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Mapping the Gyrtoni Fault (Thessaly, Central Greece) using an Unmanned Aerial Vehicle

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Abstract: *Gyrtoni Fault is an active normal fault located at the Larisa Basin, Thessaly and near the major city of Larisa. A UAV survey has been performed in order to map in detail the topographic expression of the fault, especially the visible morphological scarp. Results from the UAV survey present a detailed morphotectonic map of the fault and the ability to accurately measure fault scarp profiles.*

Key words*: morphotectonic, normal fault, digital elevation model, UAV*

INTRODUCTION

Gyrtoni Fault (GF) is an ESE-WNW-trending, normal fault that defines the northeastern boundary of the Quaternary Larisa Basin (Caputo et al., 1994). The fault is at close proximity, distance of ~13 km, from Larisa that is a major city of Greece (Fig-1 A). GF was initially described by Schneider (1968) as an important morphological feature (Gyrtoni terrace) affecting the northern Larisa Plain. It was recognized as an active tectonic structure by Caputo (1990) and Caputo and Pavlides (1993). The surface expression of the fault is composed of two right stepping en-echelon fault segments (Caputo, 1995; Caputo et al., 1994, Fig-1 B). In this area two paleoseismological trenches have been recently excavated showing that the fault is characterized by high slip-rate in the order of 0.4 mm/yr (Tsodoulos et al. 2016). The two paleoseismological trenches provide evidence of at least three, and possibly four faulting events (with ages ranging 2.16-1.42 ka, 3.77-2.80 ka, 5.59-3.77 ka, and <5.59 ka).

DATA AND METHODS

UAV mapping is progressively gain applicability as efficient and accurate solutions within a very short time compared to conventional techniques (Nikolakopoulos and Koukouvelas 2017). In the present contribution aerial mapping has been performed using a DJI Phantom 4 UAV, a commercial tetra copter mounted with a 4K camera. The camera sensor has a focal length of 3.6 mm, 12 M effective pixels, and field of view 94° (Fig.2 a). Flight planning and grid coverage was performed using the

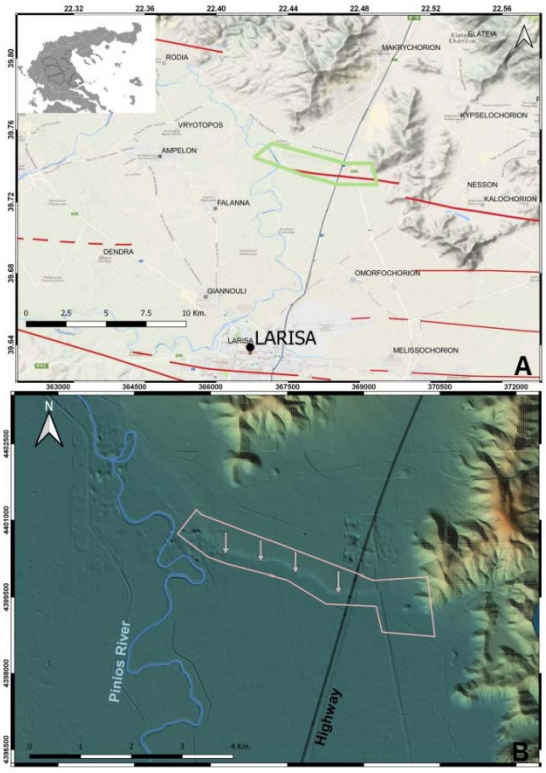

Figure 1. A) Location of GF and its proximity to Larisa city, east Thessaly. Other major active faults are shown as red lines, RF: Rodia Fault, TF: Tyrnavos Fault, AF: Asmaki Fault, LF: Larisa Fault. With the green polygon is the study area. B) Shaded relief map from Hellenic Cadastre orthophotomaps, of GF location. Fault scarp is marked by arrows. Box marks the extent of scarp high measurement displayed in figure5.

Pix4D software, and a 9.7" tablet was used for flight control. The focus of the project was to produce a morphotectonic map of the GF scarp. In order to

complete this map the study area was divided in 16 sub-areas, in which individual flights were performed. A total of 37 flights and 10.714 images were acquired to cover the study area. Two differed modes of UAV surveying have been performed one more detailed and one for wider coverage.

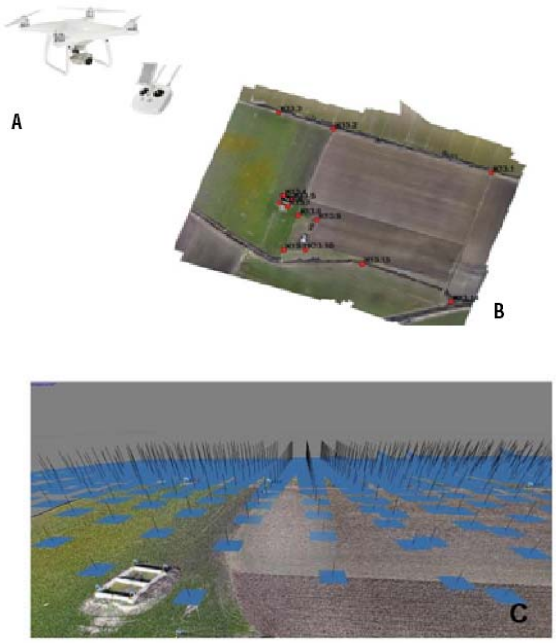

Figure 2. A) DJI Phantom 4 UAV used for aerial survey in the study area. B) Example of GCP use for a single flight path coverage. C) SfM processing of UAV imagery in Agisoft Photoscan.

Detailed mapping was used around the sites of the paleoseismological trenches (Tsodoulos et al. 2016), a relatively low flight height was applied, which allowed image acquisition with very high resolution. Some specifics for the detailed survey flights:

- Average flight height 39m, with a maximum altitude at the take-off point of 35m.
- Number of images: 368.
- Coverage area: 0.0554 Km^2.
- Coverage perimeter: 928 m
- Optimal ground resolution: 1.46 cm / pix.

The rest of GF area was mapped at a higher altitude, in order to achieve larger coverage. Although the flight height was twice the previous one, accuracy still was sufficient enough for the project purposes for specific parameters of the wide coverage survey flights see below:

- Average flight height of 67.7m, with a maximum altitude at the take-off point of 60m.
- Number of images: 941.
- Coverage area: 0.301 Km2.
- Coverage perimeter: 2.176 m
- Optimal ground resolution: 2.51 cm / pix.

All images from each flight were processed using Agisoft PhotoScan software, in order to create a detailed surface model of the area. Because the built-in GPS sensor of the UAV has not sufficient accuracy, there are large errors if only camera location used for processing, especially concerning surface altitude.

Therefore, the initial model must be corrected with the help of ground control points (GCP). Most GCP were selected from Hellenic Cadastre orthophotomaps, with a 1-1.5 m horizontal accuracy. In parts of the sites where no distinguishable features could be located with accuracy (e.g. agricultural fields) some additional GCP were manually picked using a hand-held GPS receiver and custom made ground targets (Fig.2 B). Elevation values for the GCP were extracted from Hellenic Cadastre 5m Digital Surface Model - DSM (with a vertical accuracy of 3.7 m). GCP were added at the Agisoft PhotoScan project and a corrected model was produced.

Using SfM processing in Agisoft Photoscan we get two main products:

- the point cloud dataset
- the orthophoto mosaic

From the point cloud dataset, a DSM raster file is extracted, while further processing and classification of the original point cloud enables the further extraction of a DTM raster. Figure 3 and 4 shows an example of DSM product in a part of GF scarp. The Figure 5 shows the along-strike fault scarp height measurements indicating that our UAV mapping is covering an entire fault segment. Fault scarp heights vary from 6,20m to 13,13m. In detail this profile of measurements, presented in Figure 5, suggests that the segment can be further separated into three smaller segments.

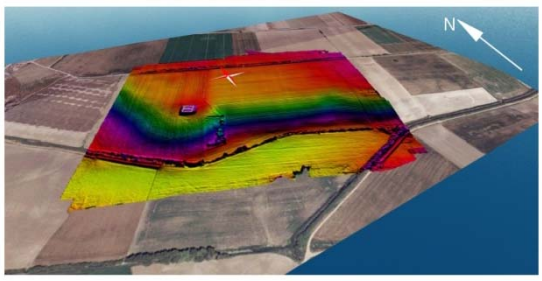

Figure 3. 3D view of a singular survey site, relief overlay on aerial imagery.

All the individual files from each flight were merged in a mosaic dataset covering the full extent of the surveyed area along GF. The DSM raster files were mosaicked using GDAL and QGIS. The full elevation model is presented in Figure 6. Total survey includes:

- Photos 10.714.
- Perimeter 12.618 Km.
- Surface: 3.0492 Km^2.

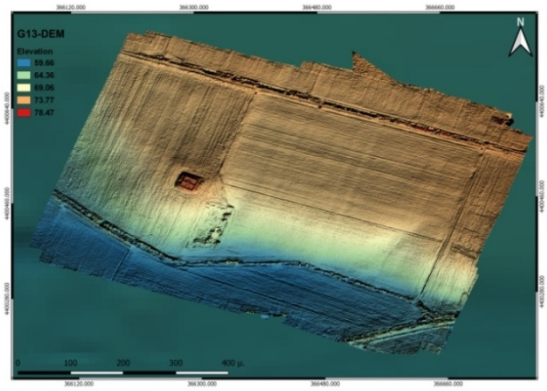

Figure 4. Shaded relief elevation output from a singular UAV flight.

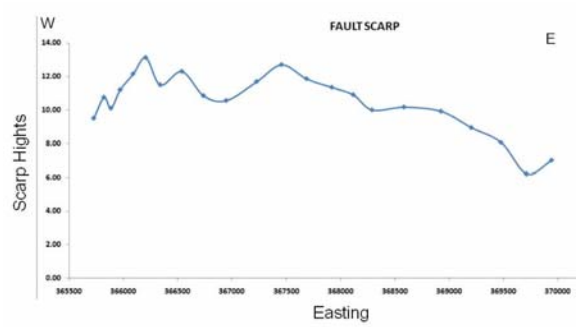

Figure 5. Fault scarp heights along GF. Scarp height measured using the high resolution DSM.

DISCUSSION

We performed a UAV mapping of GF in order to create a high resolution morphotectonic map. Multiple surveys were needed in order to cover the full length of the GF scarp in high resolution. Results are in agreement with previous paleoseismological results (Tsodoulos et al. 2016); GF is expressed through a continuous, fault scarp that is locally sinuous but in a general of WNW-ESE orientation. Scarp height values range between 6-12 m for most of the length of the fault. The morphological scarp that is interpreted as being formed by multiple events, with a mean displacement of ~0.5 m per event (Tsodoulos et al. 2016) can be further separated in smaller segments.

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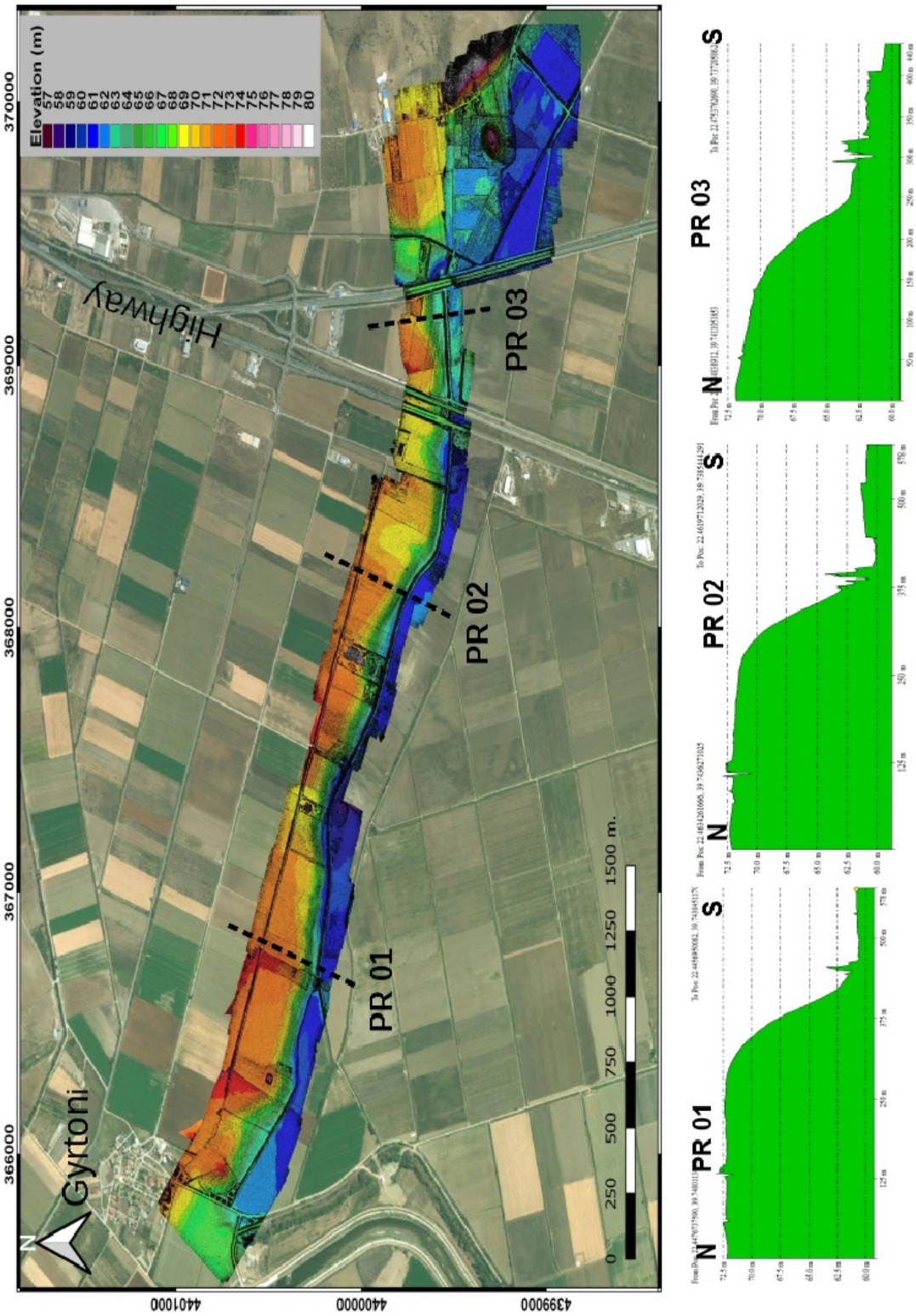

Figure 6. Overview of GF UAV survey. Slope map (0-20 degrees) mosaic created by merging multiple survey tiles. Below: Topographic profiles across the fault scarp, using the final DSM file.