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# UAV-Based Structure-from-Motion Photogrammetry used for reconstructing Late Pleistocene-Holocene deformation: an example from Krafla Rift (NE Iceland)

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Quantifying the extension rate and the spreading direction in a rift zone is fundamental for several reasons, like the assessment of seismic and volcanic hazard. However, this work requires the collection of a huge amount of precise data along a rift zone, which sometimes can be difficult to obtain, due to hard logistic conditions or to the large width of the study area. In our work we show how the use of UAVs, coupled with Structure-from-Motion (SfM) photogrammetry, allows to overcome these problems and to collect plenty of data even in difficult terrains, where field survey can be affected by the logistics.

We applied this technique in a 2.7 $km^2$ – large area located in the NW part of the Krafla Fissure Swarm (NE Iceland), an active volcanic rift in the Northern Volcanic Zone of Iceland composed of extension fractures, normal faults, eruptive fissures and a central volcano. The study area is situated about 7 km north of the central caldera, and it is characterized by the presence of extension fractures and normal faults, affecting two lava flows dated 11-12 ka BP, and a hyaloclastite ridge dated back to the Weichselian High Glacial (29.1-12.1 ka BP).

The area has been surveyed through 9 different missions, carried out during summer 2019, which allowed to collect a total of 6068 photos. Thanks to the SfM workflow, we obtained a high quality Orthomosaic (2.59 cm/pixel resolution), a DSM (10.40 cm/pixel resolution), and a 3-D Tiled model. By importing the resulting models in a GIS environment, we were able to redraw the geological map of the area, tracing the limits with very high detail, and thus to recognize and map a total of 1355 fractures, classified as normal faults (86) and extension fractures (1269). Moreover, we took structural measurements along both extension fractures and normal faults: at extension fractures, we measured opening directions, local strike and amount of opening in 568 sites, for a total of 1704 structural data, whereas at normal faults we quantified vertical offset in 284 sites. Finally, we interpolated the $\sigma_{hmin}$ values, using the unpublished software ATMO-STRESS, prepared in the framework of the EU NEANIAS project (https://www.neanias.eu/), to plot the strain field.

This approach allowed us to obtain an average spreading direction for this area of N97.7°E, with the majority of data characterized by a right-lateral component of motion, suggesting the influence of dyking at shallow depths on the surface deformation in this area. Furthermore, total

extensions of 16.6 m and 11.2 m have been calculated along the fractures affecting Holocene lava units, and an extension of 29.3 m in the hyaloclastites, resulting in an extension rate of 1.4 mm/yr in the Holocene lavas and 1.7 ± 0.7 mm/yr in the Weichselian hyaloclastite. Stretch values are 1.018–1.027 for post-LGM units and 1.049 for the Weichselian unit, suggesting the contribution of both tectonic and magmatic forces in dictating surface deformation in the area.