THE MALTA-Gozo TUNNEL PROJECT: 
PRELIMINARY GEOPHYSICAL OFFSHORE INVESTIGATION

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Introduction. In the autumn of 2016 OGS and the University of Malta carried out a series of geophysical offshore investigations in the Gozo Channel (Malta). These surveys are part of the study commissioned by the Ministry for Transport and Infrastructure of Malta to evaluate the feasibility of a sub-sea tunnel between the islands of Malta and Gozo in the Mediterranean Sea.

Objectives. The general aim of this study is to provide new contributions and improvements to the geological model of the area, so as to refine the conceptual design of the tunnel and to better drive its proposed route.

Specific objectives of the project are as follows: to characterise the nature, thickness and spatial variability of geological formations below the seafloor; to characterise the geologic, geotechnical and hydraulic properties of these formations and their spatial variability; to detect features of geologic and geomorphic relevance within these formations (e.g. faults, karstic formations); to develop a 3D geologic model of the study area.

Geological setting of the study area and its implications for tunneling. The islands are composed almost entirely of marine sedimentary rocks, mainly limestone of Oligo-Miocene age. Some minor quaternary deposits of terrestrial origin are also present.

The rock sequence comprises five main distinct formations which, although slightly disturbed by almost vertical faults displacements, lie almost horizontally across the islands with a minor generalised NE dip. The five main rock types are (in order of decreasing age):

- Lower Coralline Limestone: this is the oldest exposed rock type in the Maltese Islands and started being laid down during Oligene age. It is a 140 m thick, hard limestone unit that forms sheer cliffs that may be from ten to over a hundred meters high;
- Globigerina Limestone: this formation is subdivided into three units (Lower, Middle and Upper Globigerina Limestone) by two pebble beds. It is a softer finegrained limestone unit that forms irregular slopes, and that start being deposited during Miocene (Langhian to Aquitanian). Its thickness varies from 23 m to 207 m;
- Blue Clay: this is a very soft unit that within the islands normally forms rolling low slopes that are mostly covered by carbonate raw soil or scattered rubble. The age is Langhian to Tortonian, in the Miocene. Blue Clay is generally impermeable and holds water, with a thickness up to 65 m;
- Greensand: even if not sufficient thick (12 m), this formation proved distinctive enough to have deserved a separate name. It consists of massive, friable, intensely burrowed marly limestone, deposited during the Tortonian age in the Miocene;
- Upper Coralline Limestone: this formation is a complex association of limestone. The deposition of these marine sediments stopped around 10 million years ago when the seabed rose above sea level. This formation constitutes the coralline plateaux that top most of the hills of Gozo and Malta. It overlies the Blue Clay in an irregular pattern and its thickness can reach 162 m.

A system of horst and graben structures of E-NE trend characterizes the area interested by the project. These structures are indicated by prominent ridges and valleys, with sub-horizontal strata dominating. Rock faulting and displacements are widely present in north Malta and south Gozo and in the channel between them, where the geology is not clearly understood yet.

There are a series of geological implications for tunneling in this area. The most relevant are: 1) the presence of faults, that degrade the rock quality and its mechanic characteristics.
This represents a potential risk for the tunnel excavation in areas where the faults positions are either unknown or poorly mapped; 2) The presence of the Blue Clay formation, that it would be preferable to avoid during the tunneling because of its softness and its generally poor mechanic characteristics.

Where possible, in fact, the tunnel alignment should be developed below the impermeable Blue Clay layer, and extend as far as possible within the Globigerina and Lower Coralline Limestone formations, that are harder and where karsts formations are understood to be scarce.

**Plan of work and methodologies.** The first phase of the geophysical investigation took place in autumn 2016, and comprised the following methodologies:

1. multibeam echosounding, to generate a detailed map of seafloor morphology and composition, and to identify features of geologic and geomorphic interest; a 500 kHz Reson Seabat multibeam was used to produce a centimeter scale 3D map of the seafloor in the channel between Malta and Gozo and surrounding the island of Comino;
2. high-resolution 2D sub-bottom profiling, to reveal shallow geology beneath the seabed, with particular emphasis on the illumination of any faults displacing most recent sediments; a Ultra High Resolution boomer seismic source was used together with a single channel ministramer allowing a fine scale (between 20 and 40 cm) imaging of the sub-seafloor up to a few tens of meters;
3. multichannel reflection survey, to characterize the nature and stratigraphy of the bedrock geology and to identify any faults that intersect the area. The main concern was in this case to identify the interface between the Blue Clay and the underlying rock, at a depth ranging from 300 m to 400 m below the seafloor. The seismic source was a 60 cu.in Sercel Mini GI-gun operating in Harmonic Mode (30 G + 30 I). With this source, fed by three 320 l/min Coltri compressors operating at 140 atm., and activated every 18.75 m, a penetration of some hundreds of meters was achieved. The data were collected by means of a 96 channels, 300 m long Geometrics GeoEel liquid state digital streamer, with a trace distance of 3.125 m. Both the gun and the streamer were towed at a depth of 1.5 m to limit the ghost effect and keep the spectra as broad as possible.

A second phase, that will take place in the winter 2017/2018, will involve offshore drilling to calibrate the geophysical data and obtain samples for geologic, geotechnic and hydraulic characterization over four sites, that will be located on analyses of the geophysical data. During this phase, borehole data as well as onshore seismic refraction/reflection will be carried out.

**Ongoing activities and preliminary results.** At the time being, the geophysical data are still under processing and interpretation; in particular, an integrated data analyses is being performed on the three different scale and resolution datasets. This is allowing to correlate the geological structures directly observed onshore to those imaged by echosounding and seismic methods. Both the top and the bottom of the Blue Clay formation has been well imaged by means of the multichannel seismic, even if the data seem to suggest a geological setting more complex than expected.

**Conclusions.** Because the data are still under processing and integration, no conclusion have or can be drawn from what has been so far analysed. Furthermore, seismic data need borehole data for validation, calibration and time to depth conversion. Nevertheless, from the preliminary results it can be stated that the complete geophysical characterization of the site has been performed and this will constitute a valuable tool for the support to the assessment of the risks associated to the realization of this sub-sea infrastructure.