D view of bathymetric digital elevation model n.1. (II) High-resolution bathymetric profiles across the two landslide affecting the slope (location A & B)

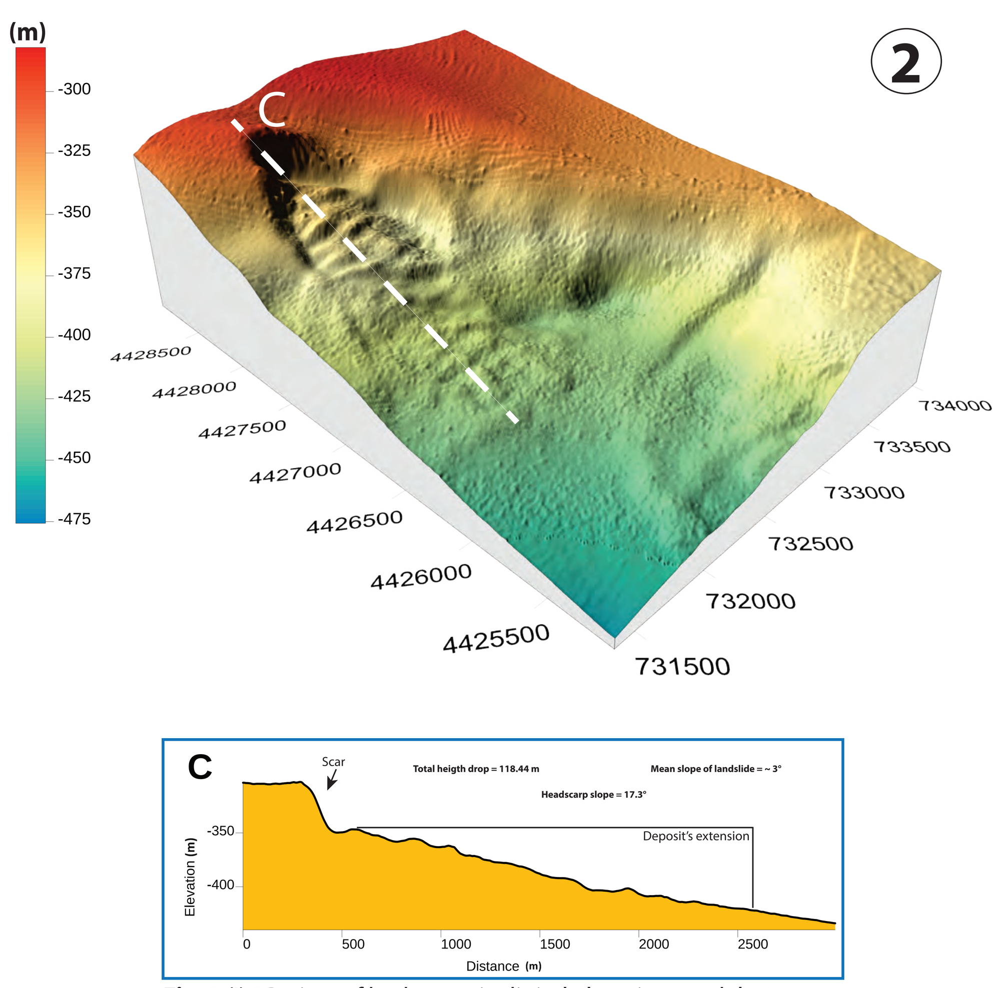


Fig. 2 (I) 3D view of bathymetric digital elevation model n.2. (II) High-resolution bathymetric profile across the landslide (location C)

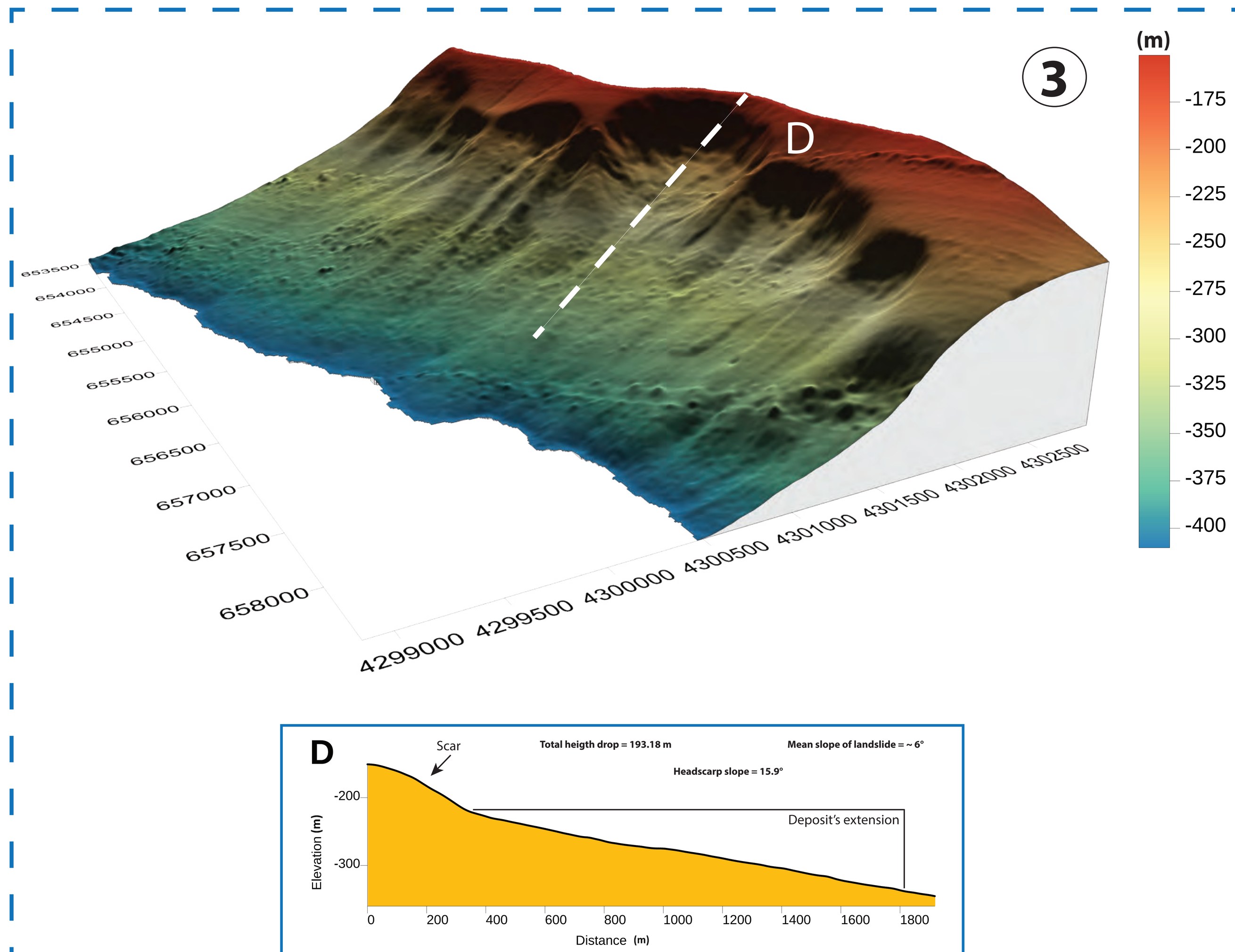


Fig. 3 (I) 3D view of bathymetric digital elevation model n.3. (II) High-resolution bathymetric profile across the landslide (location D).

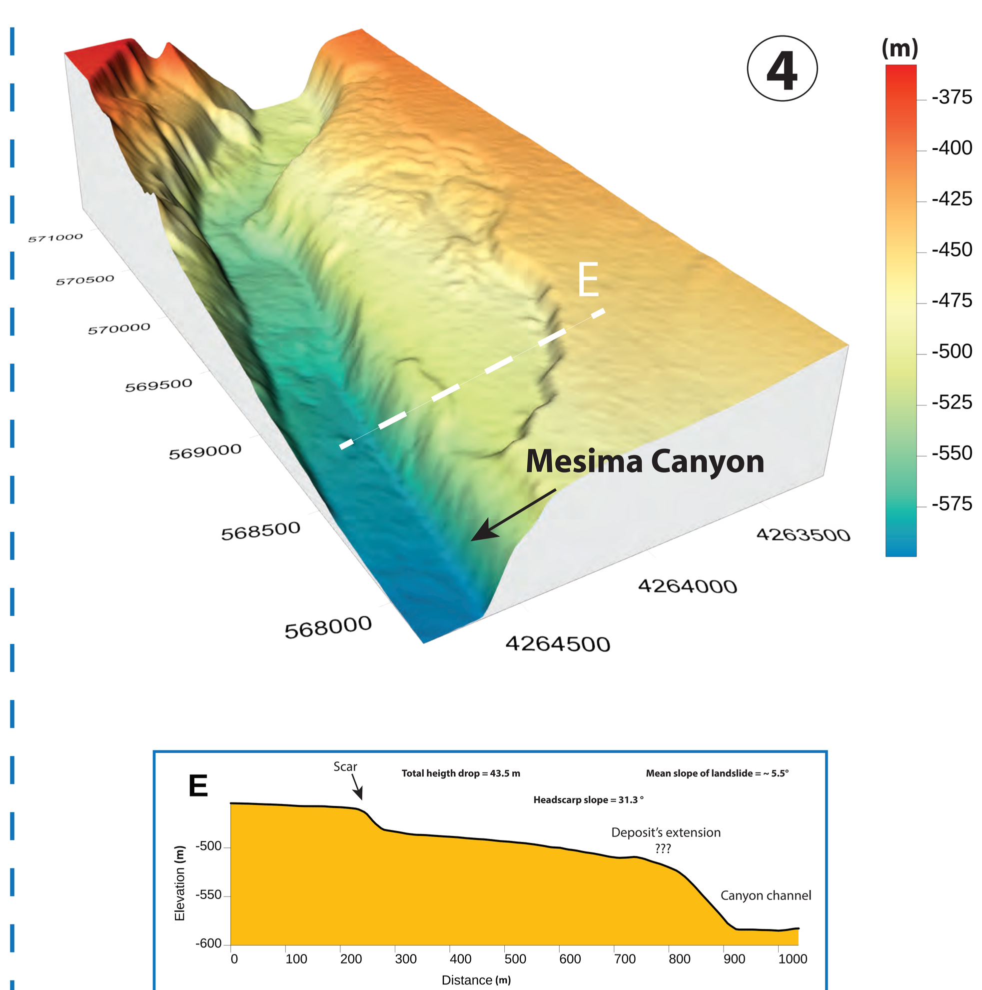


Fig. 4 (I) 3D view of bathymetric digital elevation model n.4. (II) High-resolution bathymetric profile across the landslide

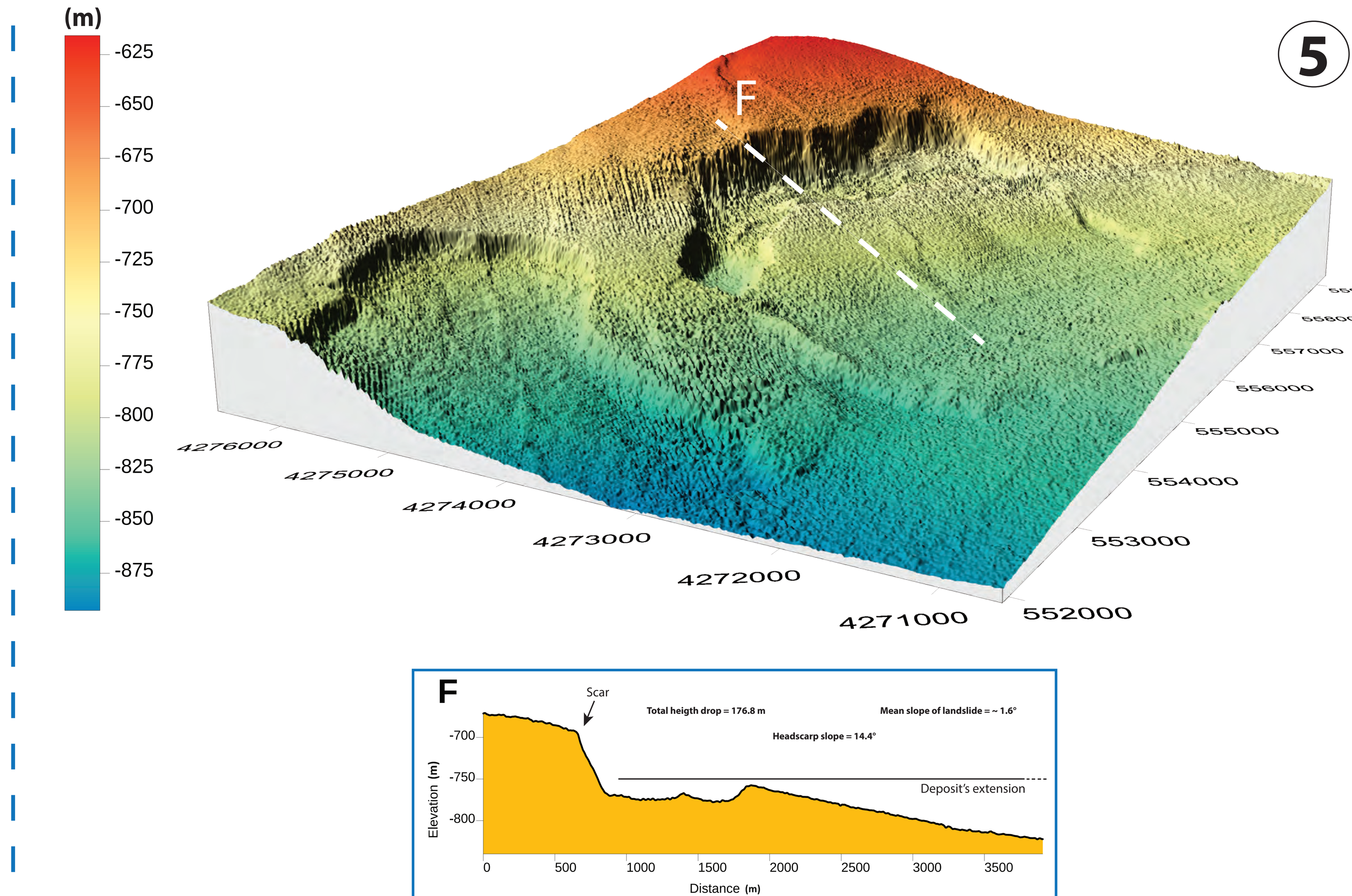


Fig. 5 (I) 3D view of bathymetric digital elevation model n.5. (II) High-resolution bathymetric profile across the landslide (location F)

L_ID	Gen_Vol (m³)	Tot_Length (km)	Min_Depth (m)	Max_Depth (m)	Ex_Slope (°)	Coast_Dist (km)	Gen_Per (km)	Gen_Area (km²)	Scar_Lenght (km)	Scar_EvLength (km)
A	38638454	2.12	-178.28	-385.57	4.8	10.73	8.98	4.25	5.31	1.51
B	19296978	2.89	-242.07	-444.55	3.0	16.38	7.25	3.06	2.99	0.75
C	9991536	2.36	-306.098	-424.445	3.1	23.28	5.96	1.76	3	1.03
D	14868952	1.86	-157.255	-350.432	5.8	4.43	5.72	1.41	2.13	0.51
E	7448680	0.76	-410.48	-531.3	1.9	8.89	7.09	1.56	//	
F	215552708	4.58	-683.3	-860.1	1.5	13.29	16.49	15.11	7.65	1.22

L_ID	Scar_Width (km)	Scar_Heigth (m)	Scar_Slope (°)	Scar_HSlope (°)	Scar_Per (km)	Scar_Area (km²)	Dep_Length (km)	Dep_Width (km)	Dep_Per (km)	Dep_Area (km²)
A	2.56	20.9	5.6	12.2	8.01	3.03	1.94	2.49	8.71	3.90
B	1.20	28.4	8.0	16.3	4.61	0.83	2.18	1.43	5.82	2.22
C	0.94	36.7	2.1	17.3	3.57	0.87	2.19	0.89	5.72	1.54
D	1.14	58.3	4.4	15.9	3.08	0.63	1.65	0.93	5.14	1.09
E	//	//	//	//	//	//	//	//	//	//
F	3.84	72.8	1.9	14.4	12.64	4.39	3.48	3.64	13.89	10.96

Tab. 1 Landslide morphometric parameters (see Tab. 2) divided in: scar morphometric parameters, deposit morphometric parameters and general parameters that allow us to observe the general framework of these six landslides that have been explored in this preliminary work.

Table legend

Landslide ID = Sequential number/letter of each landslide entry in the database.

Scar_Length = Length of scar perimeter including side scarps.

Scar_EvLength = Length of the scar from base of the headscarp to the upslope limit of the deposit.

Scar_Width = Maximum measured width of scar.

Scar_Heigth = Heigth difference from the maximum convex point of the headscarp to the maximum concave point at the toe.

Scar_Slope = Mean slope of the evacuated area of the landslide.

Scar_Hslope = Maximum slope of the headscarp.

Dep_Length = Total mappable length of the slide deposit (not include outrunner blocks).

Dep_Width = Maximum deposit width, measured orthogonal to the length.

Tot_Length = Total mappable lenght of the entire slide, from the upslope limit of the heascarp to the downslope limite of the deposit.

Ex_Slope = Slope measured laterally away from the scar, outside of the zone of the deformation.

Coast_Dist = Minumum distance of the coast from the whichever point of the landslide

a

	Landslides morphological parameters	
1	Minimum water depth (m)	8 General parameters
2	Maximum water depth (m)	
3	Area (km²)	
4	Volume (km³)	
5	Perimeter (km)	
6	Total length (km)	
7	Lateral slope (°)	
8	Distance from the coast (km)	
9	Scar area (km²)	8 Scar parameters
10	Scar perimeter (km)	
11	Scar length (km)	
12	Evacuated length (km)	
13	Scar width (km)	
14	Headscarp heigth (m)	
15	Headscarp slope (°)	
16	Sliding surface slope (°)	
17	Deposit area (km²)	4 Deposit parameters
18	Deposit perimeter (km)	
19	Deposit length (km)	
20	Deposit width (km)	

b

Environmental background	
Lithological characteristics	Gas expulsion
Sedimentation rates	Pore water overpressure
Tectonic activity	Turbidity and countour currents
Seismicity	Associated morphological features

Tab. 2 a) Landslide morphological parameters (and ID that allow us to count the landslides) that this work aims to measure, in order to characterize the landslide features and successively to analyse the results with statistical method. **b)** Environmental factors .

Methods & Approach

The dataset consists of high resolution bathymetry models that cover the seafloor of the Ionian and Tyrrhenian continental margins (Southern Italy) from the shallow water (very close to the coastline) until depths around 4000 m. The resolution of each digital elevation model depends on the depth at which it was acquired, since the resolution tend decreases with increasing depth (5 m to 20 m of grid resolution). Therefore, the study will be carried out on distinct bathymetric ranges in order to avoid a possible resolution biases.

The first step will be the morphometric analysis based on multibeam derived parameters, whose results will be stored in a database.

The landslide morphometric parameters selection procedure will be carried out on the basis of a review of available literature concerning submarine landslides and the existing geodatabase (e.g. Urgeles & Camerlenghi 2013, Clare et al. 2018, Clarke et al. 2019 Gamboa et al. 2021)

When the database will be complete, the phase of statistical analysis will begin. Firstly, an exploratory data analysis (EDA) will be carried out, to determine the distribution and summarize the main characteristics of the available features, using a statistical graphs, a series of tests and data visualization methods (e.g. PCA "Principal component analysis"). The next step, when the characteristics and distribution of the data are clear, will be possibly to define the fittest statistical approach to use (e.g. logistic regression, multivariate analyses …).