16th International Congress of the Geological Society of Greece

17-19 October, 2022 - Patras, Greece

Bulletin of the Geological Society of Greece, Sp. Publ. 10

Ext. Abs. GSG2022-050

Monitoring of the erosional phenomena next to the active fault of Psatha (Attica, Greece) with diachronic Terrestrial LiDAR data acquisition

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The topic of coastal erosion and the derived risk have been subjects of growing interest for public authorities and researchers. The combination of erosion along with alterations, caused by active faults in coastal areas, represents an even bigger challenge because of the apparently continuous evolving geomorphology (Abellán et al., 2006). Traditional methods for mapping such areas are generally time- as well as cost-consuming and potential to result in questionable accuracy issues (Oppikofer et al., 2009). In contrast, Light Detection And Range (LiDAR) – airborne and terrestrial – have been used in numerous case studies (Abellán et al., 2013), varying from acute natural hazard mapping (volcanoes) to fast developing landslides and rockfalls, producing remarkably precise 3D Digital Elevation Models (DEMs) (Konsolaki et al., 2020). These models are based on measuring highly accurate X, Y and Z as well as RGB values on each point of a produced cloud.

Psatha Bay represents an exemplary case for perusing the advantageous utilization of terrestrial LiDAR, as it reveals a steep coastline and anaglyph along with the visible throw of 185m, caused by the tectonic activity during the post-alpine period (Zygouri, 2008). This area became noticeable due, on the one hand, to the disastrous earthquakes of 1981, in the wide area of Eastern Gulf of Corinth and on the other hand to the frequent civil protection warnings and briefs about the rockfall threats of driving through the nearby coastal road. In terms of geology, a mix of limestone, calcite and related debris can be observed. Concerning the fault, Triassic-Jurassic limestones form the foot wall while thick Pleistocene debris covers the spectacular fault surface (Sakelariou et al., 1998). Erosion, rock falls and slope failures are present in certain parts, causing a continuous natural alteration, influenced by human intervention, namely the lately roadworks, without implementing any preventive/protective infrastructure. Since this area is outlined as highly touristic during the summer season, the construction of a risk map for estimating likely unstable areas (Ferrero et al., 2011) can be of great importance. The latter could be based on the production of a very high-resolution Digital Elevation Model (DEM) for deriving some primary topographic attributes (Agliardi & Crosta, 2003). The initial topographic information and result can be used as a reference point for future similar studies, in the frame of detecting changes on the slope, including failure widenings and rock piece detachments, quantifying them and finally introducing and/or improving risk maps (Mavroulis et al., 2022).

A multiple-phase study within a period of 11 years was conducted in the area. In the first phase, in June 2011, high resolution close range remote sensing campaign was conducted, by using a terrestrial LiDAR (a Leica ScanStation C10) for acquiring a dense point cloud, representing the micro-topography of the open to the air fault surface of the Psatha active fault (Figure 1a). It was coupled with near surface applied geophysics data, which were also conducted on the hanging wall to investigate the subsurface structure of the debris (Alexopoulos et al., 2013). A series of scanning campaigns followed during the next decade and the high-risk areas on the steep slope were located, in high detail. The research is mainly focused on the easternmost segment of the fault surface. We used a Leica P50 terrestrial LiDAR during the most recent campaign, that took place in July 2022. The data acquisition was concentrated on the contact between the debris and the carbonate fault surface, where we observed significant rockfalls and slope failures, compared to the previous campaigns (Figure 1b). Hence, this selected segment was investigated with a strategy ideal for producing a higher density point cloud generation, based on detailed scanning from different angles, which caused setting up five bases from which three were newly established.

After the necessary pre-processing of the point cloud data, which included cloud geo-rectifying, merging, cleaning and quality checking, a dataset (point cloud) with almost 150 million points has been created. The geo-rectification included high accuracy measurements with the use of Real Time Kinematics - Global Navigation Satellite System (RTK - GNSS) equipment, for ensuring the precise registration of all the datasets that have been acquired diachronically to be comparable, with the minimum error possible (Figure 1c). Several quantification techniques were applied, and specific volumes of rock particles were found displaced on top of the hanging wall due to rock falling, which in turn are mainly attributed to severe weather phenomena but also to small earthquake events, that continue to happen at the very active Gulf of Corinth.

In conclusion, we argue that the described methodology, which is a technique based on the advances of innovative surveying equipment, could be applicable to any coastal area characterized by similar features, such as steep slopes, frequent rockfalls, proximity to coastline with wide coastal front. This methodology is ideal to use in estimating any involving risks and laying out plan and protection actions/measures.

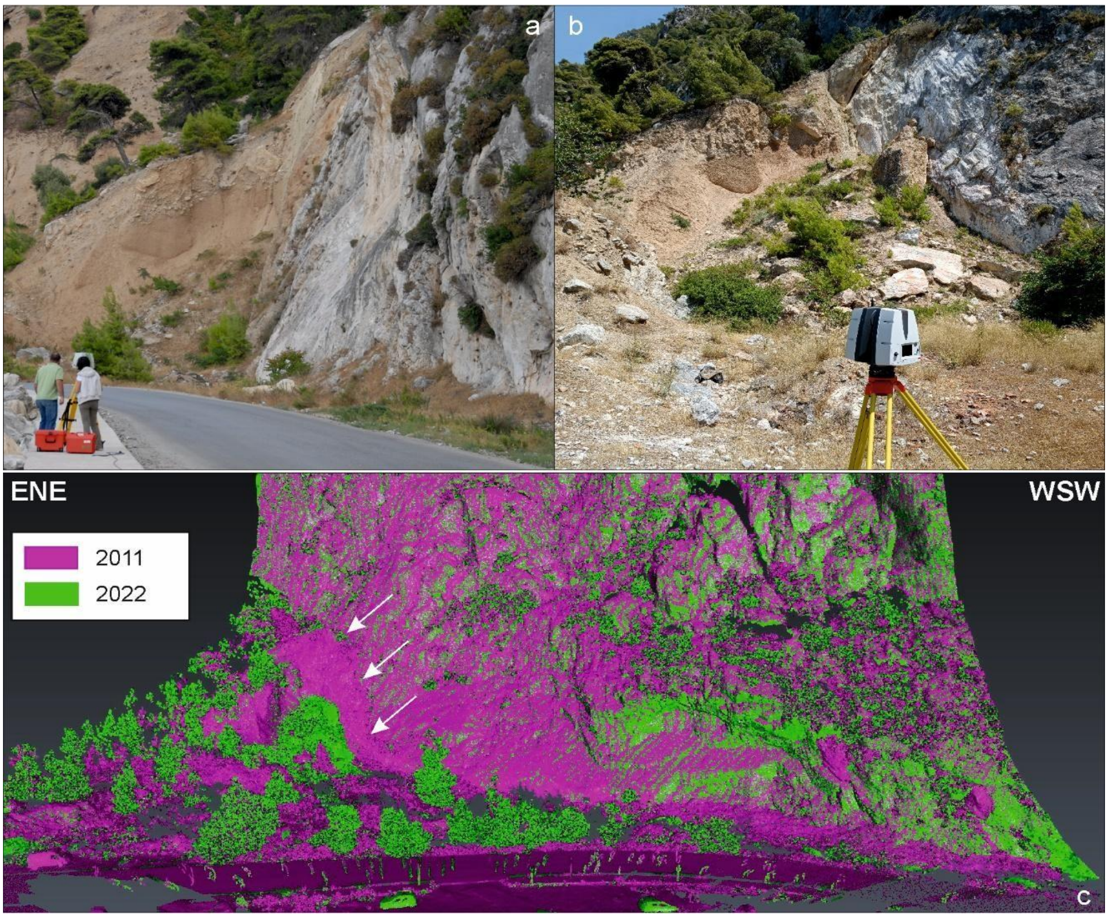

Figure 1. Aspect of the fault surface and the contact between the debris and the carbonates, during the 2011 campaign (a). Recent rock falls on the hanging wall, observed during the 2022 campaign (b). Comparative representation of the two period point clouds showing the changes during the last decade. White arrows show the debris area where most of the changes have been recorded (c).

Acknowledgements

The authors would like to thank Metrica SA (Greece) for their contribution in the field campaigns regarding the data acquisition by providing a Leica ScanStation C10 (2011, 2012) and their overall support during data processing.

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