Innovative integration of UAV and geophysics techniques for monitoring Natural Arches in Malta and Gozo: the case study of Wied Il-Mielah (Gozo).

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INTRODUCTION

The geomorphological features of natural arches make these structures important tourist attractions worldwide but, at the same time, they are exposed to rapid erosive processes induced by wind and sea waves.
The Maltese archipelago (Central Mediterranean Sea) hosts a great number of natural rock arches.
On the 8th March 2017, a natural arch known as Azure Window (Fig.1) collapsed into the sea, at around 8:30 AM UTC (9:30 AM local time) (Fig.2), leaving no trace above the waterline (Galea P. et al., 2018).
The collapse of the Azure Window, which was an iconic feature of the island of Gozo, motivated the need to characterise this type of natural structures and evaluate the risk of collapse to ensure the safety of visitors to the sites.

Figure 1. Azure Window before and after the collapse.

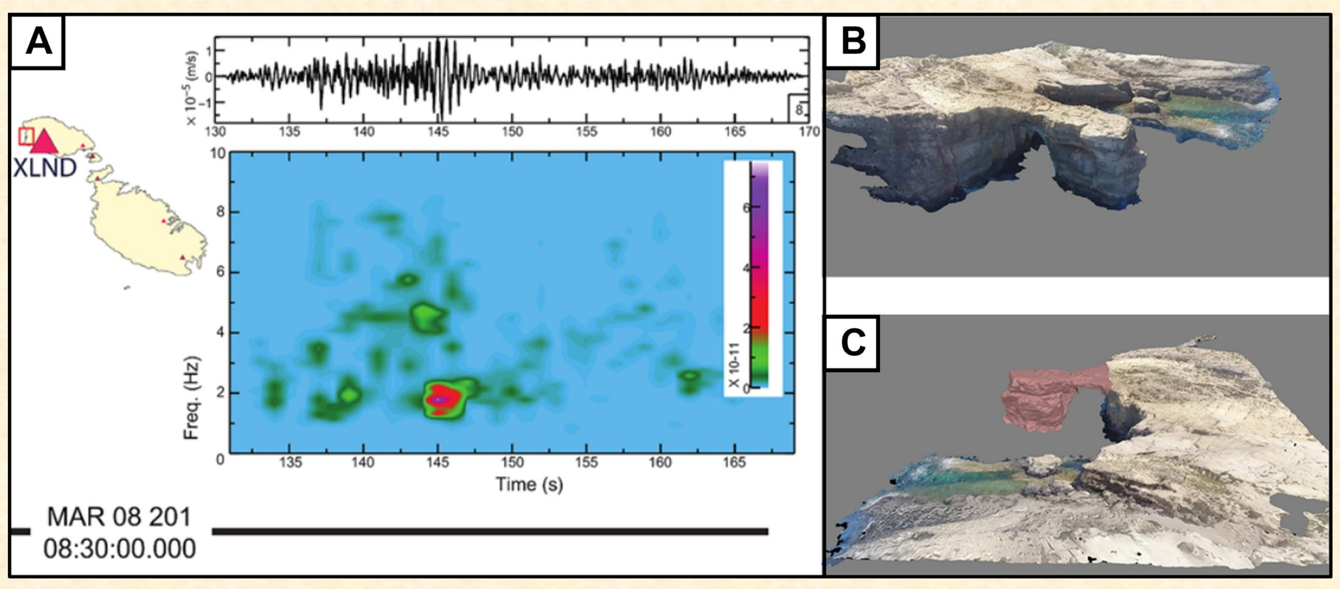

Figure 2. (A) 40-s segment of high-pass-filtered seismogram (> 1 Hz) of the collapse impact on the seafloor recorded at XLND seismic station and corresponding spectrogram, (B) 3D reconstruction of the Azure Window by UAV photogrammetry. (C) The shaded volume of the arch was used to estimate the mass of rock above sea level that collapsed (~3.8 x 10^7Kg) (Galea P. et al., 2018).

STUDY REGION AND GEOLOGICAL CONTEXT

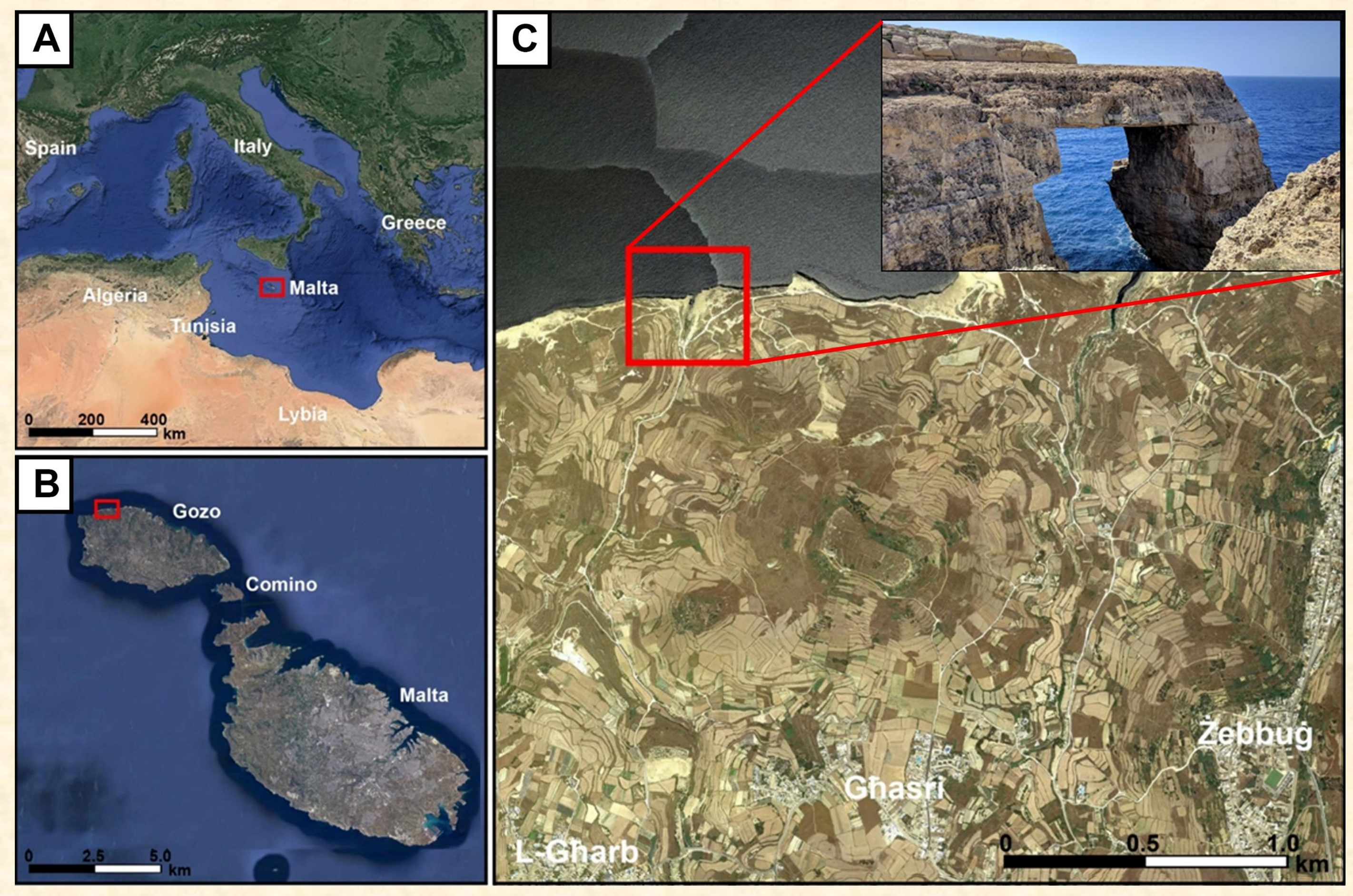

Figure 3. (A) The Maltese archipelago in the central Mediterranean and (B) the North-western coast of the Island of Gozo, where is located the Wied Il-Mielah arch (C), that has become an icon of the Maltese islands after the collapse of the most famous Azure Window arch.

- The Wied Il-Mielah arch (Fig.3) is composed of sub-horizontal strata belonging to the several members of the Lower Coralline Limestone (LCL) formation, a hard and compact grey limestone of Oligocene age (Chattian) (Fig.4). The limestone forming the arch is intensely jointed, testifying the natural proneness to gravity-induced instability of this natural structure.

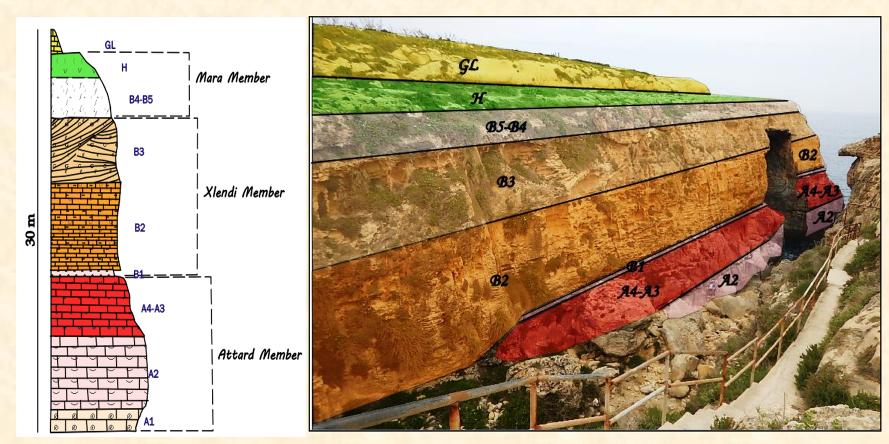

Figure 4. Stratigraphic succession compiled by field activities.

UAV SURVEY - DATA PROCESSING & RESULTS

- The use of Unmanned Aerial Vehicle (UAV) systems has been growing in coastal applications in recent years (Colica et al. 2017) and, in particular, it is essential for the monitoring of coastal arches because of their protruding position on the sea. An aerial-photogrammetric survey by UAV was carried out to obtain a high resolution 3D model of the Wied Il-Mielah arch (Fig.5). From this model it was possible to identify the thickness of the different geological layers and the extension and thickness of cracks.

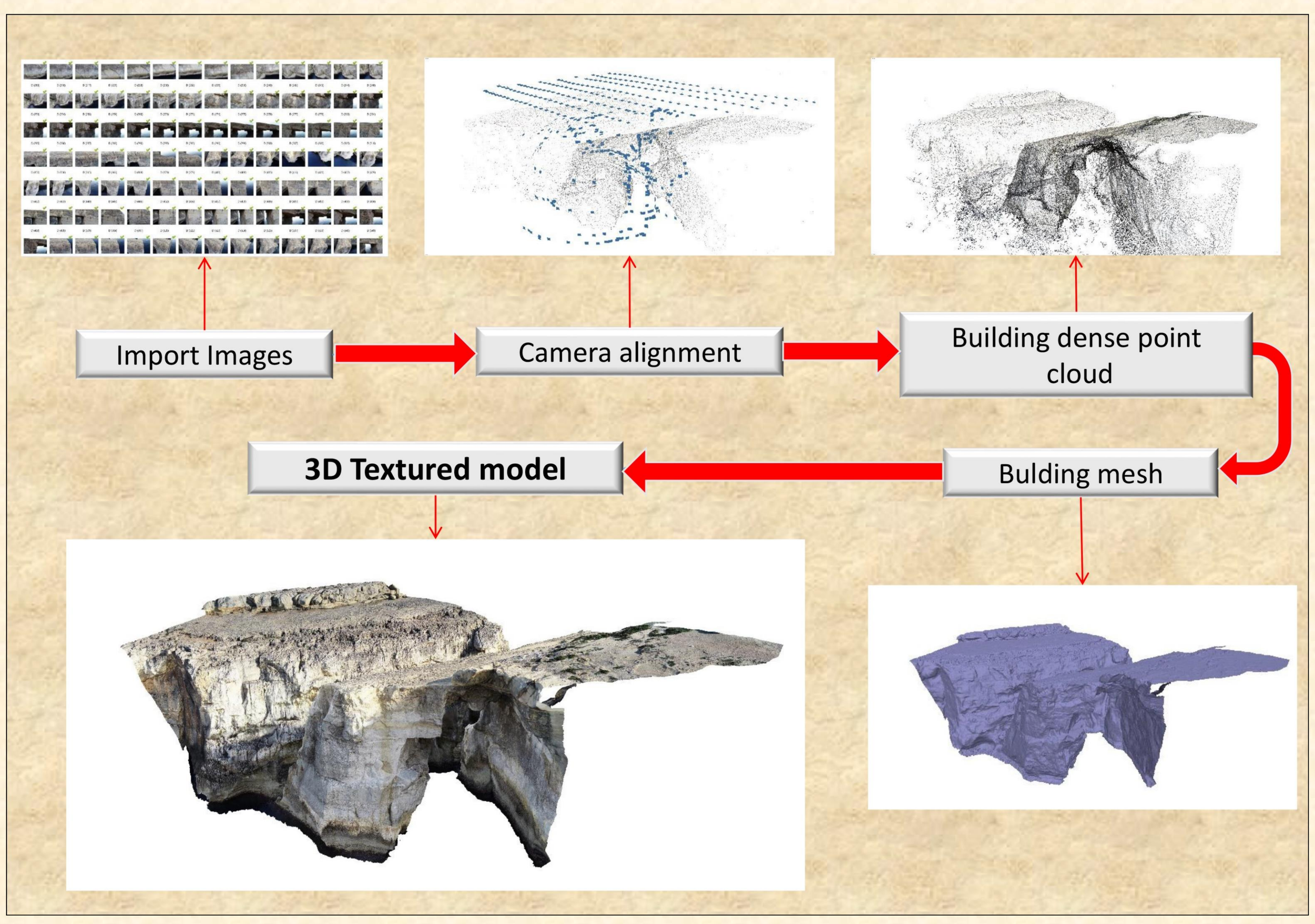

Figure 5. Photogrammetric workflow for the generation of 3D model.

- The 3D model was imported into ANSYS® Workbench™ software where it was possible to perform a modal analysis of the structure with the Finite Element Method (FEM) (Fig.6).

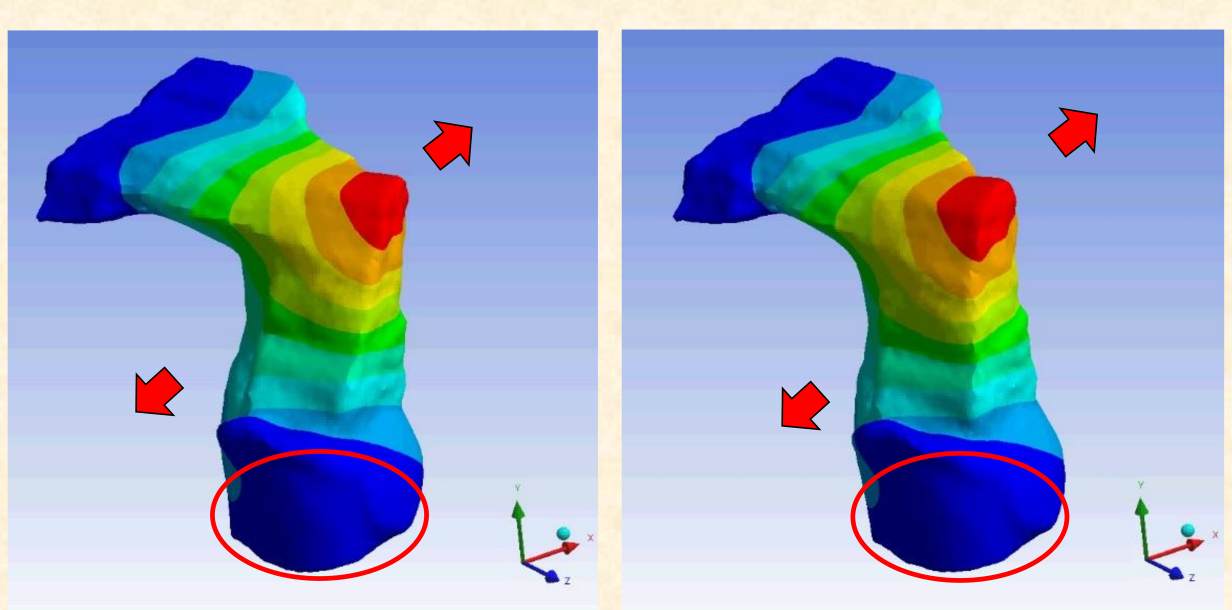

Figure 6. First experimental modal frequency obtained in ANSYS® Workbench™ software , in which red arrows show the oscillation of the Wied Il-Mielah arch and red circles show the submerged part of the pillar reconstructed using bathymetric data as reference.

VALIDATIONS

- Other ground-based data were obtained during a geophysical survey where three-component accelerometers were used to measure the fundamental frequency of the natural arch.
This methodology had highlighted a different seismic response of the different elements that constitute the arch in which we recorded a value of 5Hz on the pillar and between 5Hz and 6Hz on the beam of the arch (figure 7).
These results are comparable with the results outputted by FEM simulations in which we obtained an average value of 5.91Hz on beam and pillar of the arch.

- The harmonization of these aerial and terrestrial non-invasive techniques allows to enhance the output of this study that aims to evaluate seismic response of the arch and the risk of collapse.

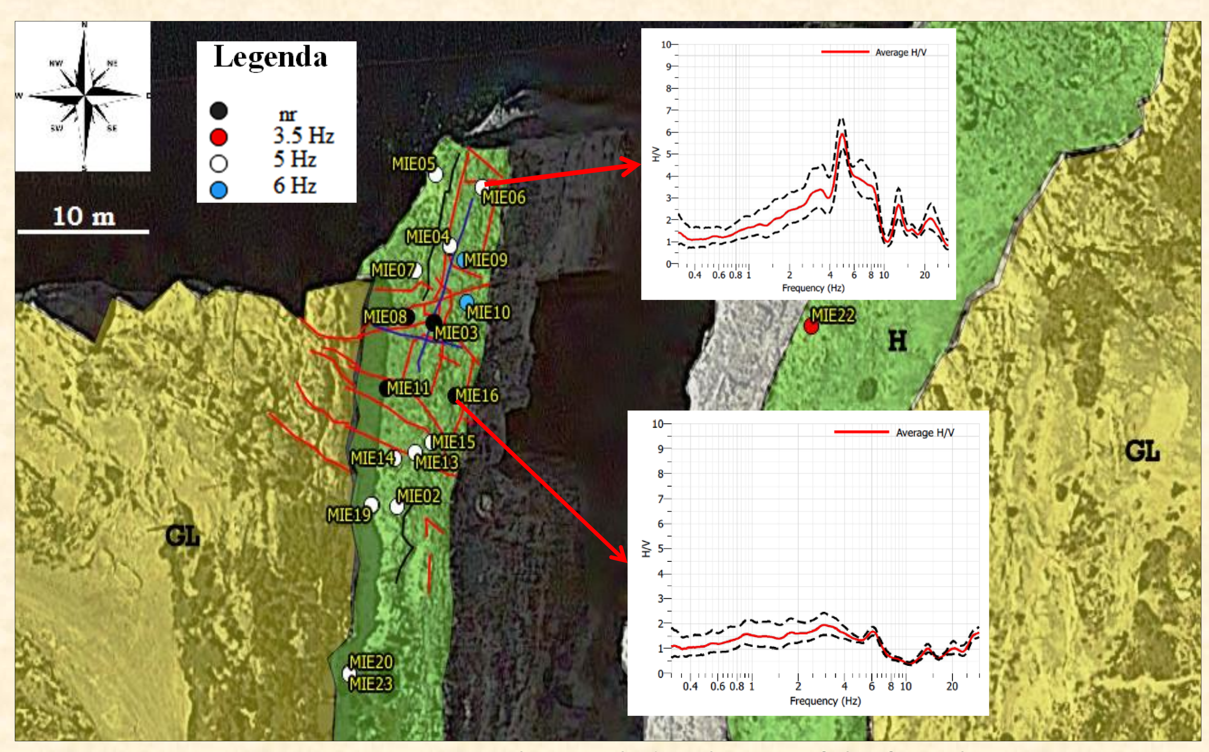

Figure 7. HVSR analysis with distribution of the f_0 peaks.

FUTURE WORKS

- Such preliminary results can represent a contribution for planning future activities (Fig.8), such as:

1. installation of a monitoring network to ensure the safety of visitors and the designing of consolidation interventions to preserve the Wied Il-Mielah arch;
2. periodic GPR surveys with the aim of reconstructing the depth of the fractures and monitoring their changes;
3. periodic UAV surveys to monitor the morphological evolution of the Wied Il-Mielah arch over time;
4. bathymetric survey with an Autonomous Surface Vessel equipped with an interferometric Side Scan Sonar in order to determine the exact shape of the submerged pillar. This will be useful to understand the degree of erosion at the base of the pillar and to improve the results. in the FEM simulation;
5. extend this monitoring methodology to all natural arches in the Maltese archipelago.

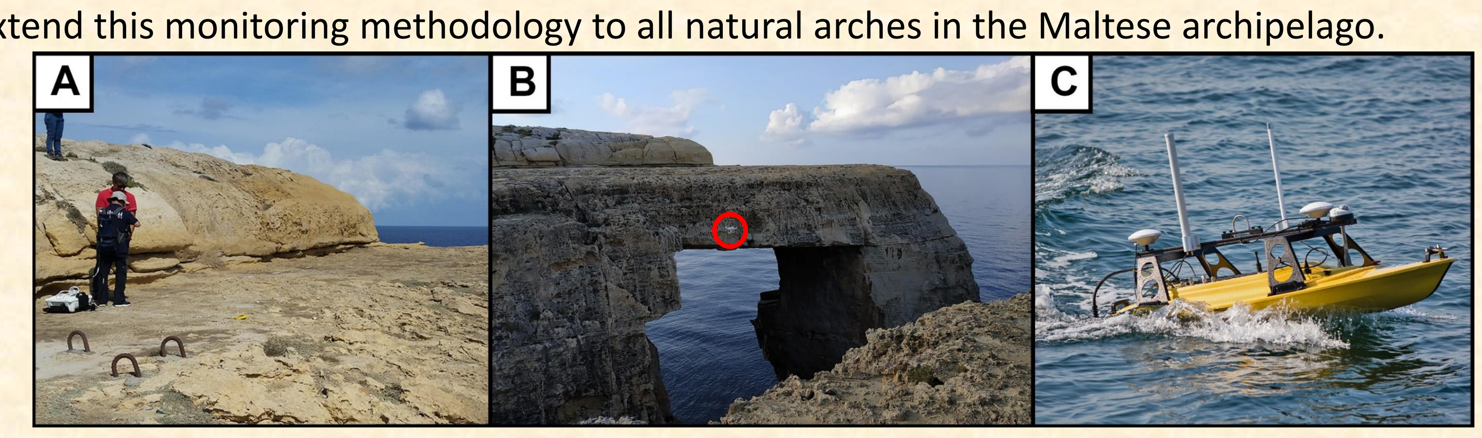

Figure 8. (A) The first GPR survey performed in September 2018 at the Wied Il-Mielah arch; (B) in the red circle a DJI Phantom 4 Pro during the photogrammetric survey of the arch; (C) EchoBoat Autonomous Surface Vessel owned by the University of Malta.

References

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