T-LIDAR Applications for Studying Active Faults and Extracting Deformation Rates in Greece

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Introduction

Fault specific approaches are of decisive value for seismic hazard assessment by providing quantitative assessments through measurement of geologically recorded slip on active faults (Wesnousky, 1986). The geometry and kinematics of active faults are important for locating and characterizing the seismic sources. In addition, the long-term prediction of future earthquakes can be achieved through the study of the cumulative patterns of slip on active faults. Fault slip-rates that govern earthquake recurrence can be extracted from dated geologic and/or geomorphic indicators offset by faults, covering a time span that generally encompasses a large number of earthquake cycles. Terrestrial Light Detection and Ranging (T-LIDAR) is nowadays a major tool for earthquake geology and seismic hazard assessment by providing high spatial resolution (Papanikolaou et al. 2015). Resolution usually ranges from several cm to a few mm, depending on the distance to the target. T-LIDAR has been early used for studying the fault geometry and quantifying the fault plane characteristics. The Arkitsa fault Plane in Central Greece plane was one of the first worldwide applications and the first one in Greece by Jones *et al.*, 2009.

Methodology

Over the last few years we have implemented a large number of T-LIDAR studies for several active faults in Greece, introducing also some pioneer methodologies. These include: a) the extraction of kinematic data for the Spili fault in Crete (Wiatr *et al.*, 2013), b) the extraction of fault slip-rates based on the height of postglacial fault scarps in the Lastros Fault (Mason *et al.*, 2016), c) tracing of paleoevents based on the reflectivity and roughness changes along the scarp, (Wiatr *et al.*, 2015), d) tracing of paleoevents from fault plane weathering features, combined with Cosmogenic isotope dating offering info regarding both the slip and date of past events (Mechernich *et al.*, 2018), e) the combined use of LiDAR multispectral analysis with GPR (Ground Penetrating Radar) in paleoseismic trenching, (Schneiderwind *et al.*, 2016) using as an example the Kapareli trench site (Kokkalas *et al.*, 2007,) f) the identification of undiscovered paleoshoreline notches in the Perachora Peninsula adding more info regarding local tectonic movements (Schneiderwind *et al.*, 2017).

Results & Discussion

Kinematic indicators were accurately calculated on the Spili fault scarp in Crete (Fig. 1), where the percentage threshold error of the individual vector angle is lower than 3% for the dip direction and dip for planes.

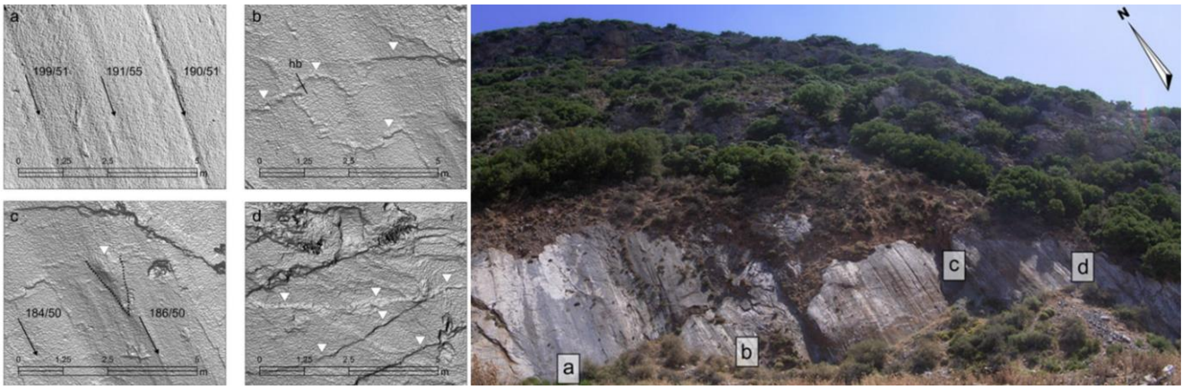

Figure 1. Kinematics indicators on the bedrock fault plane of the Spili fault, after Wiatr *et al.*, 2013.

Vertical displacements along a 1.3km long scanned segment of the Lastros fault in Crete were accurately determined using a T-LIDAR induced 3D model of the fault scarp, yielding a slip rate of 0.69±0.15mm/y (Fig. 2, left). T-LIDAR backscatter analyses at the Pisia fault scarp, along with Cosmogenic ^{36}Cl isotope dating, provided evidence for at least 6 paleoearthquakes (Fig. 2, right). The combination of laser scanning with GPR provided a 3D visualisation of a paleoseismic trench site in Kapareli, showing that trench stratigraphy and logging can be made using both techniques. Moreover, data from terrestrial laser scanning of coastal cliffs enhanced the recognition of tidal notches and supported palaeoseismic studies by providing spatial information and exact measurements of horizontal movements (Fig. 3).

All the above applications in Greece strongly imply that T-LIDAR is a major tool for earthquake geology and tectonic geomorphology, by offering quantitative data on the fault geometry, fault kinematics and deformation rates.

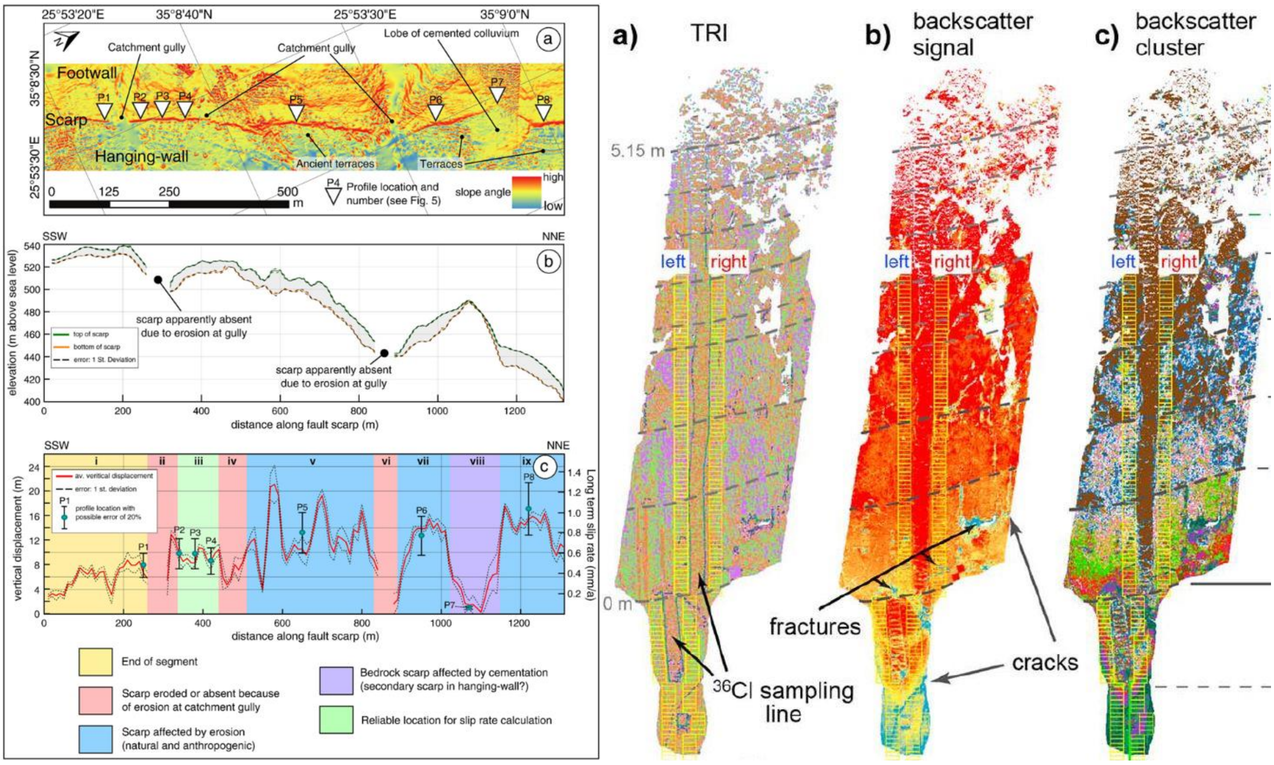

Figure 2. Left: The Lastros fault scarp geometry in relation to the postglacial rates of movement, after Mason *et al.*, 2016. Right: Surface characteristics of the Pisia fault scarp, based on T-LIDAR scanning, after Mechernich *et al.*, 2018.

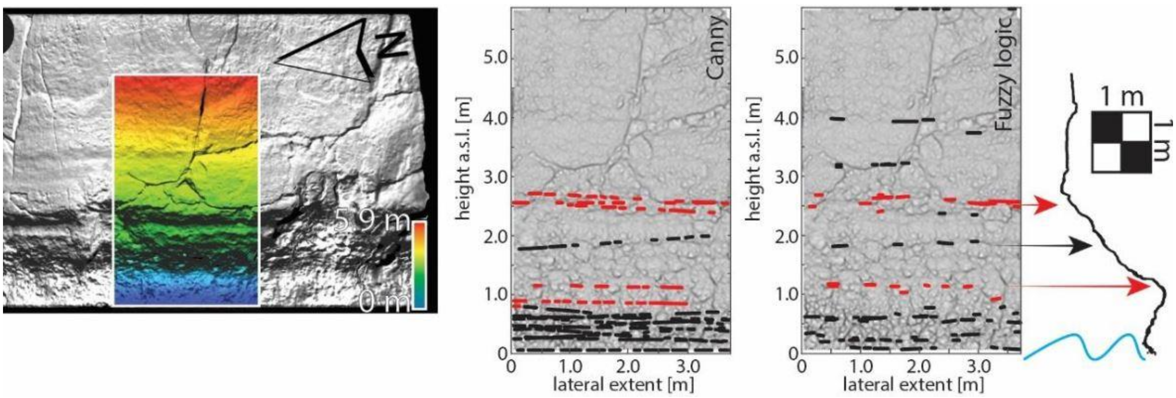

Figure 3. T-LIDAR scanned coastal cliff at Perachora peninsula, after Schneiderwind *et al.*, 2017.

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