

Rockfalls monitoring along eastern coastal cliffs of the Favignana island (Egadi, Sicilia): preliminary remarks

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Favignana island is a historical and environmental attraction site frequented by tourists during the long warm season of the year. For several centuries the calcareous sandstone outcropping in the east side of the island has been extracted and used as building stone. Actually the quarries and the caves are undergoing to erosional and gravitational processes that are influencing the touristic use. As well as putting at risk the safety of people attending the area, the diffused rock falls are likely to jeopardize sites of great anthropological value that, once destroyed, can no longer be reconstructed. An integrated monitoring project of the cliffs is aimed to identify the most active areas and to provide support to the local government's policies in the implementation of mitigation measures. If adequate measures will be taken in the future, operators and users of the tourist circuit will have the opportunity to enjoy these amazing areas with lower level of landslide risk.

Keywords: rock fall, monitoring, Favignana, Sicily

1. Introduction

In the Favignana island outcrops a quaternary calcareous sandstone, improperly called as tuff. Its good resistance brought this rock to be extracted and used as building stone. The exploitation of the Favignana sandstone is ancient, but it was mainly in the period between 1700 and 1950 that reached its maximum development. Many buildings were constructed in Tunis with the “tuff” of Favignana and Messina was rebuilt with it after the earthquake of year 1908. After the II world war the “tuff” has gone out of the market and the mining areas have been abandoned to a degradation process which increased the risk of walls collapse. Among the quarry areas there are also the high cliffs overlooking the sea situated along many parts of the eastern coast.

The landslides along these rock slopes, often highly fractured and exposed to the intense activity of aggressive exogenous agents, occur mainly with the detachment

and fall of blocks extremely variable in sizes (fig. 1). The ongoing climate change and particularly the variation in temperature regimes and fluctuations in sea level in the Mediterranean and Sicily seem to intensify the falls activity (Puglisi et alii, 2007). These climatic dynamic indeed increase thermoclastic processes and erosion at the foot of the cliffs. The low human activity in these areas reduces the real risk conditions that remain concentrated in some bays frequented by tourists during the long warm season of the year. Local government of Favignana pays special attention to the evolution of the coastal system, consisting in the high coast and the emerged and submerged beach below. Rock falls, in fact, can heavily influence the availability of the beaches below, resulting in a partial and/or total access and bathing ban in places that for their beauty are often a popular tourist attraction. In addition, the quarries and the caves are a natural and cultural heritage of great anthropological value that, once destroyed, can no longer be reconstructed.



Figure 1- Rock blocks fallen at Cala del Bue Marino

2. Objective of the study

The aim of the study is to contribute to the mitigation of geomorphological risk in the Favignana island. The cliffs monitoring and the movements characterization are aimed to identify the most active areas and to provide support to the local government's policies in the implementation of mitigation measures. Given the characteristics of the sites, inserted into the largest European marine protected area, the intervention measures will must also be characterized by a high degree of environmental sustainability. If valid, effective and pleasant measures will be taken in the future, operators and users of the tourist circuit will have the opportunity to enjoy these amazing areas with lower level of landslide risk.

3. Study area

The study is focused on Cala Rossa, Cala del Bue Marino and Cala Azzurra, located in the eastern portion of the island, in areas classified with high and very high landslide hazard (Regione Siciliana, 2006). A calcareous sandstone rich in marine fossils (bivalves, corals ...), with nearly horizontal layers of about half a meter thickness, are outcropping all over the area (fig. 2). In the west side of Cala Rossa and Cala Azzurra, underlying the rock slab, whose thickness varies from few meters up to 30 and more meters, plastic clays are outcropping. The overlapping of hard rock masses on a plastic substratum leads to mechanical instability due to the diverse response of the materials to the applied perturbations, such as man-made excavations, weathering or erosion (Gigli et alii, 2012). The mass movements can be classified into two different but strictly interconnected typologies: lateral spread and rock blocks fall (Cruden, Varnes, 1996)



Figure 2 – Bivalves (left) and layers (right) in the calcareous sandstones

4. Methodology

The monitoring activity was launched in October of 2012, will end in April 2014 and is led through the use of direct and indirect instruments. The direct measurements are made through mechanical joints gauges of different kind (tell-tale, removable jointmeters, 3D jointmeters) in relationship with the different characteristics of the walls, discontinuities and types of movement (one-dimensional or three-dimensional). Altogether were installed 70 mechanical jointmeters, distributed along the cliffs of the three bays and also within the numerous cavities that open inside of the cliffs. The indirect measurements are carried out through laser scanner and GPS instruments with two substantially different purposes. The laser scanner is used for the acquisition of areal data in all the three areas of the study and will permit to identify any movements of each of the points highlighted by the laser beam along the entire cliffs. For the

identification of possible displacements along the cliffs, several scanning spaced in time will be acquired (Abellán et alii, 2010; Stock et alii, 2012). Various Digital Terrain Models will be processed and their comparison will permit to derive displacement maps of the observed cliffs. The GPS, instead, is used only in Cala Rossa and is directed at the control of 4 points identified in specific portions behind the cliff edge. The GPS technique will permit to identify movements with sub-centimetric detail level. For this purpose a local GPS network has been designed, consisting in four presumably stable vertices (fig. 3). Accurate geological and geomechanical surveys of the selected sites were carried out with the aim of identifying predisposing parameters to be subsequently used in the rock fall susceptibility GIS analysis (Frattini et alii, 2008).

5. Results

The rock mass shows a high degree of fracturing and evidence of previous blocks falls is also visible all over the study area. Several blocks of different sizes appear to be in conditions of high instability and in proximity of falling.



Figure 3 – The GPS network at Cala Rossa and the four measuring points

An example is given by the block of approximately 0.3m^3 collapsed on the morning of October 26, 2012 from the west cliff of Cala Rossa and recorded by the Laser Scanner monitoring (fig. 4). In the inner part of the same cliff, approximately 25 meters from the edge, have been recognized two important

discontinuities, longer than 100 meters, 50 cm open and 40 cm offset (fig. 5). Nevertheless the integrated monitoring system did not return evidences of significant movements in the first months of the project. This can be explained with the discontinuous nature of the processes of rock collapse and does not exclude the possibility of future movements.

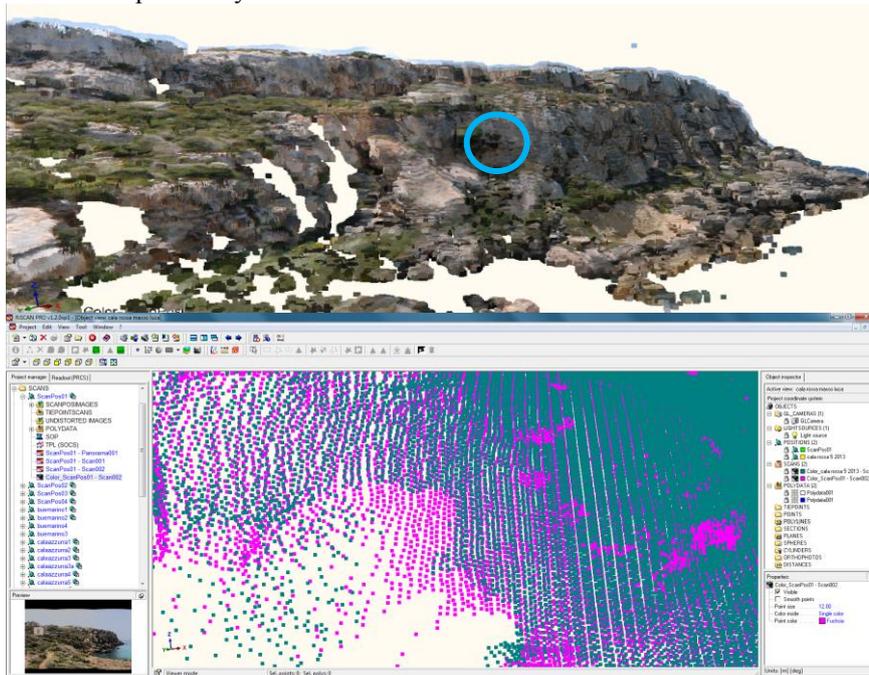


Figure 4 – Comparison between the laser scanner images registered before (fuchsia dots) and after (blue dots) the block fall from the west side of Cala Rossa (blue circle) occurred in October 26, 2012. Where the rock has not moved the points lie on the same surface.

6. Conclusions

The results of the project give information on the movements in the monitored areas, as well as a contribution to the development of the technologies used by the mutual control of direct and indirect system used. The monitoring of the ancient mining areas of Favignana is a necessary and appropriate action to prevent that the cliffs and the most significant quarries at least become abandoned to an inexorable degradation process of the historical and environmental features. The enhancement of the safety level of these areas is an essential step for a sustainable and secure tourism in the island. This is the way to ensure that what was left of the

quarries, back to being an economic resource, while respecting the historical and the environmental context.



Figure 5 – Giant joint of Cala Rossa

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