Coastal SAGE – First Stakeholders' Meeting

27 January 2021

Research on coastal hazard assessment in Malta:
The contribution of the CNR/UNIMORE Research Team

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

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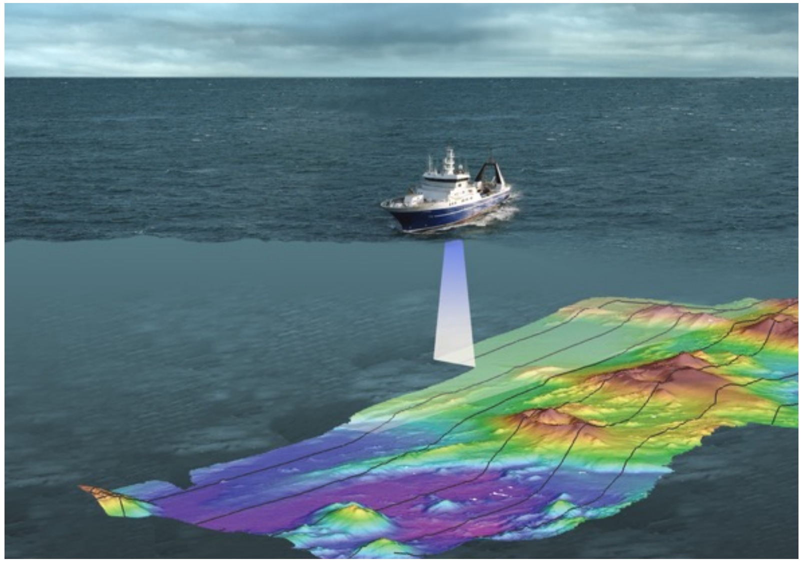
Coastal research interest and main outputs

Landsliding vs erosion

Recognition, mapping and monitoring of coastal landslides

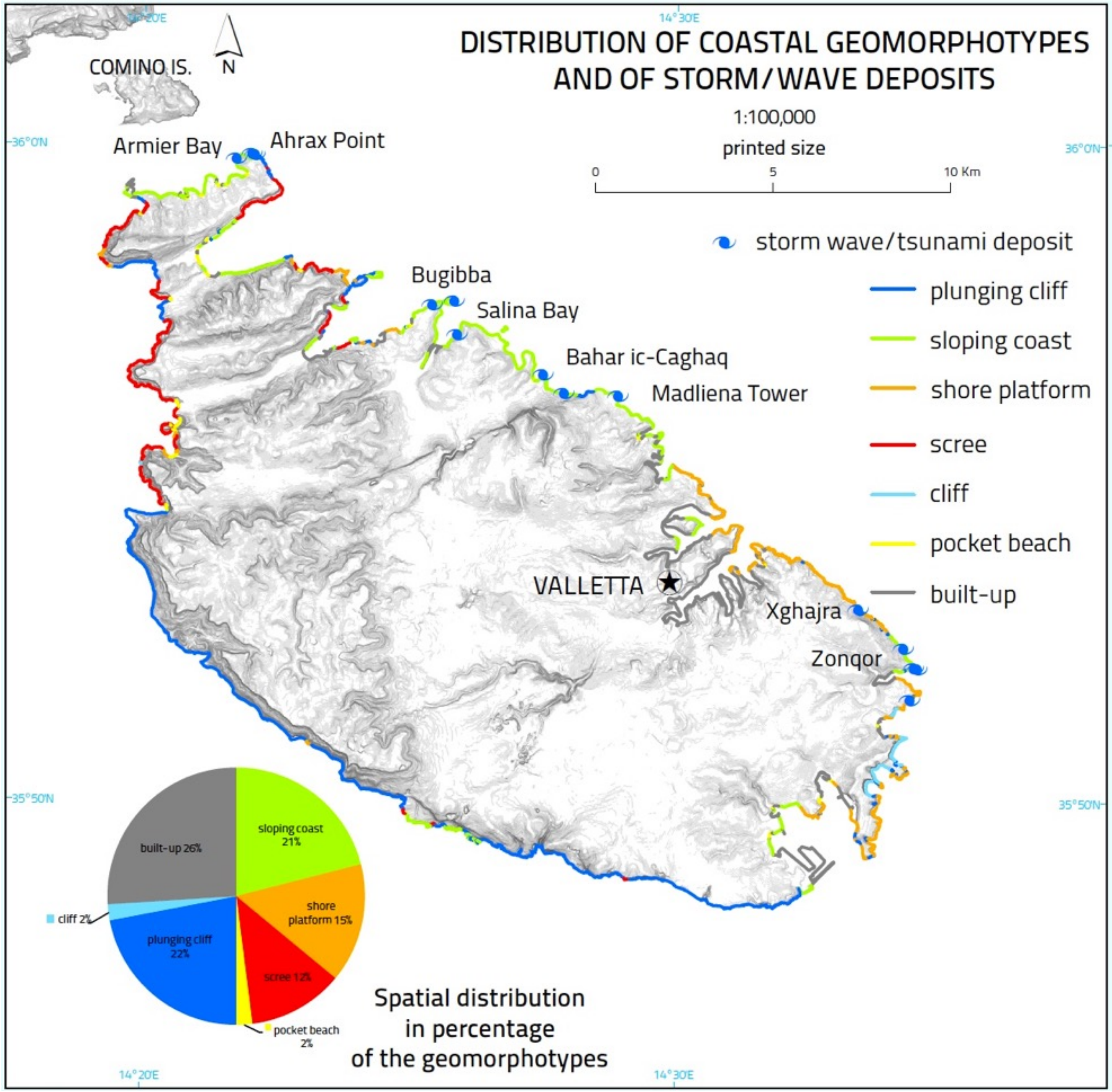
Discovery of submarine 'hidden landslides'



Integration of terrestrial and marine datasets aiming at comprehensive hazard assessments

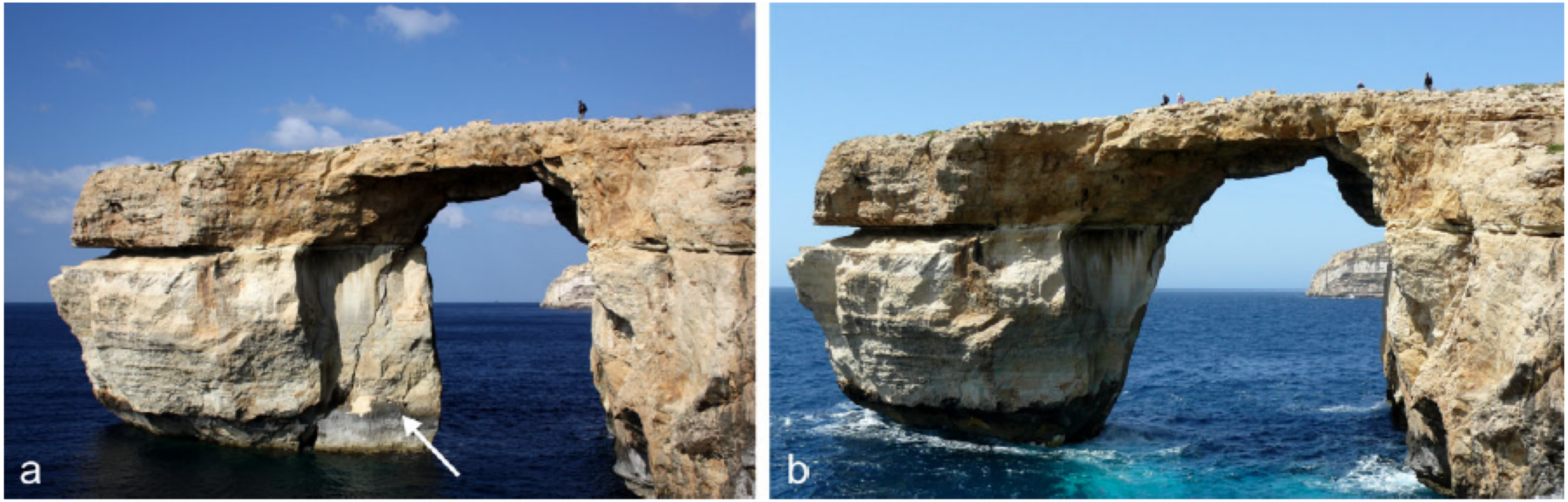
Identification of chronological constraints to the onset and development of coastal landslides

Landslides vs erosion



Biolchi et al. 2016, Journal of Maps 12(1)

Azure Window, Gozo
The disappearance of an icon of the Maltese landscape



Azure Window before (a) and after (b) the collapse of 2012

Source: Coratza et al. 2016, Geoheritage 8(1)

Azure Window before and after the collapse of 8 March 2017

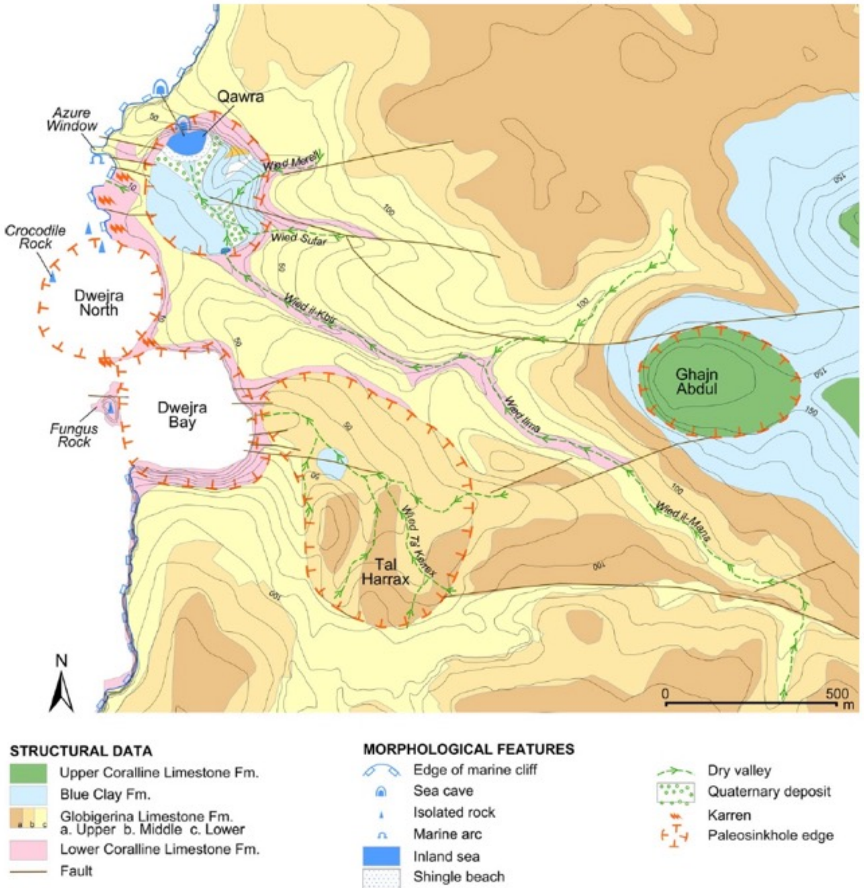
Geoheritage (2016) 8:91–103
DOI 10.1007/s12371-015-0167-7

ORIGINAL ARTICLE

Bridging Natural and Cultural Values of Sites with Outstanding Scenery: Evidence from Gozo, Maltese Islands

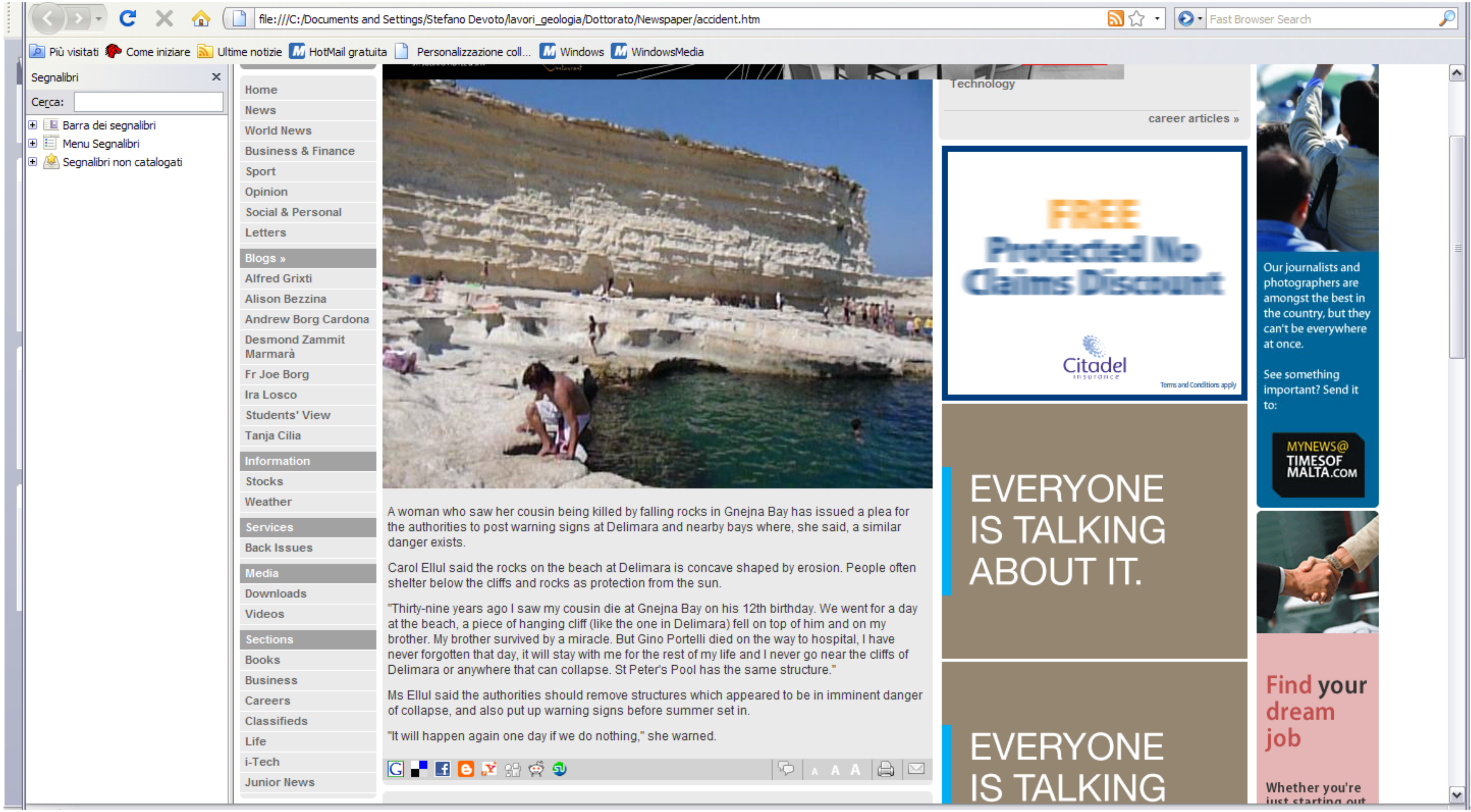
Paola Coratza [1] · Ritienne Gauci [2] · John Schembri [2] · Mauro Soldati [1] · Chiara Tonelli [1]

Fig. 3 Geomorphological sketch of the study area



Landslide risk issues in Malta

In 1970 a 12 years old boy was killed by a rock fall on the NW coast of Malta, at Gnejina Bay and other injuries were reported more recently



A woman who saw her cousin being killed by falling rocks in Gnejna Bay has issued a plea for the authorities to post warning signs at Delimara and nearby bays where, she said, a similar danger exists.

Carol Ellul said the rocks on the beach at Delimara is concave shaped by erosion. People often shelter below the cliffs and rocks as protection from the sun.

"Thirty-nine years ago I saw my cousin die at Gnejna Bay on his 12th birthday. We went for a day at the beach, a piece of hanging cliff (like the one in Delimara) fell on top of him and on my brother. My brother survived by a miracle. But Gino Portelli died on the way to hospital, I have never forgotten that day, it will stay with me for the rest of my life and I never go near the cliffs of Delimara or anywhere that can collapse. St Peter's Pool has the same structure."

Ms Ellul said the authorities should remove structures which appeared to be in imminent danger of collapse, and also put up warning signs before summer set in.

"It will happen again one day if we do nothing," she warned.

Source: Times of Malta, 16 April 2009

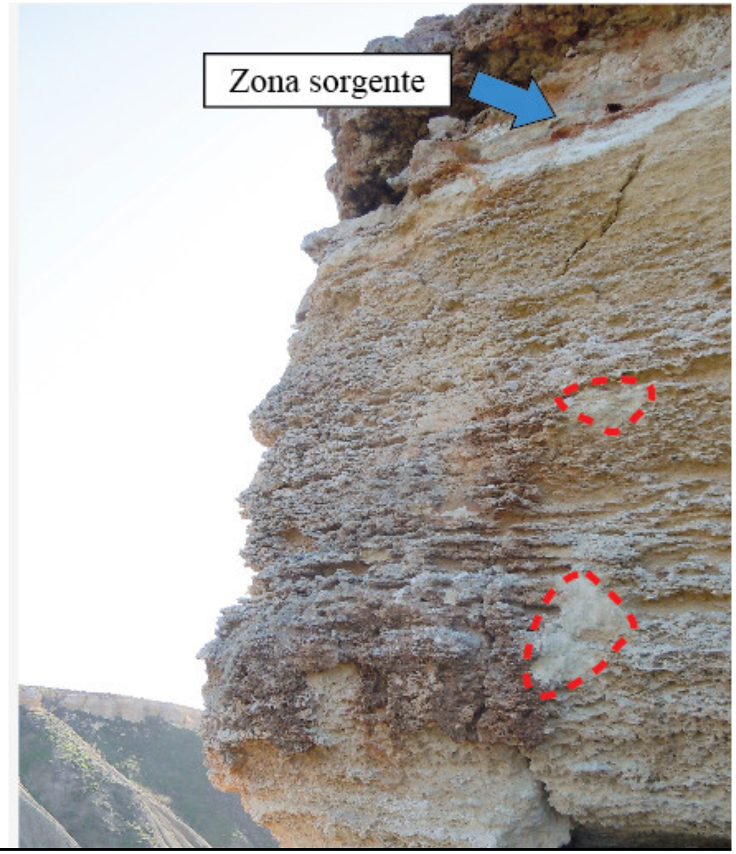

TIMES OF MALTA

Latest | National | World | Community | Sport | Business | Opinion

Storm causes rockfall at Xatt l-Aħmar in Gozo

People urged to keep away from a section of the bay for their own safety

Rock fall, Gozo, November 2019



Rock falls NW Malta, 2011, 2012

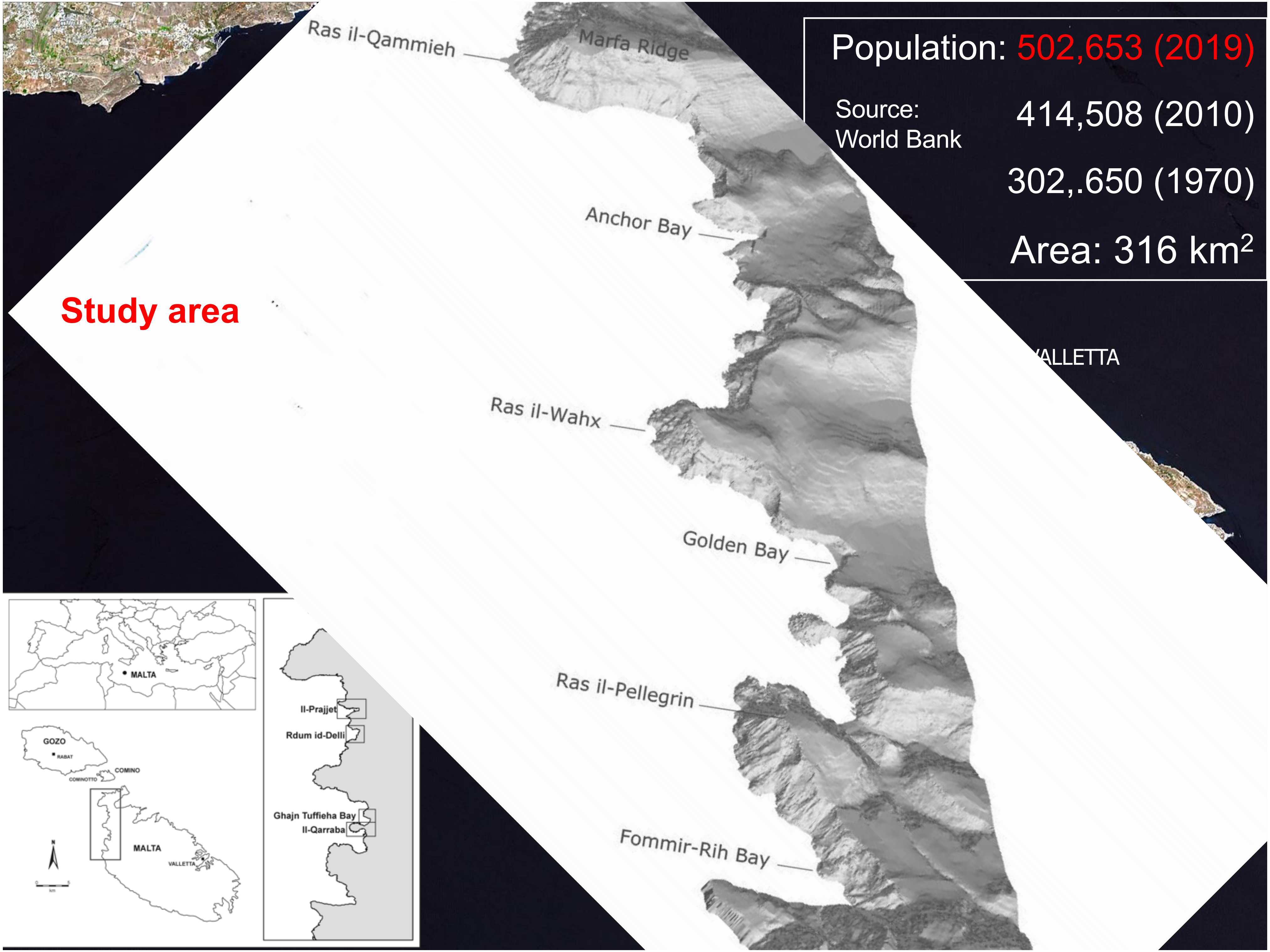
Recognition, mapping and monitoring of coastal landslides

Landslide research on the NW coast of Malta

EUR-OPA Major Hazards Agreement
COUNCIL of EUROPE

PROJECT: Coastline at Risk:
Methods for multihazard assesssment

PROJECT: Hazard and vulnerability assessment:
The path to identifying risk


Population: 502,653 (2019)
Source:
World Bank
414,508 (2010)
302,.650 (1970)
Area: 316 km²
Study area
Ras il-Qammieh
Marfa Ridge
Anchor Bay
Ras il-Wahx
Golden Bay
Ras il-Pellegrin
Fommir-Rih Bay
VALLETTA
MALTA
GOZO
RABAT
COMINO
COMINOTTO
MALTA
VALLETTA
Il-Prajjet
Rdum id-Delli
Ghajn Tuffieha Bay
Il-Qarraba

Methods and phases

An integrated multi-technical approach was used including:

❖ Geomorphological survey and mapping, including sampling for landslide CRE dating	Geomorphological map (1:7500)
❖ Different monitoring techniques	✓ Interferometric analyses ✓ 2 GPS networks ✓ 2 tape-extensometer networks ✓ 2 automatic fissurimeter ✓ LiDAR
❖ Photogrammetry	1957 and 2004 Aerial photos
❖ Geophysics	GPR and ERT investigations
❖ PSI combined with WofE	Landslide susceptibility mapping
❖ PSI combined with PSTime	Definition of displacement trends

Geological control on landform development

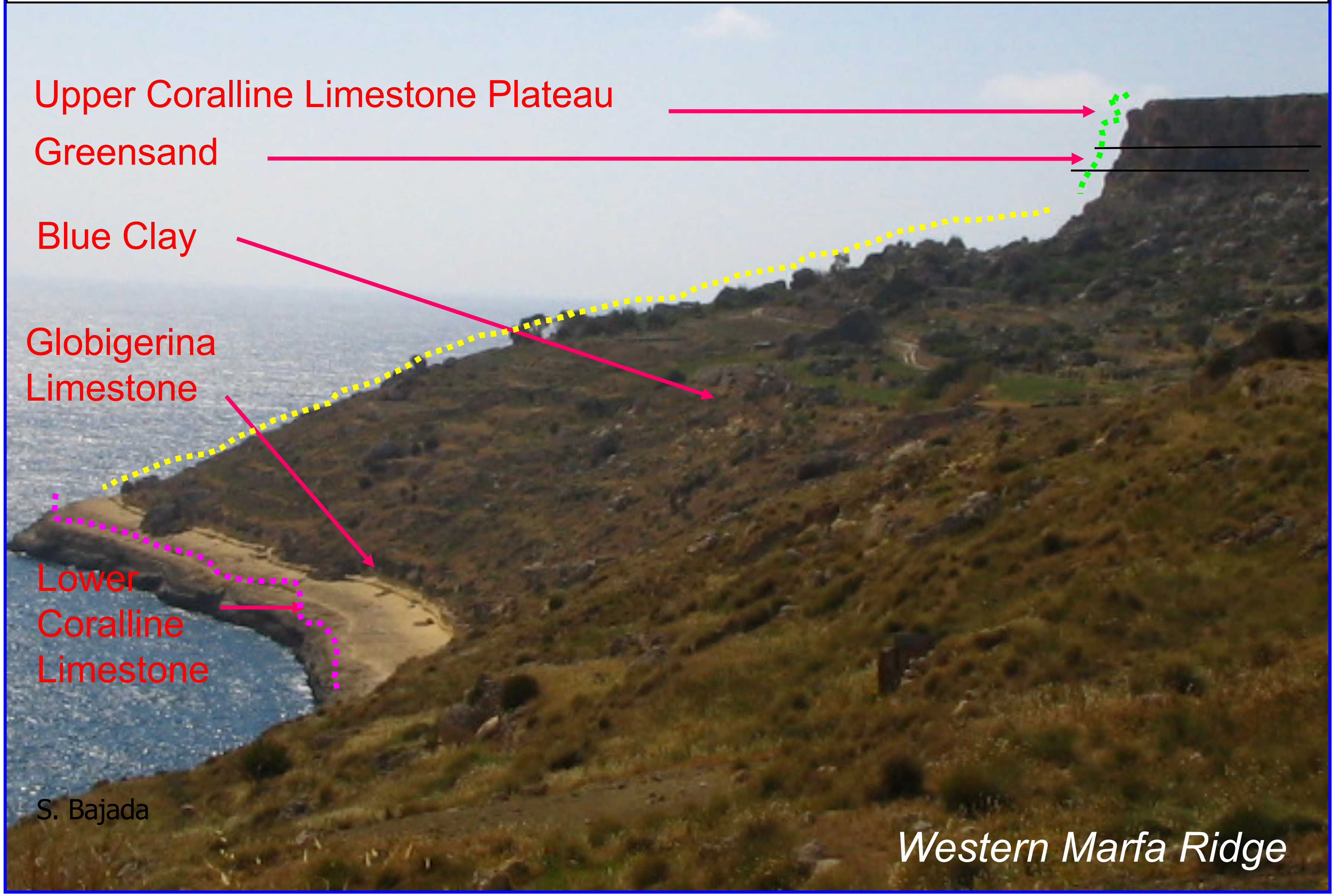
Il-Qarraba

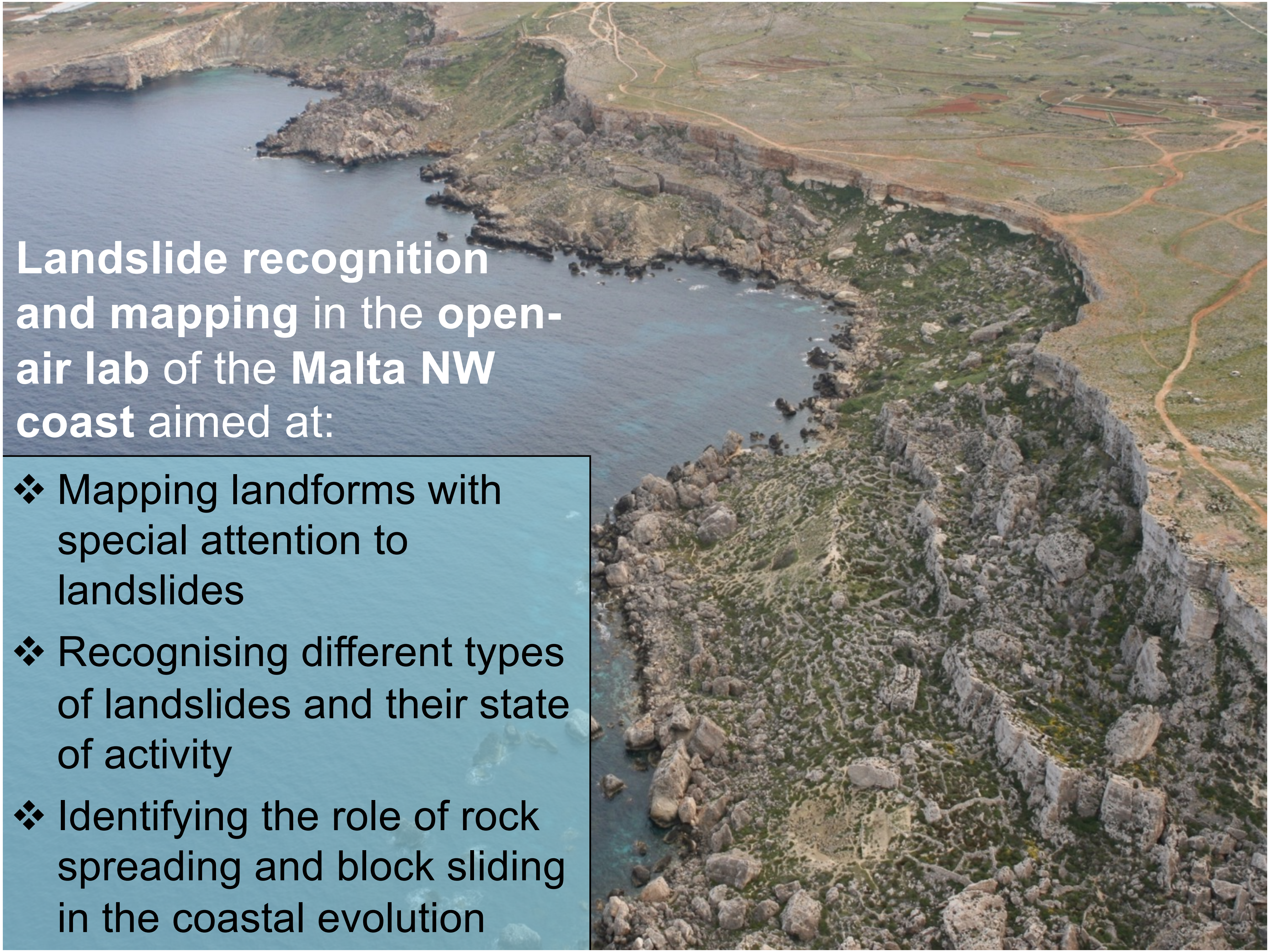
Limestones plateaus overlying marly and clayey terrains characterize the coasts of northern Malta

Spectacular rock spreads and block slides can be found along the NW coast

Geological features

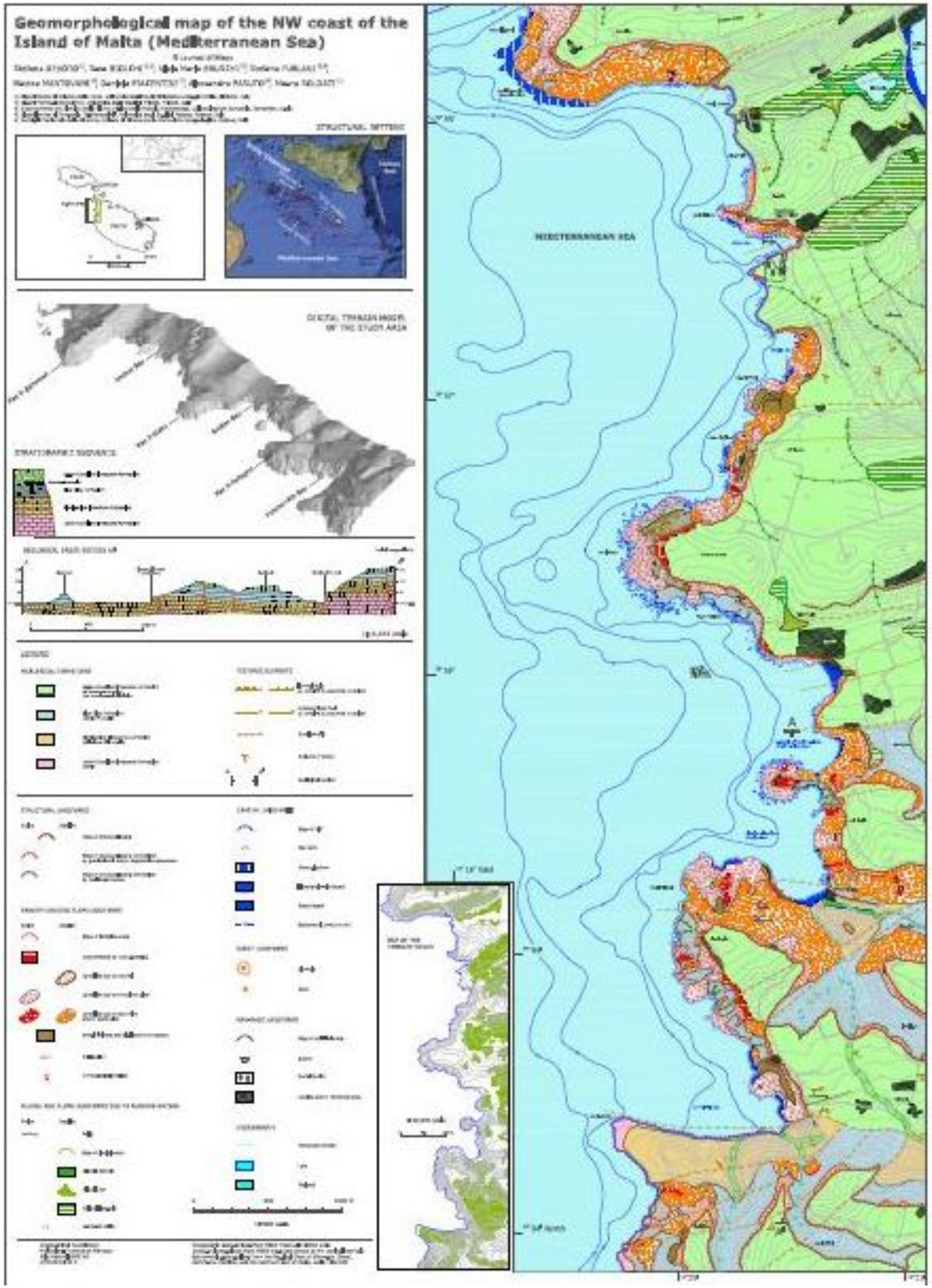
Coastal morphology is controlled by the different mechanical and physical properties of the outcropping rocks

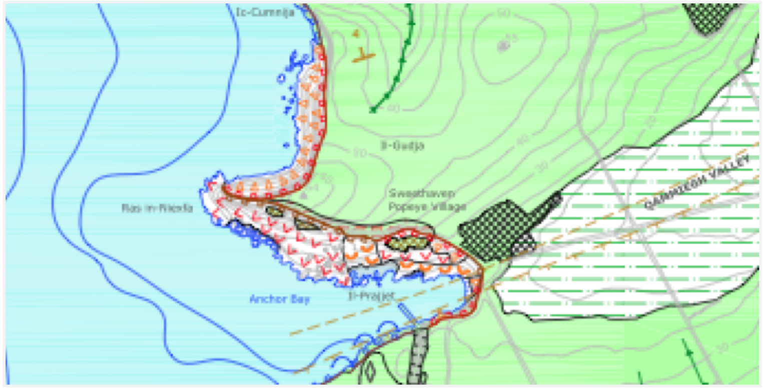




Landslide recognition and mapping in the **open-air lab** of the **Malta NW coast** aimed at:

- ❖ Mapping landforms with special attention to landslides
- ❖ Recognising different types of landslides and their state of activity
- ❖ Identifying the role of rock spreading and block sliding in the coastal evolution



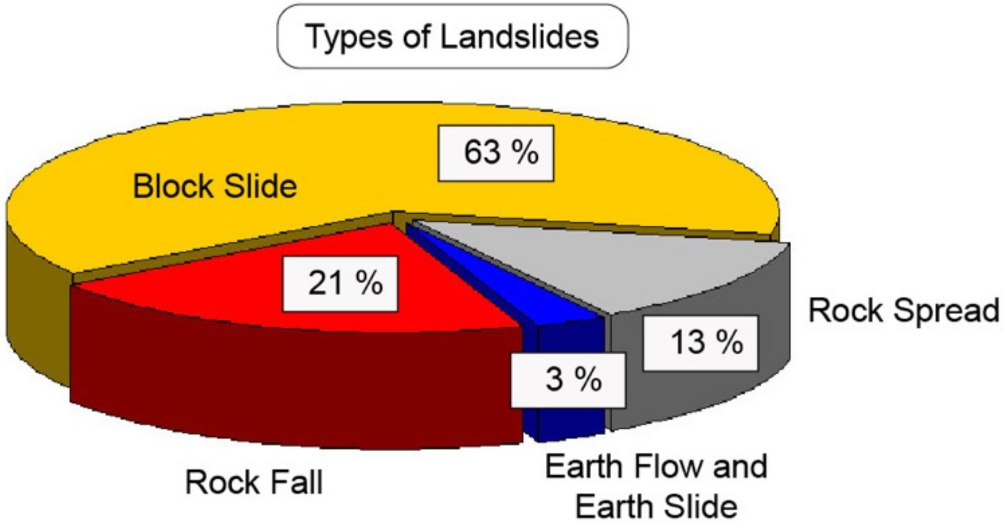


Geomorphological map at 1:7500 scale

Source: Devoto et al. 2012, Journal of Maps, 8(1)

Types of landslides

- Rock falls (limestones)
- Rock spreading (limestones and clays)
- Block slides (limestones and clays)
- Earth slides/flows (clays)



Source: Devoto et al. 2013,
Landslide Science and Practice

Type of movement

+

Material involved in movement

↓

Different types of coastal instability

↓

Different hazard (and vulnerability) for different landslide types!!

Lateral spreading and block sliding

Lateral spreading is favoured by the overlapping of rocks showing different mechanical behaviour.
The lateral extension of rock masses tend to evolve into **block sliding**.
Outstandings examples have been recognised along western sector of Marfa Ridge, Anchor Bay and Il Qarraba peninsula.

remote sensing

MDPI

Article

Advantages of Using UAV Digital Photogrammetry in the Study of Slow-Moving Coastal Landslides

Stefano Devoto [1,*], Vanja Macovaz [2], Matteo Mantovani [3], Mauro Soldati [4] and Stefano Furlani [1]

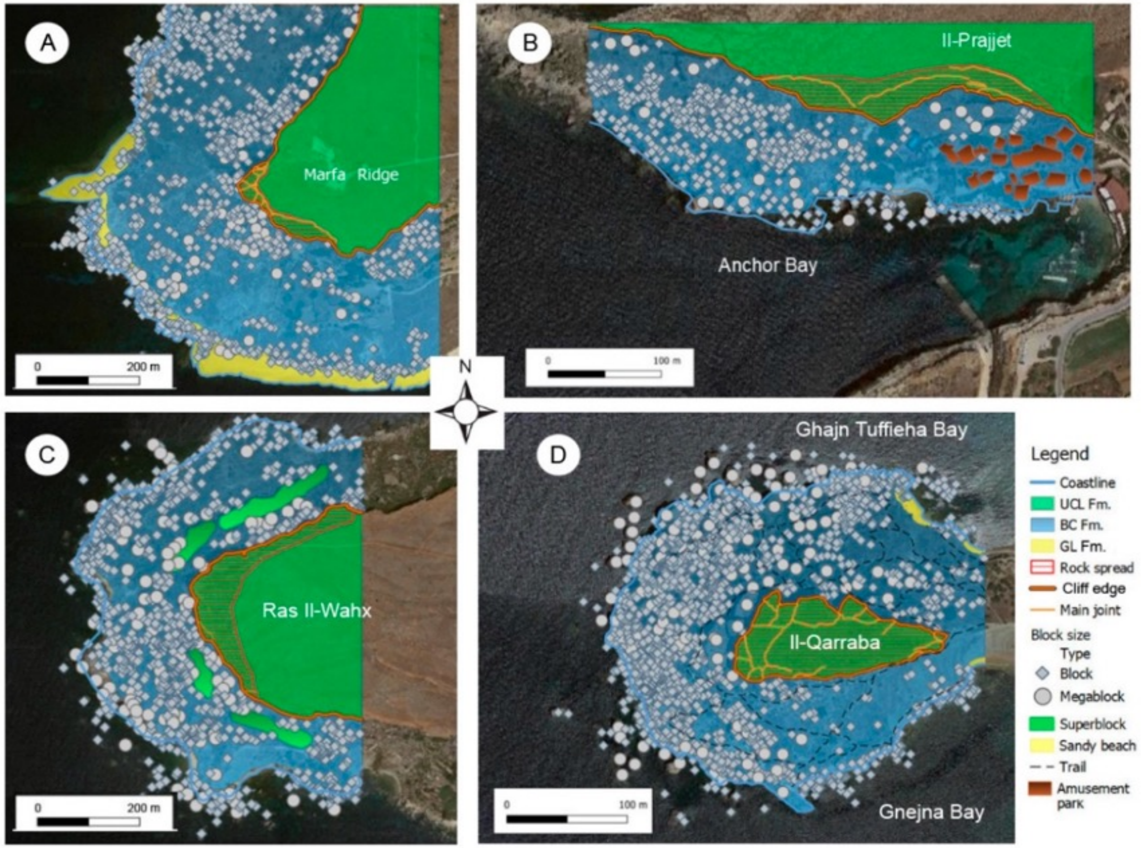
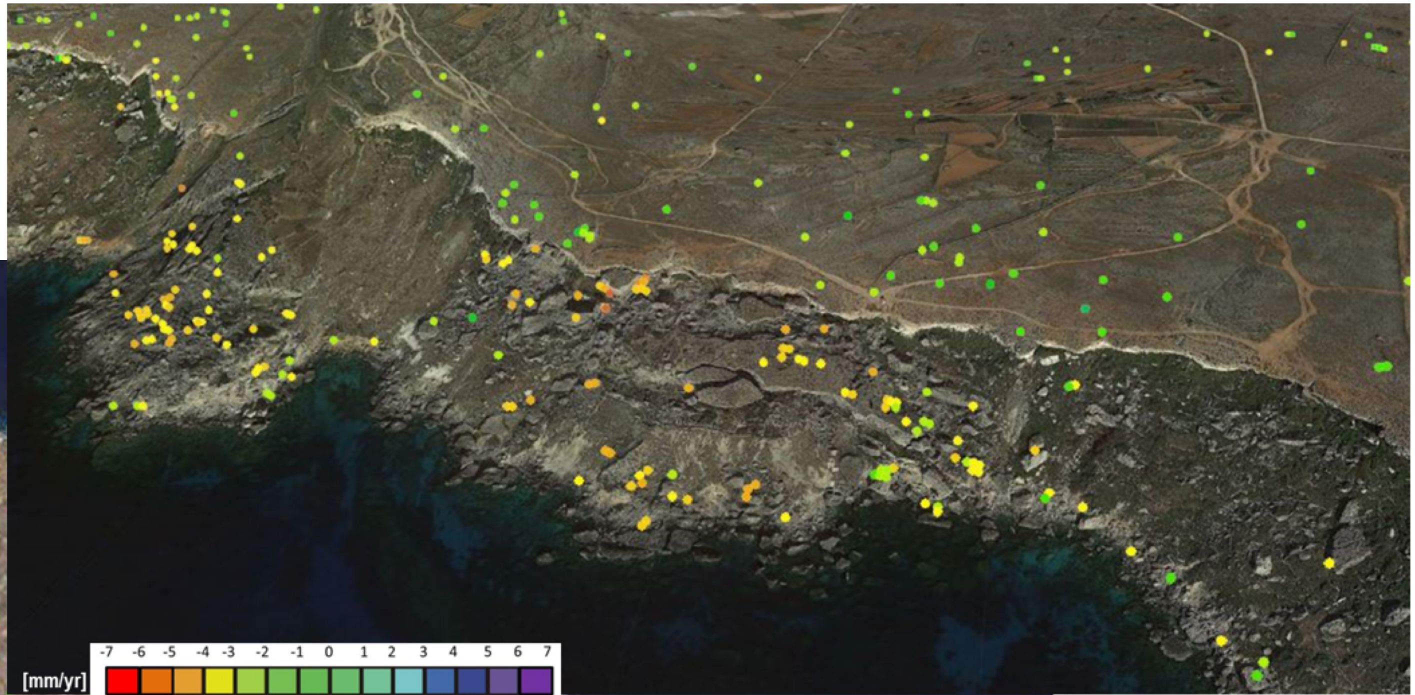
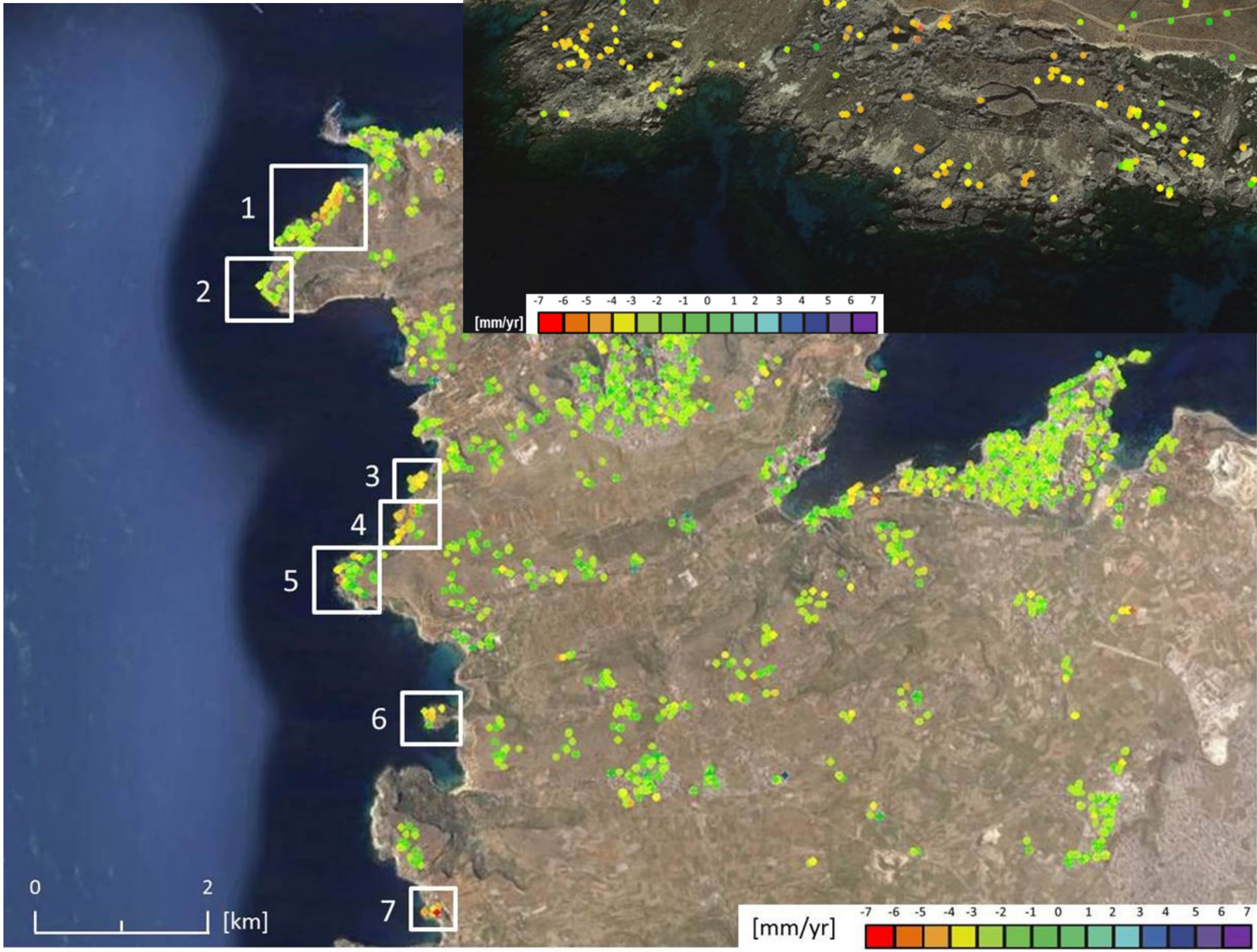


Figure 8. The spatial distribution of categorized megaclasts of: (**A**) Marfa Ridge; (**B**) Anchor Bay; (**C**) Ras Il-Wahx headland; and (**D**) Il-Qarraba peninsula.

State of activity: Interferometric analysis





First evidence of **active** deformation

remote sensing

MDPI

Article

Advanced SAR Interferometric Analysis to Support Geomorphological Interpretation of Slow-Moving Coastal Landslides (Malta, Mediterranean Sea)

Matteo Mantovani [1], Stefano Devoto [2], Daniela Piacentini [3], Mariacristina Prampolini [4,*], Mauro Soldati [4] and Alessandro Pasuto [1]

Remote Sens. 2016, 8, 443;

Nat Hazards (2015) 78:681–697
DOI 10.1007/s11069-015-1740-8

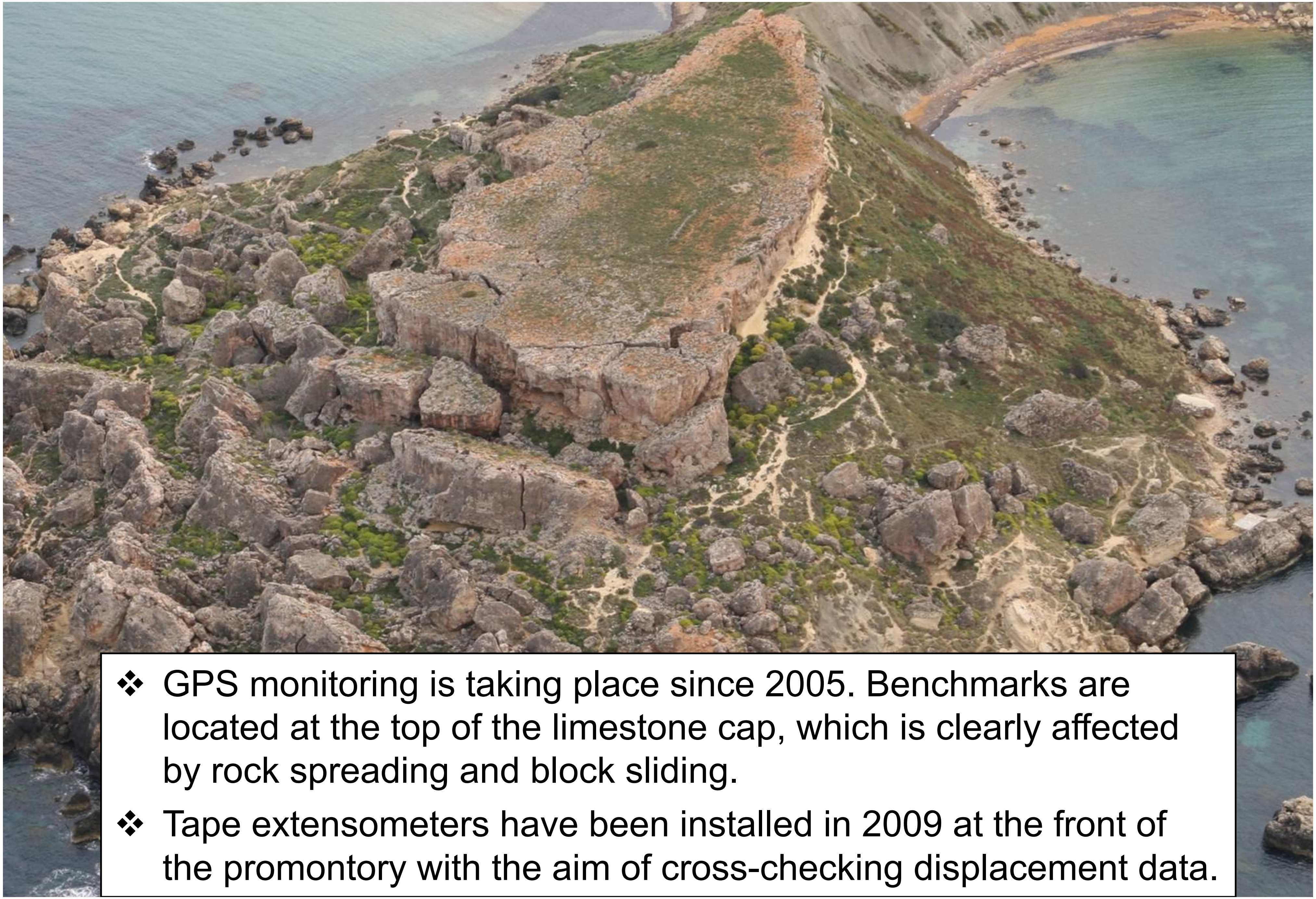
CrossMark

ORIGINAL PAPER

Landslide susceptibility modeling assisted by Persistent Scatterers Interferometry (PSI): an example from the northwestern coast of Malta

Daniela Piacentini[1] · Stefano Devoto[2] · Matteo Mantovani[3] · Alessandro Pasuto[3] · Mariacristina Prampolini[4] · Mauro Soldati[4]

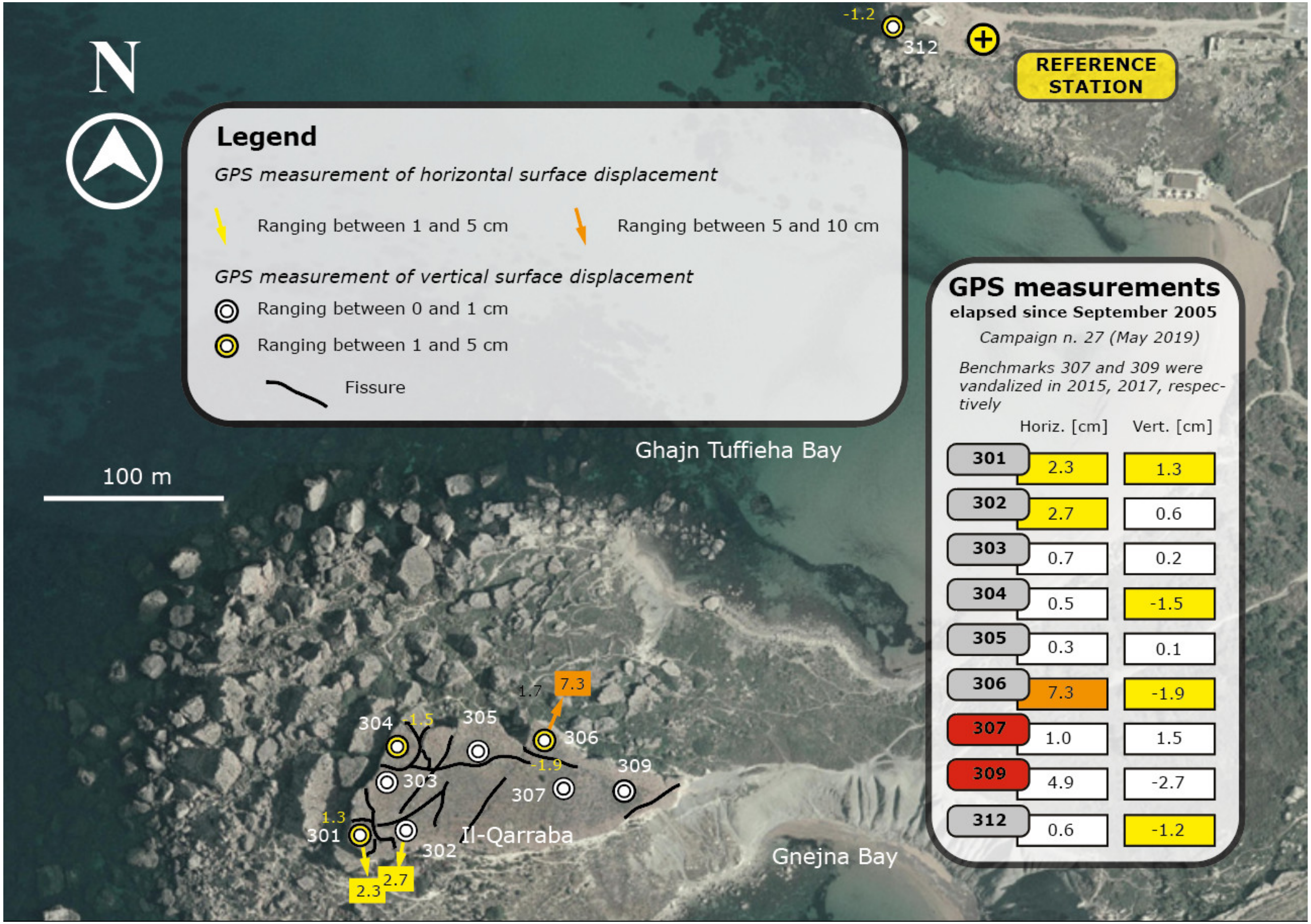
Il-Qarraba monitoring site – NW Malta



- GPS monitoring is taking place since 2005. Benchmarks are located at the top of the limestone cap, which is clearly affected by rock spreading and block sliding.
- Tape extensometers have been installed in 2009 at the front of the promontory with the aim of cross-checking displacement data.

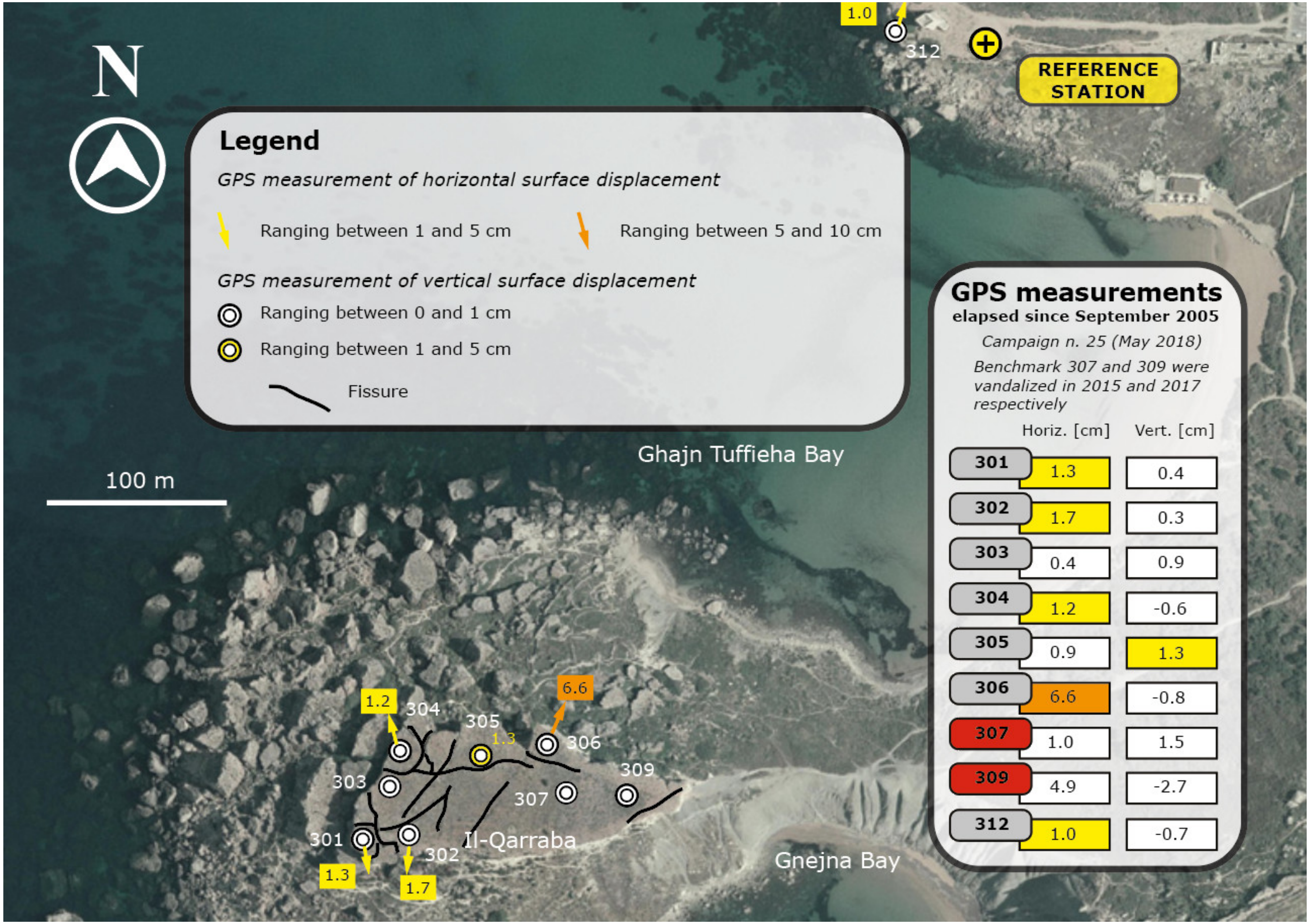
Monitoring results – Il-Qarraba updated 2019

Benchmarks	9
Reading 0	September 2005
Reading 27	May 2019



Monitoring results – Il-Qarraba updated 2018

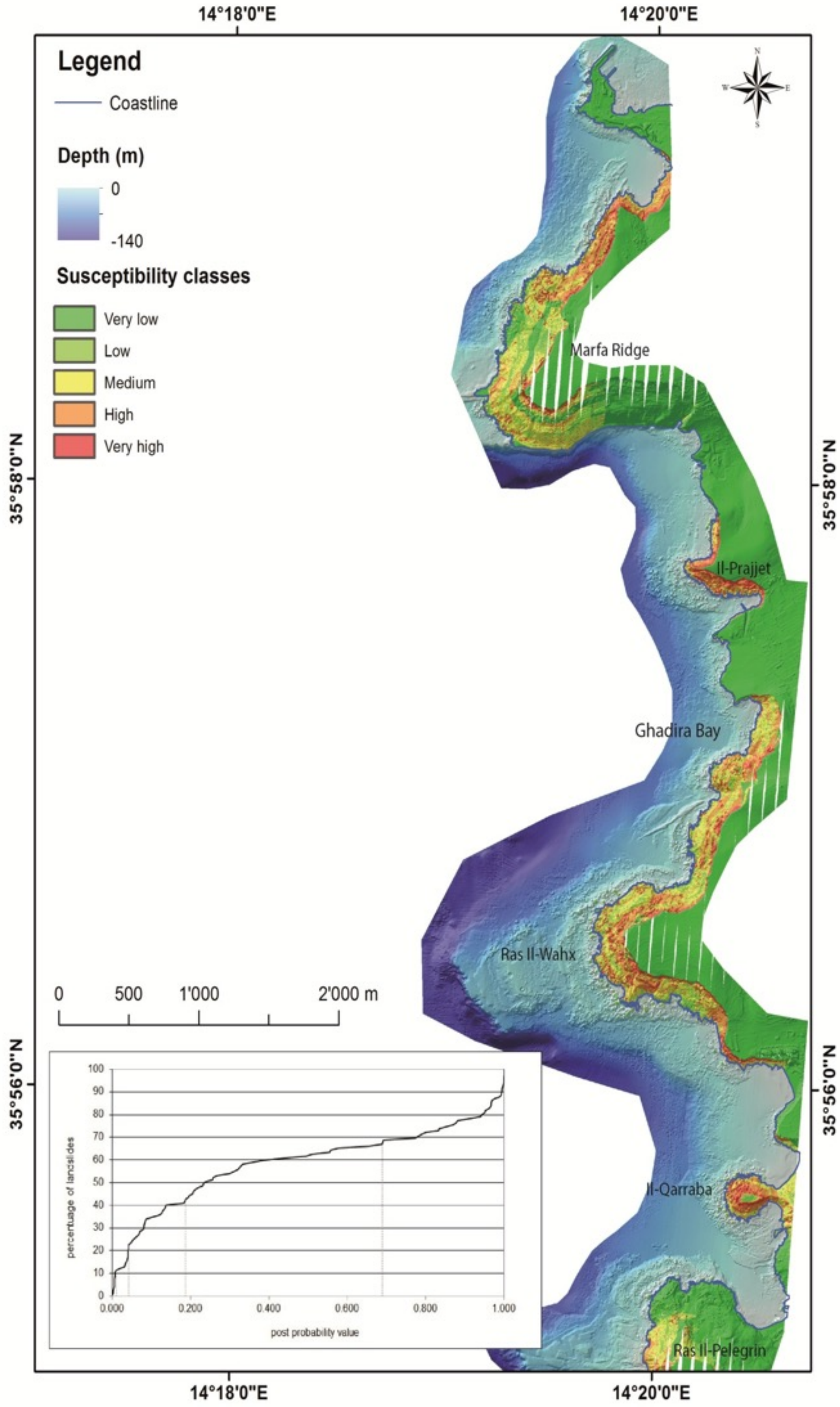
Benchmarks	9
Reading 0	September 2005
Reading 25	May 2018



Benchmark	Horiz. [cm]	Vert. [cm]
301	1.3	0.4
302	1.7	0.3
303	0.4	0.9
304	1.2	-0.6
305	0.9	1.3
306	6.6	-0.8
307	1.0	1.5
309	4.9	-2.7
312	1.0	-0.7

The advantages and limits of the monitoring techniques used

Technique	Time interval between available data	Main advantages	Main limits
Interferometry (C-band)	35 days - 1992-2012 12 days - 2014-2016 6 days - 2016-now	(Recent) historical analysis and monitoring	Line of sight displacements, high costs
GPS	5-6	Reliable	Time consuming
Tape extensometer	3-4	Easy to be carried out and cost-effective	Relative displacements along the scanlines. Low precision
Automatic fissurimeters	6 hours	High accuracy measurements. Possibility to correlate displacements and precipitation	To be installed only in secure areas, to avoid vandalism



Landslide susceptibility map of NW coast of Malta

New approach that combines the WofE method and PSI analysis

Parameters considered:

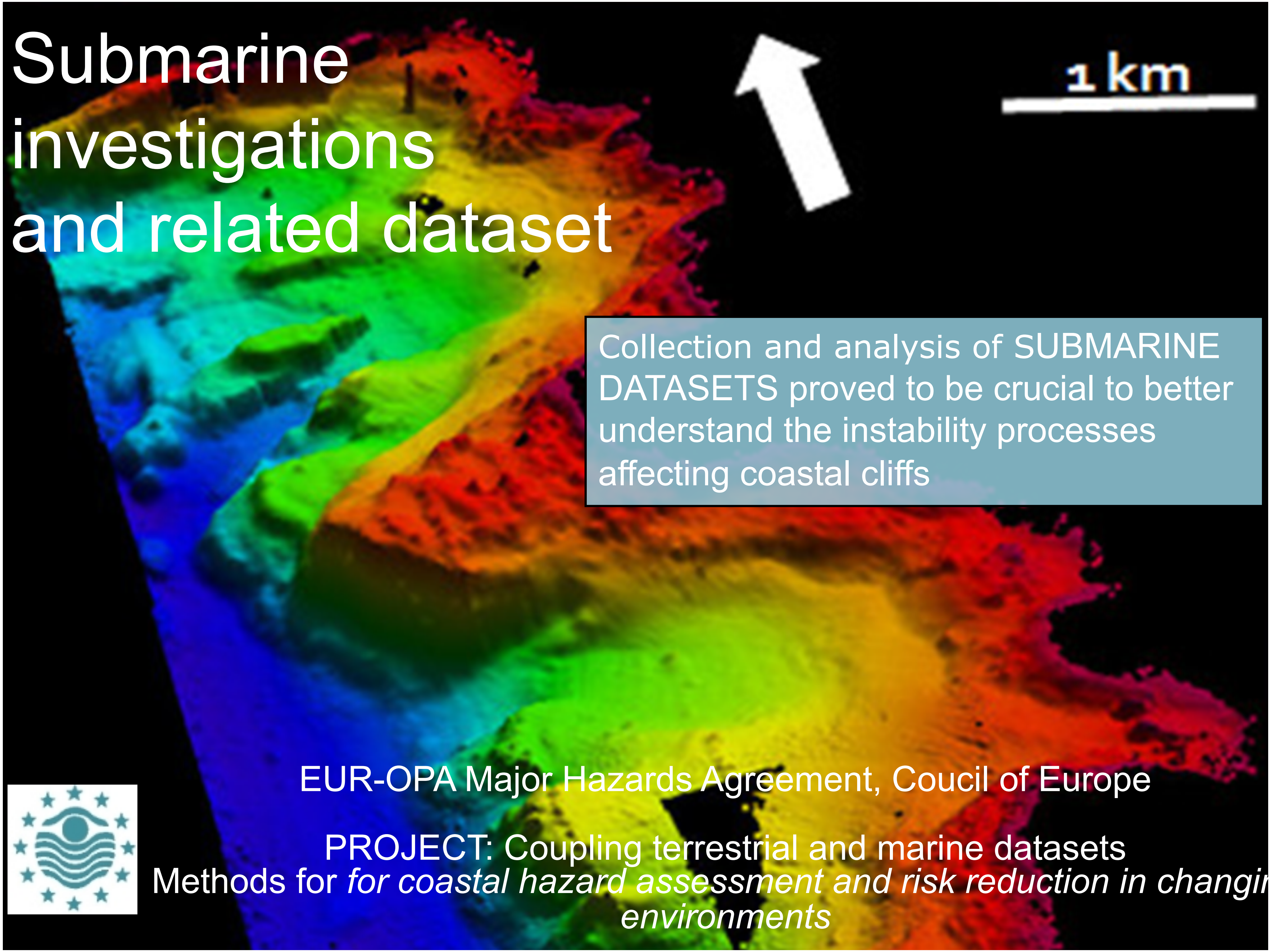
- slope angle
- curvature
- distance from coastline
- distance from scarp
- distance from faults
- distance from joints
- Topographic Position Index

The results were verified by a cross-validation, field surveys and on-site GPS measurements

Source: Piacentini et al. 2015, Natural Hazards, 78

Discovery of submarine ‘hidden landslides’

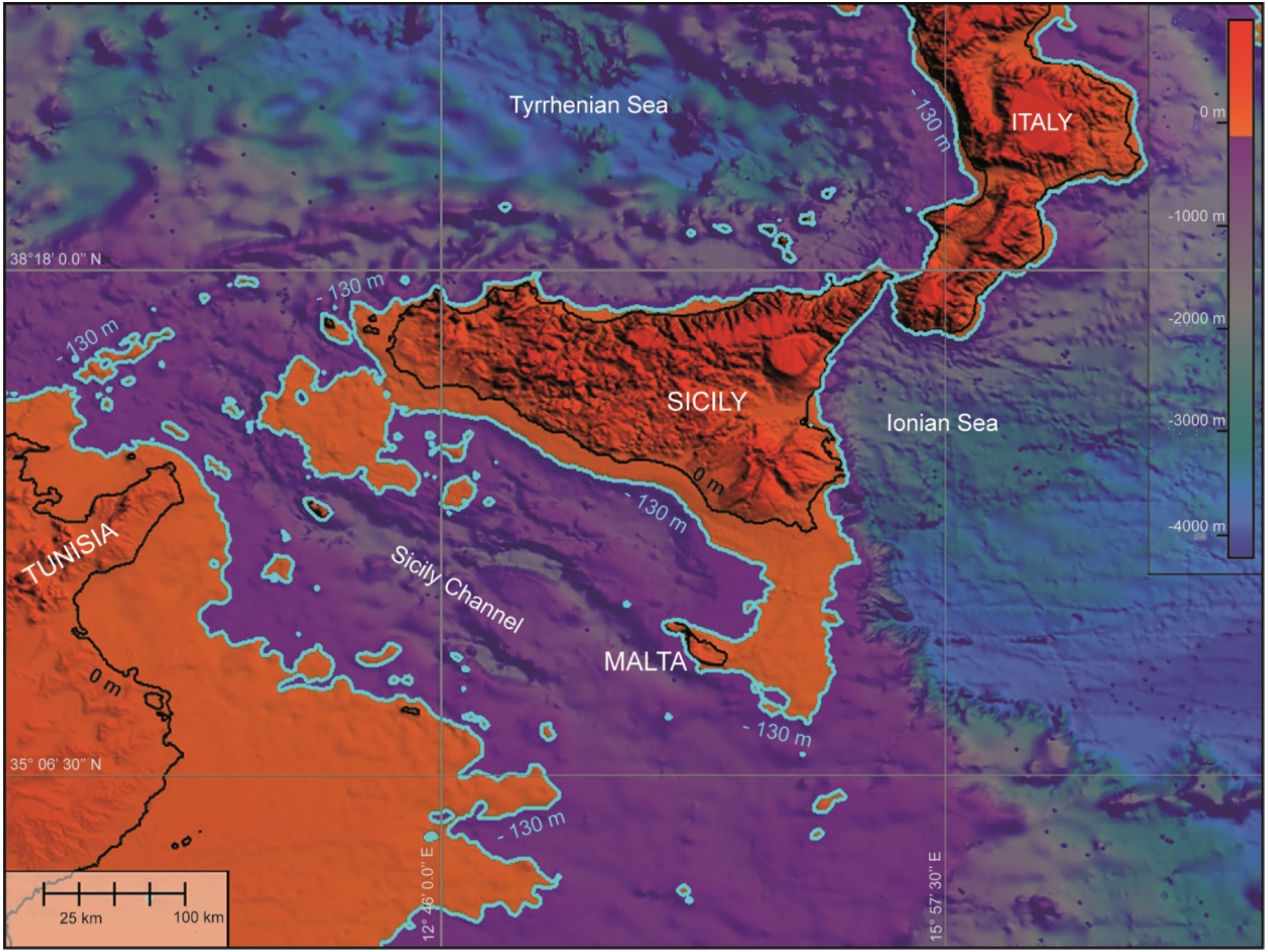
Submarine investigations and related dataset



Collection and analysis of SUBMARINE DATASETS proved to be crucial to better understand the instability processes affecting coastal cliffs

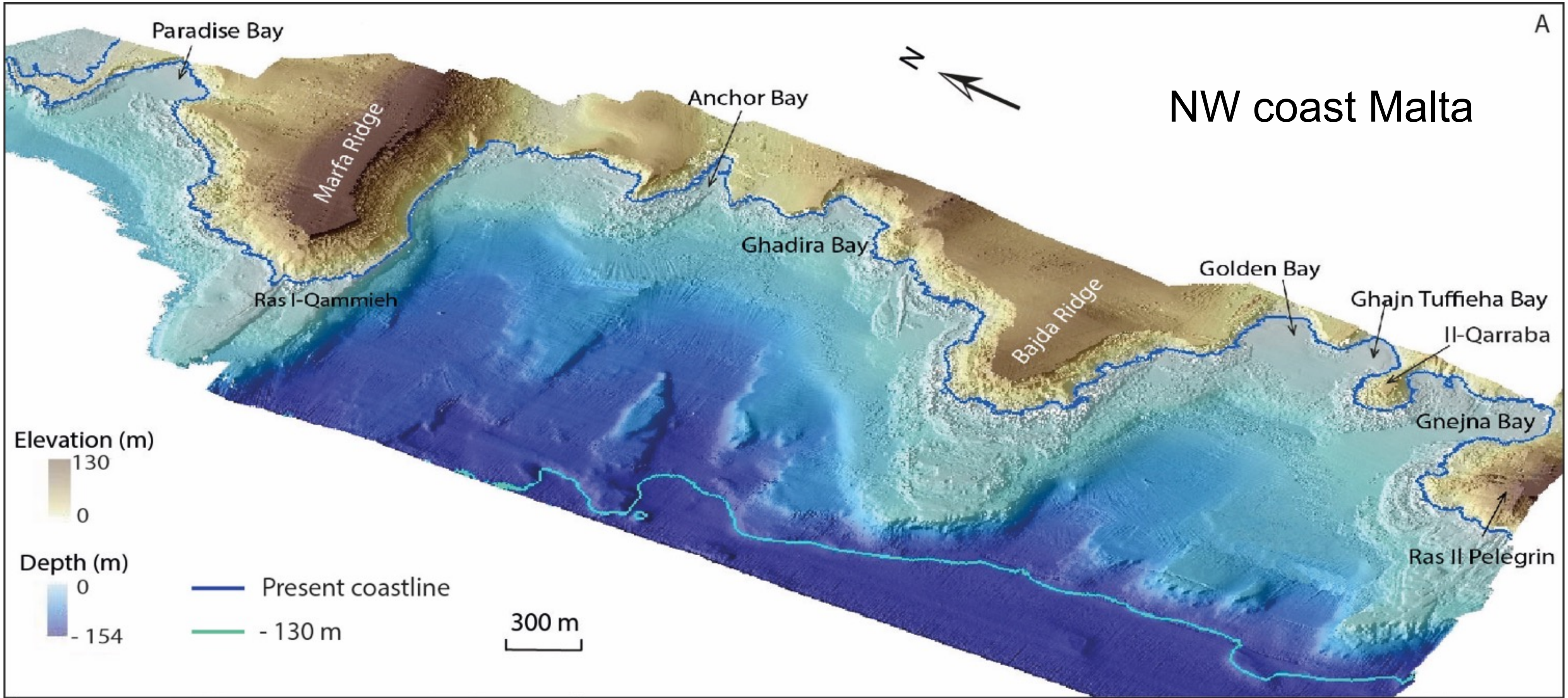
EUR-OPA Major Hazards Agreement, Coucil of Europe

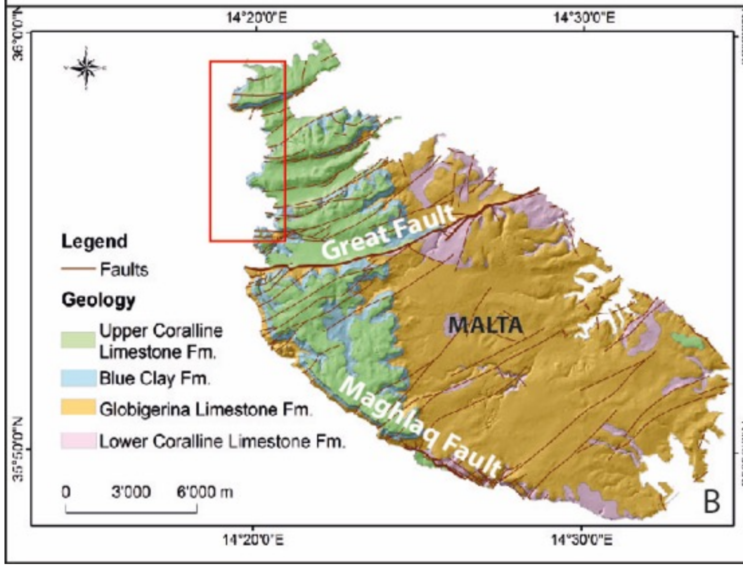
PROJECT: Coupling terrestrial and marine datasets
Methods for *for coastal hazard assessment and risk reduction in changi*
environments



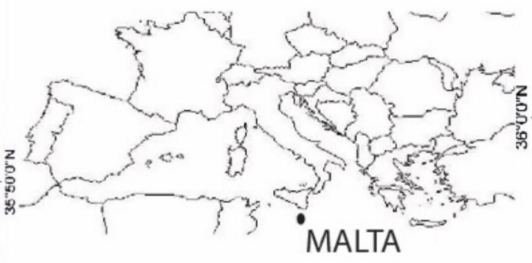
Coastlines in the central Mediterranean Sea during LGM

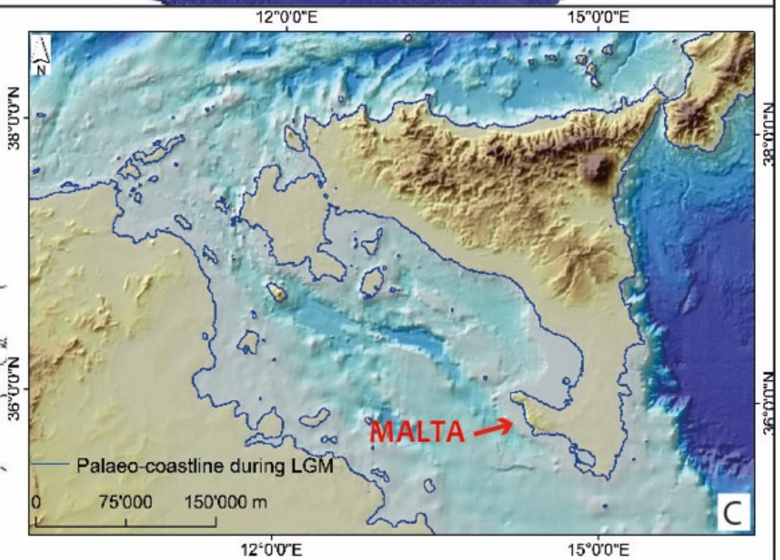
Source: Furlani et al. 2012 - Quaternary International, 288



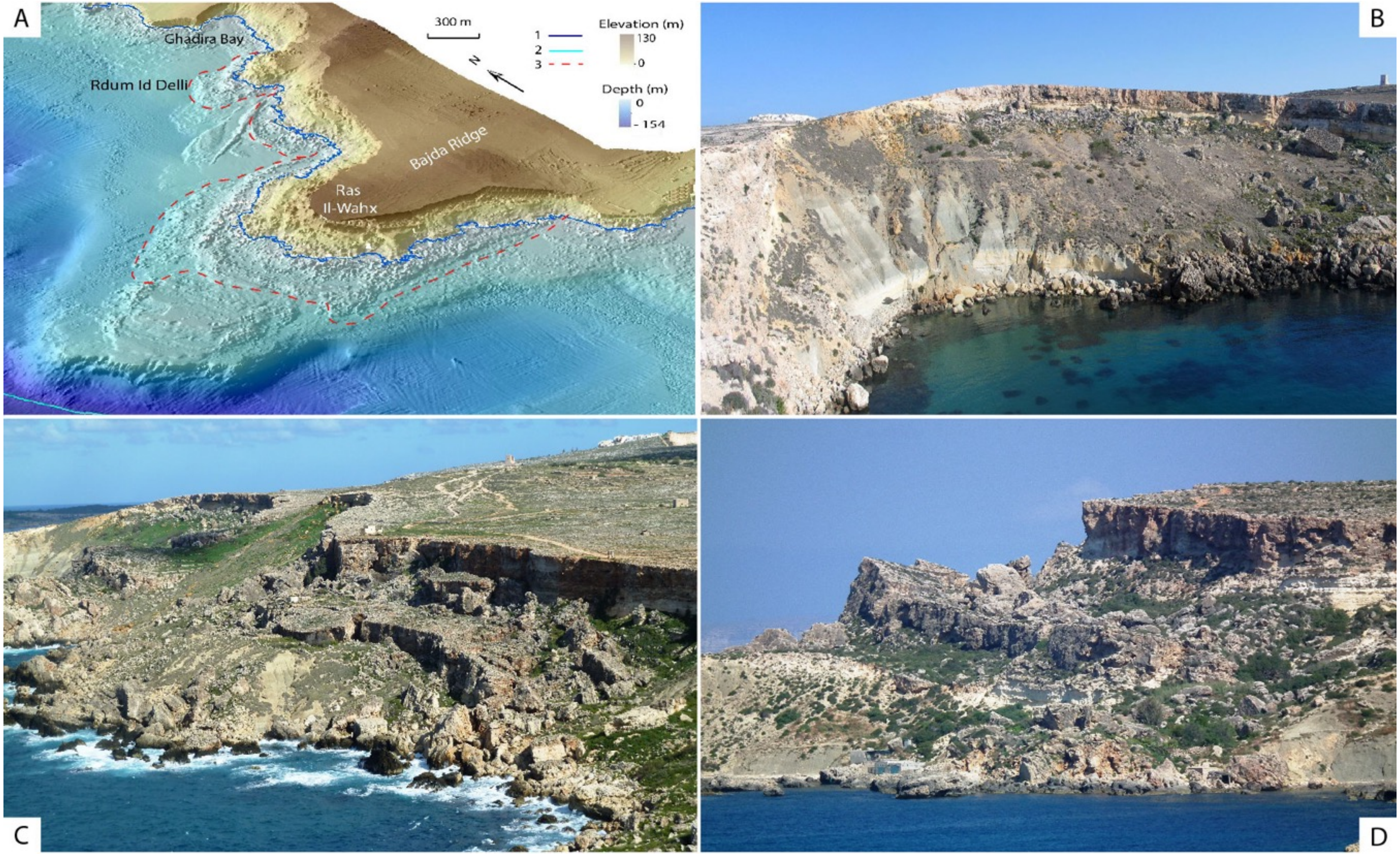


Source: Soldati et al. 2019
In: Landscapes and Landforms of Malta

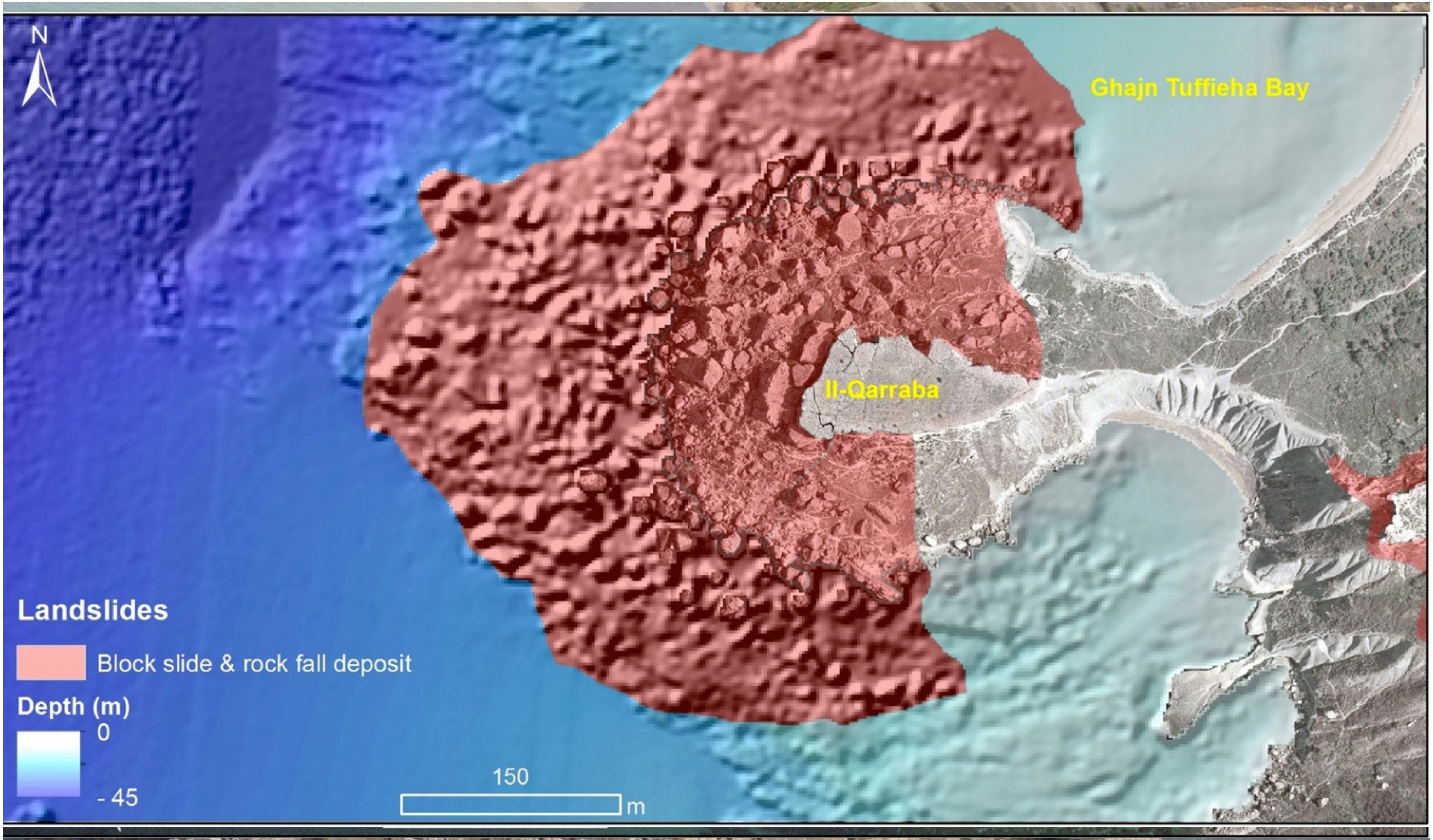




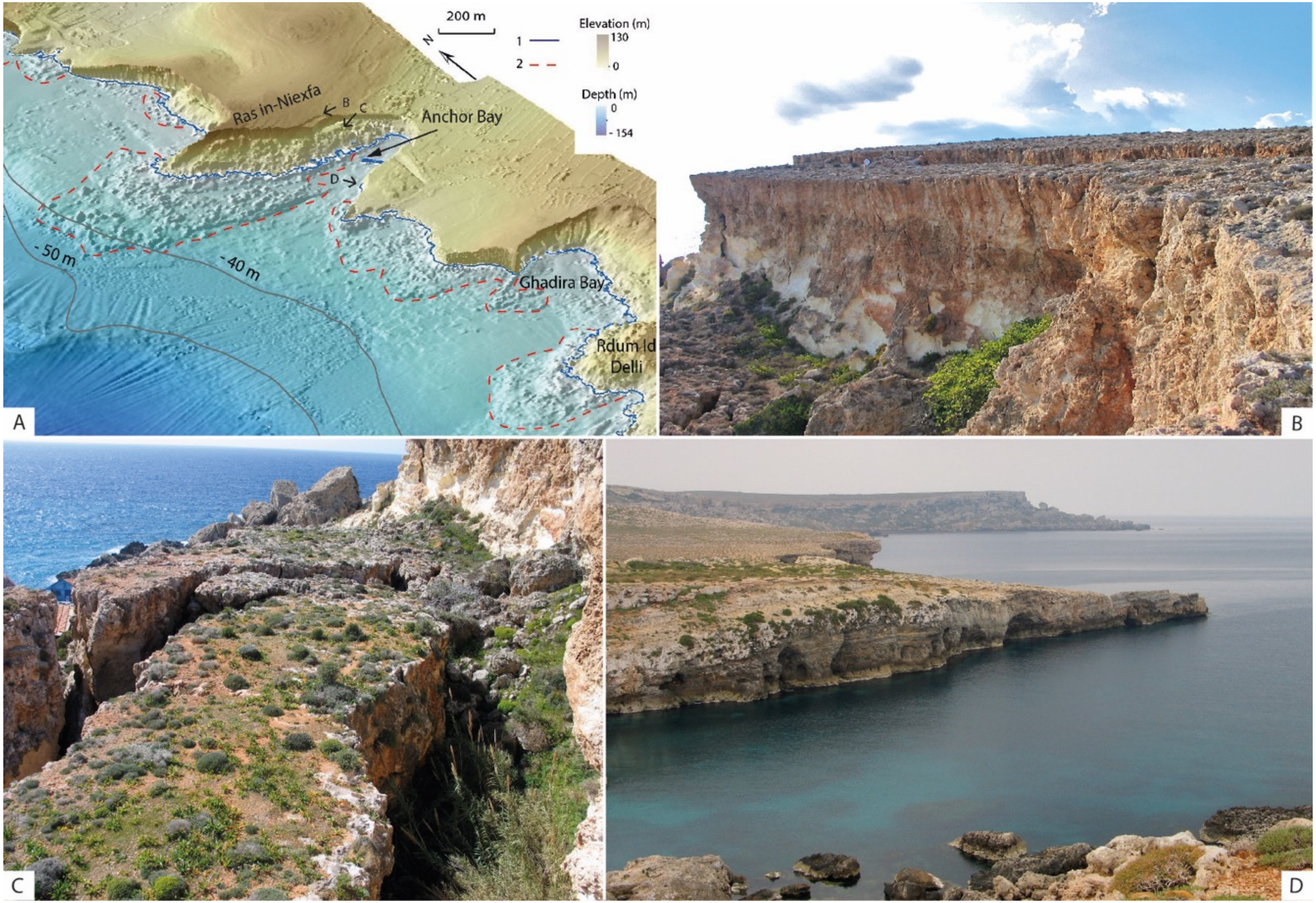
Bajda Ridge


A
Ghadira Bay
Rdum Id Delli
Ras
Il-Wahx
Bajda Ridge
300 m
N
1
2
3
Elevation (m)
130
0
Depth (m)
0
- 154
B
C
D

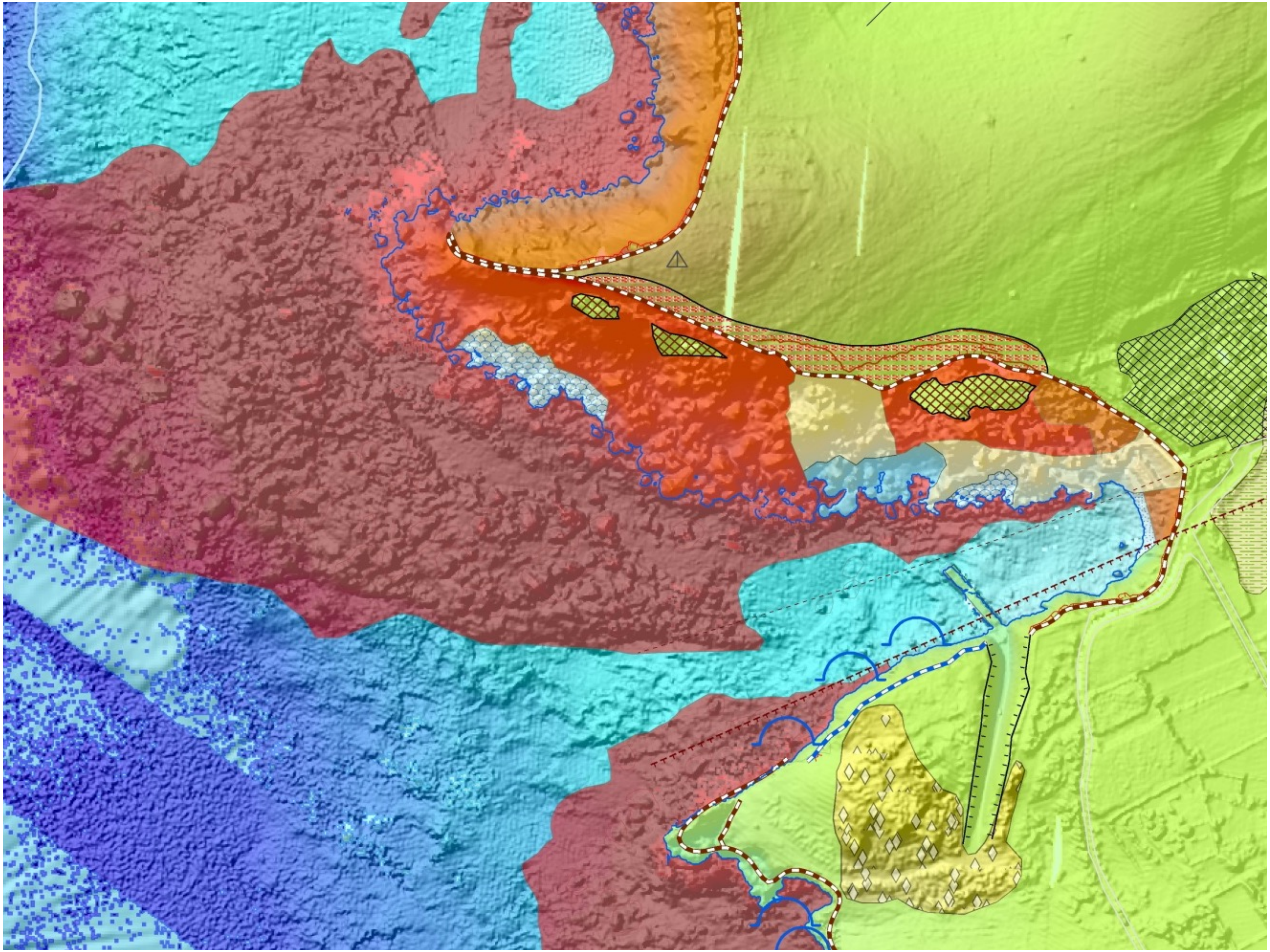
Landslides at Il-Qarraba site – NW Malta



Anchor Bay

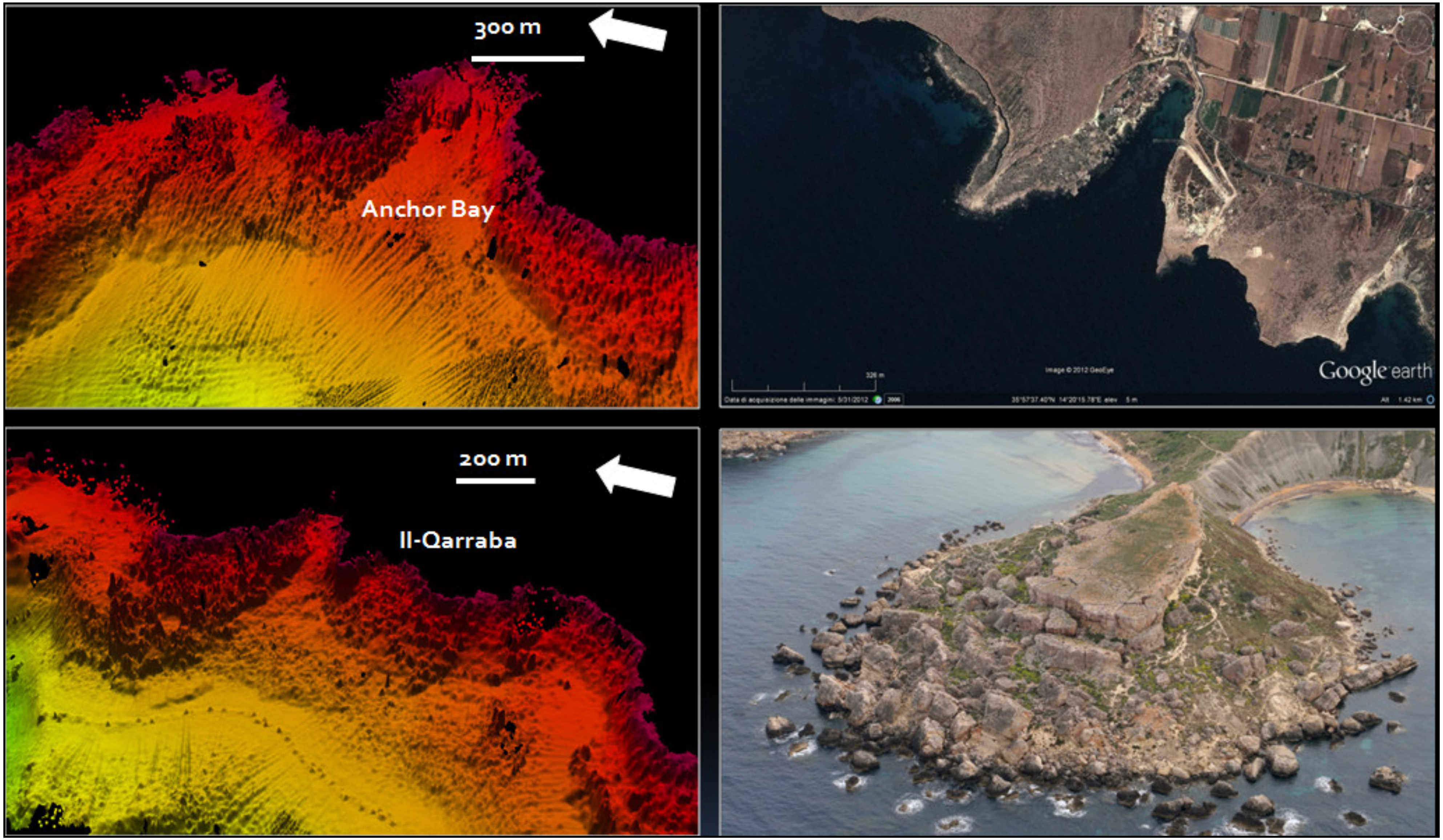


200 m
N
1
2
Elevation (m)
130
0
Depth (m)
0
- 154
Ras in-Niexfa
B
C
Anchor Bay
D
- 50 m
- 40 m
Ghadira Bay
Rdum Id Delli
A
B
C
D

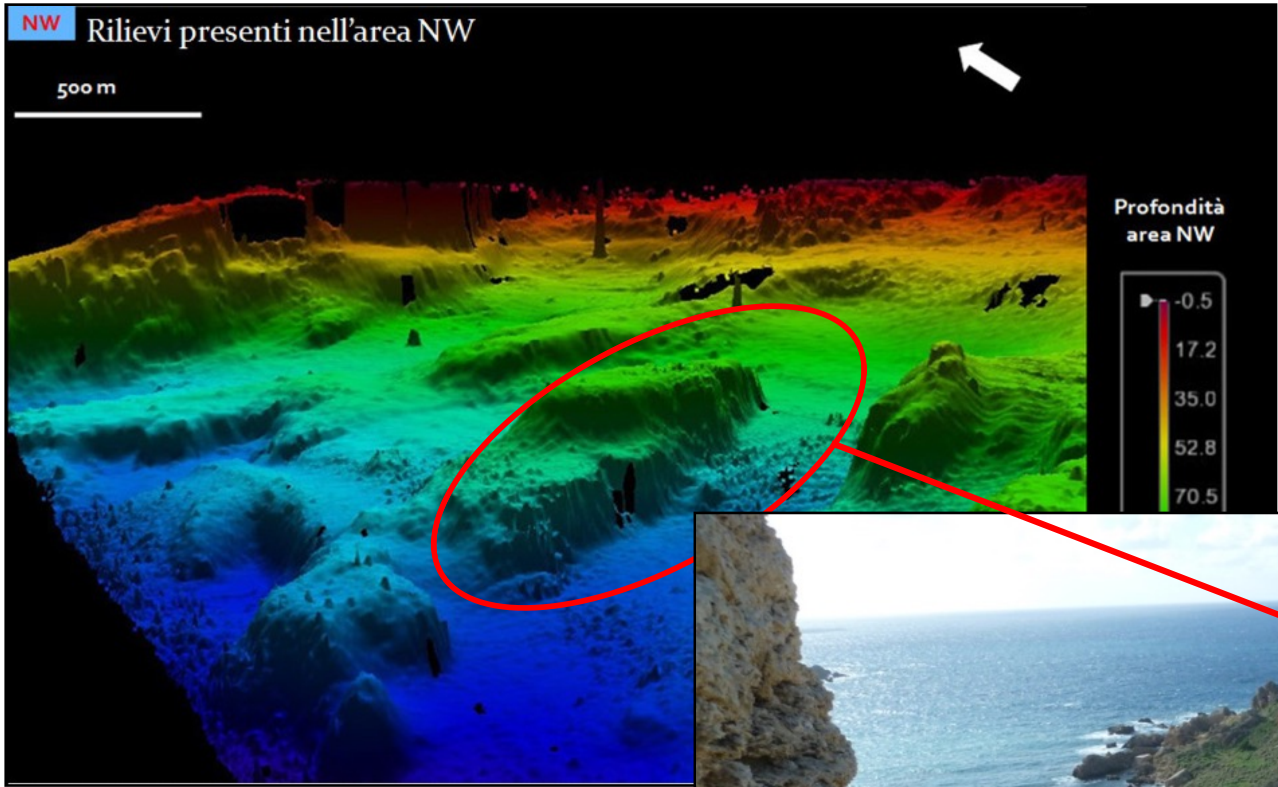


Integration of terrestrial and marine datasets

Submerged and terrestrial landslide deposits

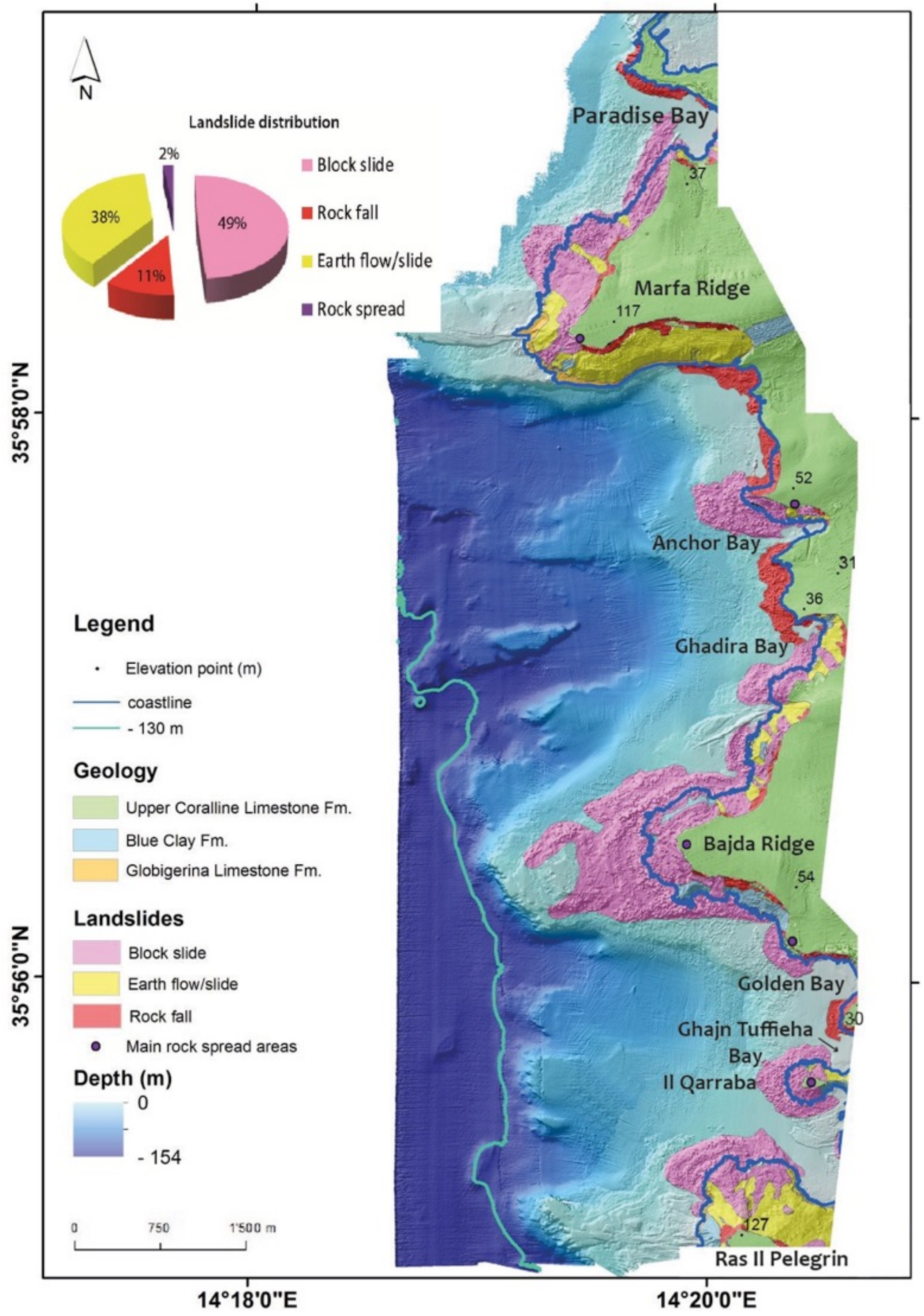


Comparison of submerged/emerged features



Structurally-controlled plateaus

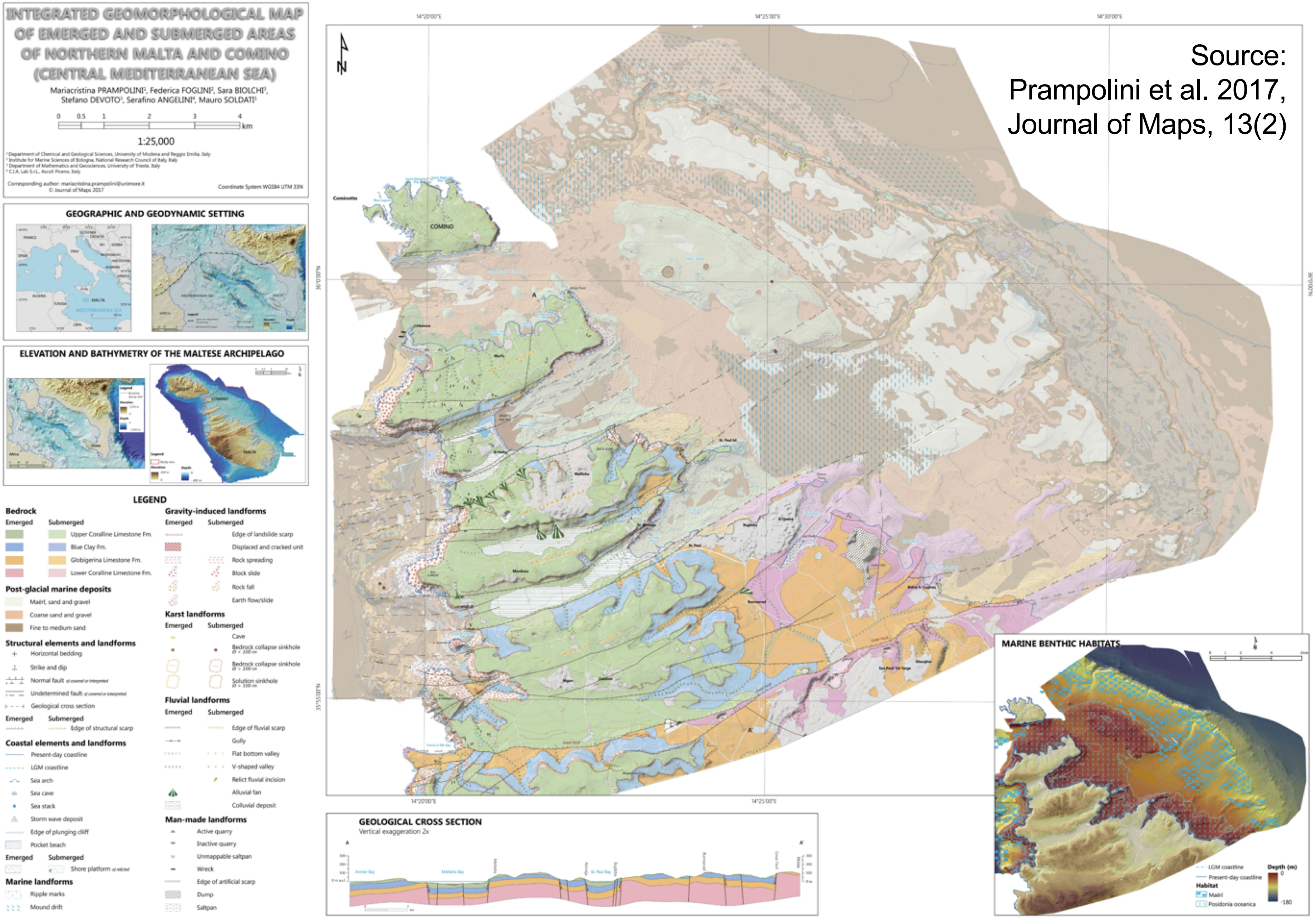
NW coast of Malta



Map of the emerged and submerged landslide deposits along the NW coast of Malta

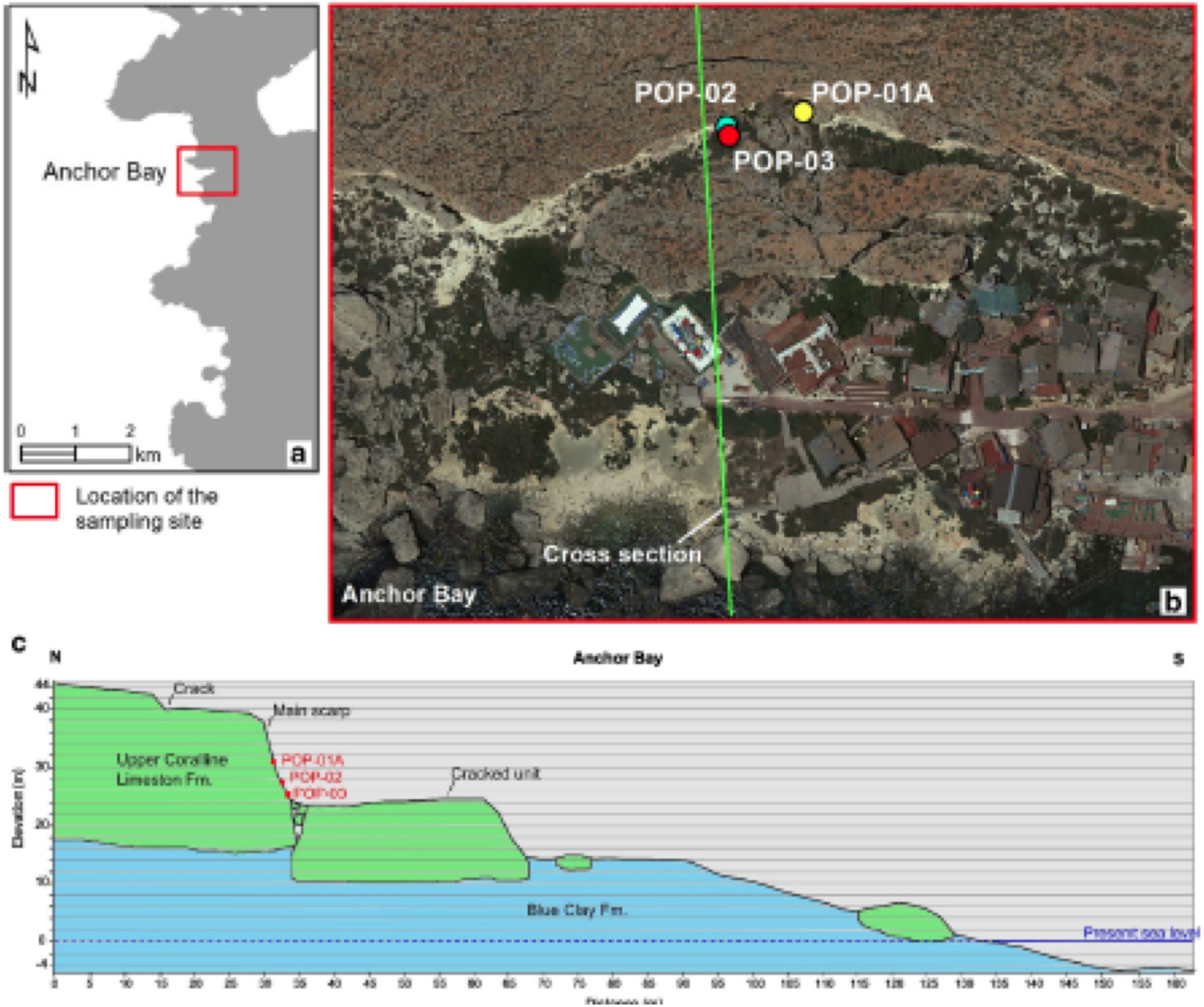
Source: Soldati et al. 2017, Proceedings of Romanian Geomorphological Symposium

Integrated geomorphological map of emerged and submerged areas of northern Malta and Comino



Identification of chronological constraints to the onset and development of coastal landslides

Cosmogenic Ray Exposure (CRE) dating at Anchor Bay & Il-Qarraba

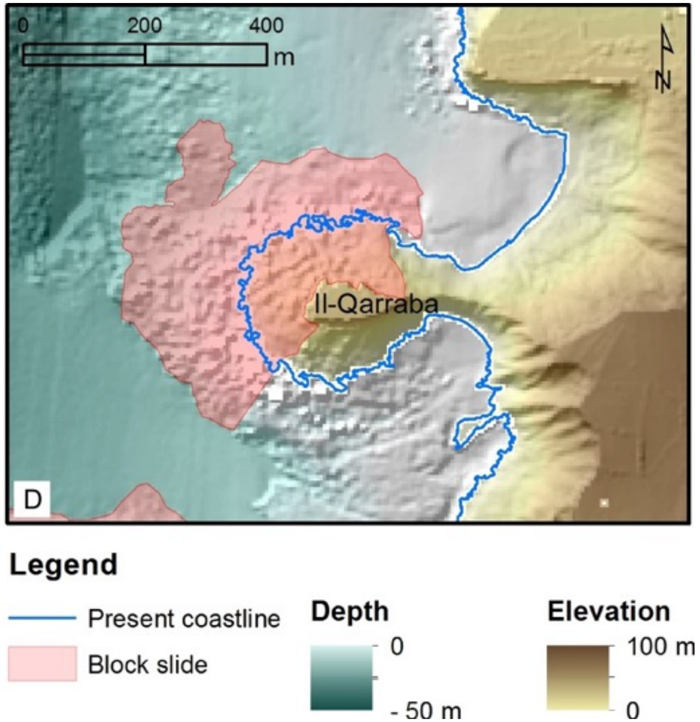


Sampling campaign and analysis carried out in collaboration with the University of Exeter (UK)

Dating performed at the Australian National University, Canberra

Source: Soldati et al. 2018, Journal of Coastal Conservation, 22

Cosmogenic Ray Exposure (CRE) dating at Anchor Bay & Il-Qarraba



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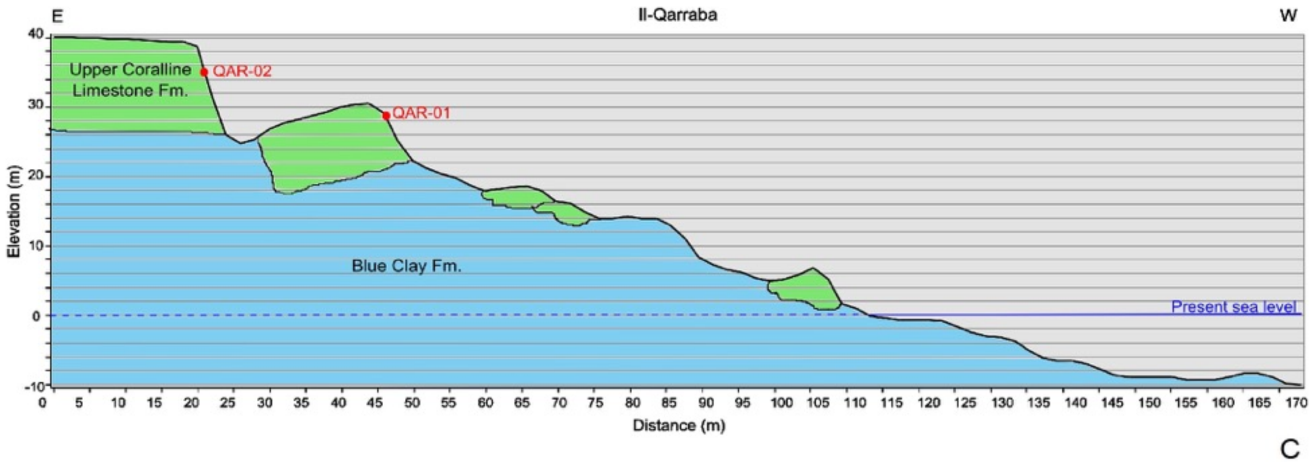
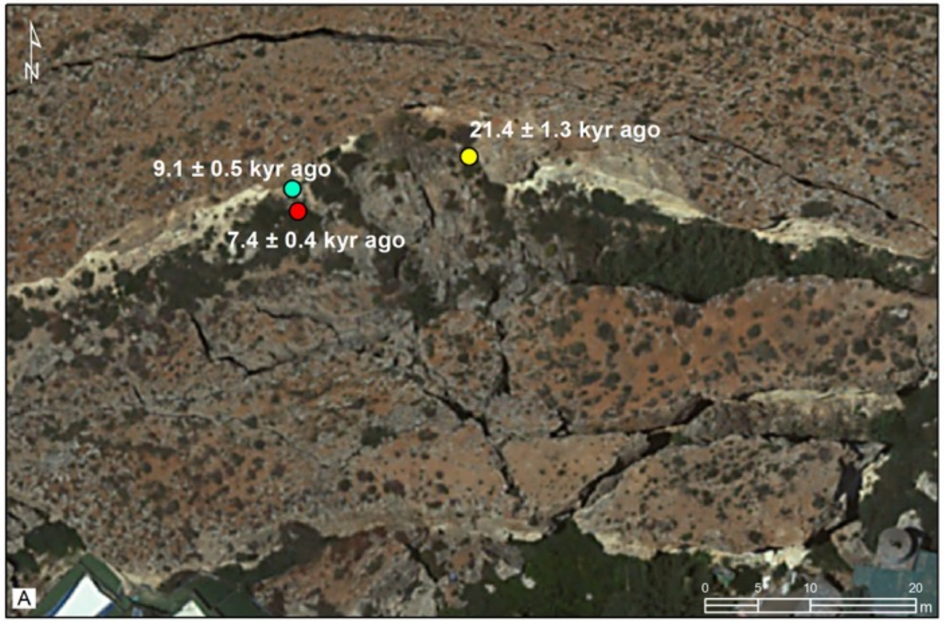
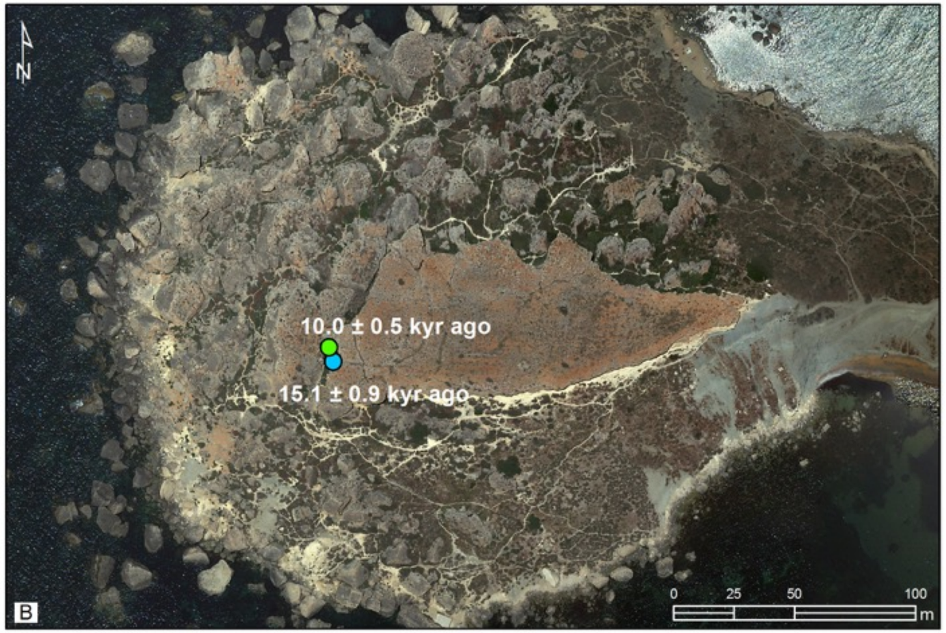


Cosmogenic Ray Exposure (CRE) dating at Anchor Bay & Il-Qarraba





Sample	[36Cl]c (x105 g-1)[1]	[36Cl]r (x102 g-1)[2]	Exposure age (kyr)
	Il Prajjet (Anchor Bay)		
POP-01A	3.00 ± 0.15	1.6 ± 0.5	**21.4 ± 1.3**
POP-02	1.23 ± 0.06	4.9 ± 1.2	**9.1 ± 0.5**
POP-03	1.08 ± 0.05	7.3 ± 1.7	**7.4 ± 0.4**
	Il-Qarraba		
QAR-01	1.48 ± 0.06	4.2 ± 1.0	**10.0 ± 0.5**
QAR-02	1.87 ± 0.09	6.81 ± 2.4	**15.1 ± 0.9**

Data are normalised to the GEC standard (36Cl/Cl = 444 x 10-15).

Carrier 36Cl/Cl = 1 x 10-15

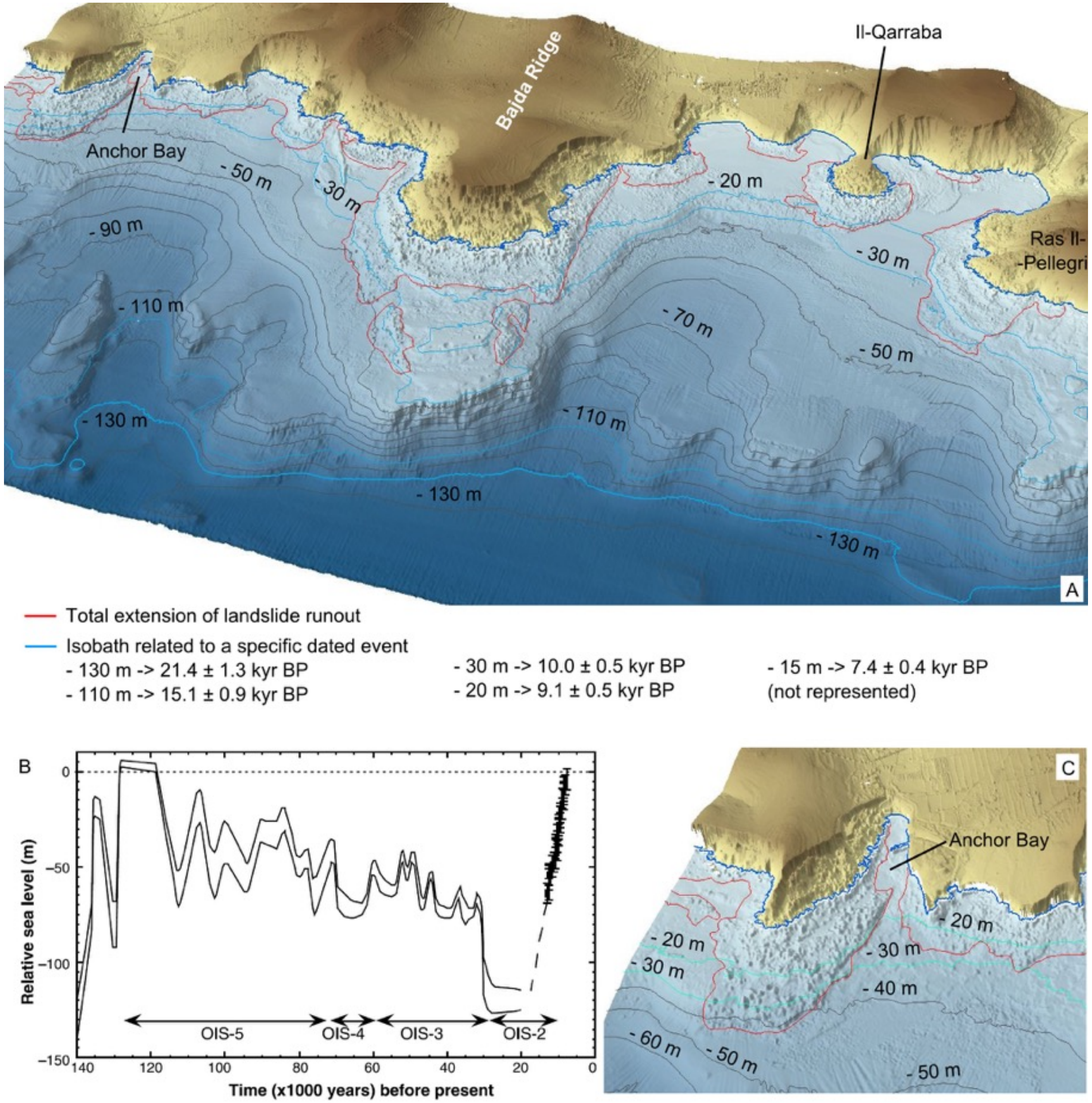
^{36}Cl decay constant 2.3 x 10-6 yr^{-1}.

[1]c = cosmogenic component

[2]r = background nucleogenic component

Source: Soldati et al. 2018, Journal of Coastal Conservation, 22

Cosmogenic Ray Exposure (CRE) dating at Anchor Bay & Il-Qarraba



Older events located more inland than younger events

→ first-time failure that involved a large portion or the entire slope

- First chronological constraint to coastal block slides: minimum ages of development

(ca 21.4 kyr ago)

- Palaeo-environmental conditions: subaerial and more humid environment

Source: Soldati et al. 2018, Journal of Coastal Conservation, 22

Research perspectives

- Acquisition of necessary knowledge to define methods to perform landslide monitoring offshore
- Production of risk maps also taking into account issues related to climate change (sea-level change, more frequent extreme meteorological events etc.)
- Definition of protocols which can be utilised in coastal environments for risk reduction and resilience improvement


With contributions of
S. DEVOTO,
M. MANTOVANI,
A. PASUTO,
M. PRAMPOLINI
Thanks for your attention!
Grazie per l'attenzione!
Grazzi hafna ghall-attenzjoni taghkom!
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