TS9.3 - Studying active tectonics and volcano-tectonic processes using aerial (UAVs) and field-based Structure from Motion techniques

Structural mapping and analysis of rifting events using UAVs in the North Volcanic Zone (Iceland)

Elisabetta Panza*, Joël Ruch*, François Martin**

* Department of Earth Sciences, University of Geneva, Rue des Maraîchers 13, CH-1205 Genève
Elisabetta.Panza@unige.ch
** Services Industriels de Genève (SIG), Chemin Château-Bloch 2, Ch-1219 Vernier

UNIVERSITÉ DE GENÈVE

FNSNF
SWISS NATIONAL SCIENCE FOUNDATION

Where will magma erupt?

- Understanding how magma propagates in the crust and eventually erupts is one of the key points in volcanology research.
- In this project we investigate the role of **pre-existing structures** and their **reactivation** during **magma propagation** in extensional tectonic environments.

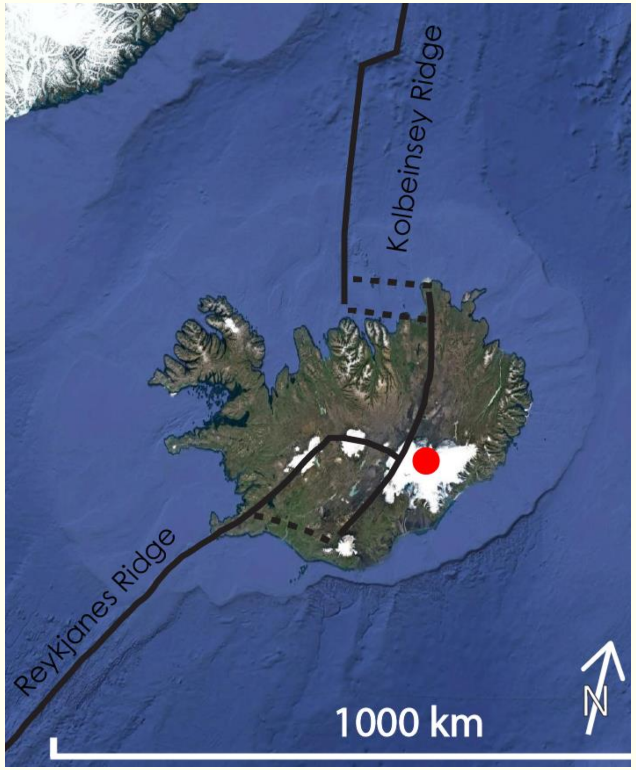


Fig. 1 The Mid-Atlantic Ridge (black line) cutting through Iceland and the current position of the Icelandic mantle plume (red dot). Modified after Thordarson and Larsen (2007).

- Iceland lies on both a spreading plate boundary and a mantle plume
  ⇒ occurrence of **volcano-tectonic events**
- Natural laboratory to examine the interaction of **structures** and **propagating magma**
- Scarcity of vegetation ⇒ terrain suitable for UAV surveys
- Historical reports of volcanic events since the first settlements (~ 870 AD)

Icelandic *Fires*: historically recorded volcano-tectonic events

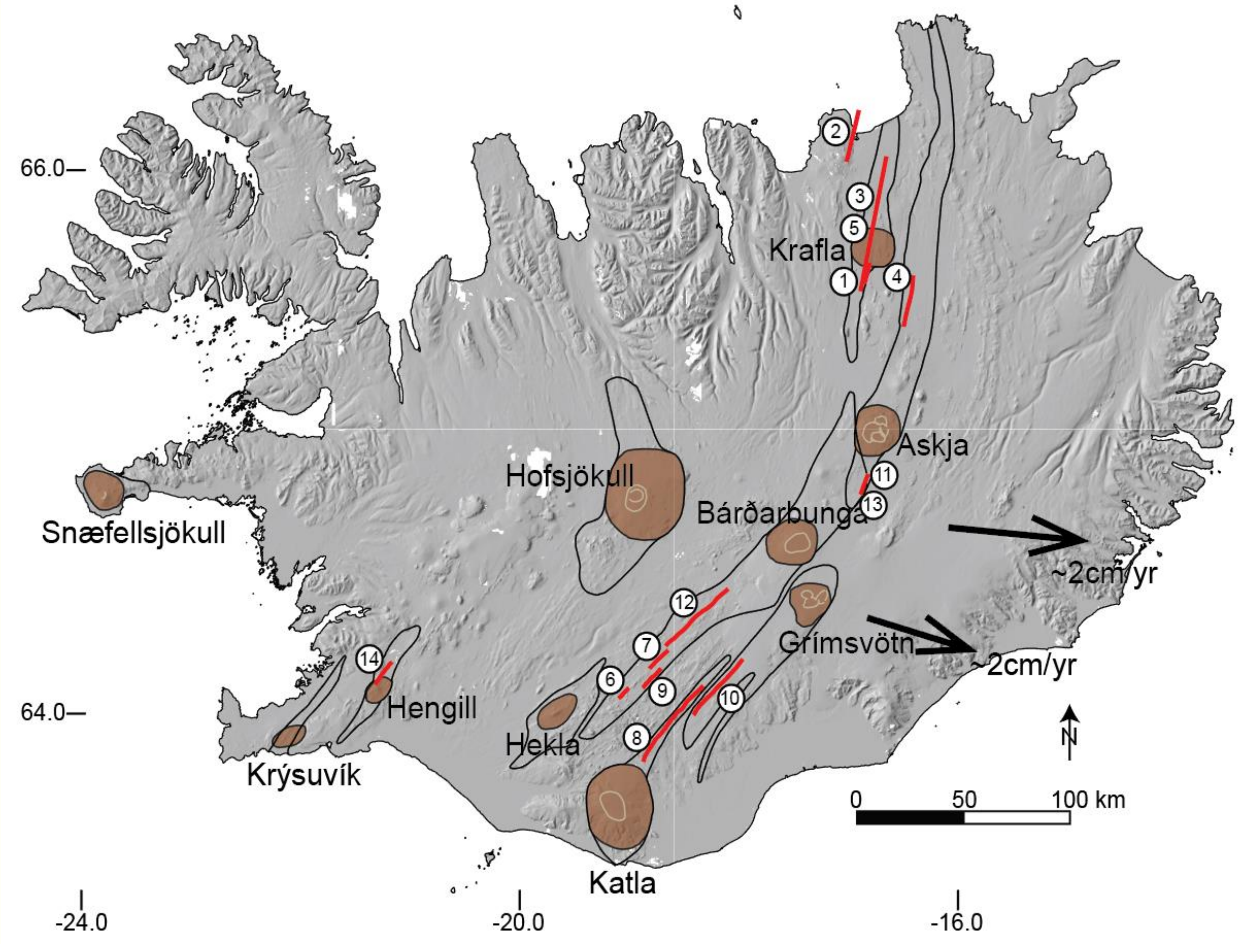


Fig. 2 DEM (ArcticDEM) overlaid by the principal volcanic systems, composed by a central volcano (in brown) and a fissure swarm (outlined in black), and the locations of the historical volcano-tectonic events (in red). The numbers correspond to the events listed in the table. The two black arrows are the rift opening rate obtained by geodetic studies (e.g. DeMets et al., 2010).

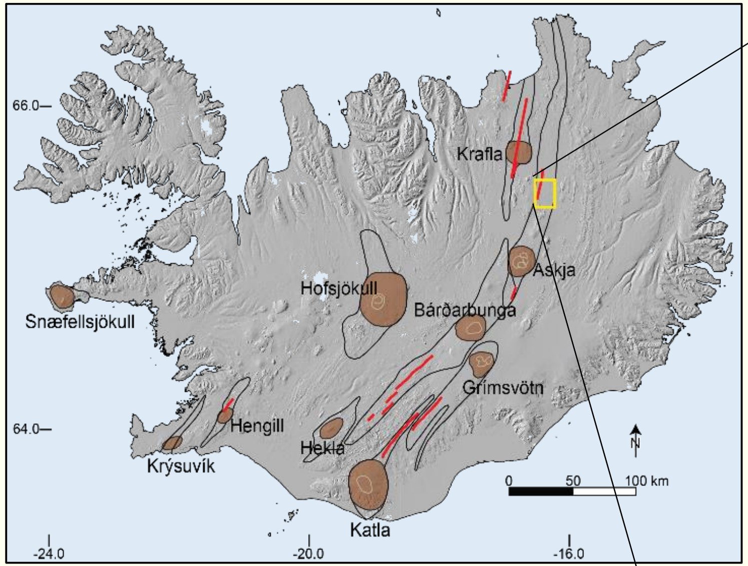
Icelandic ***Fires*** involve:

- **transport of magma** in the crust
- Eruptions
- Formation of graben structures
- Often **reactivation** of pre-existing structures.

VOLCANO-TECTONIC EVENTS (*FIRES*)			
Event #		Volcanic system	Age
①	NORTH VOLCANIC ZONE	Krafla	ca. 550 BC
②		Þeistareykir/Krafla	1618
③		Krafla	1724-1729
④		Askja	1875
⑤		Krafla	1975-1984
⑥	EAST VOLCANIC ZONE	Barðarbunga-Veidivötn	ca. 150
⑦		Bárðarbunga	ca. 870
⑧		Katla/Bardarbunga	ca. 934-940
⑨		Barðarbunga-Veidivötn	1480
⑩		Grímsvötn	1783-1785
⑪		Barðarbunga	1797
⑫		Bárðarbunga	1862-1864
⑬		Bárðarbunga	2014-2015
⑭		Hengill (West Volcanic Zone)	1789

Fieldwork August 2019

- A UAV survey has been carried out in **Fjallagjá**, structurally relevant and logistically accessible area in the Askja volcanic system.
- Fjallagjá is a graben ~15-20 m deep and ~1 km wide that extends parallel to **Sveinagjá** graben for ~18 km
- Sveinagjá graben was activated and it subsided 3 to 6 m during the 1875 volcano-tectonic event (Gudmundsson and Bäckström, 1991).



- 21 flights
- 13.5 km^2 coverage
- 31865 total images
- 540 Gb total images data
- 1.0 – 1.5 cm/px GSD @ ~100 m

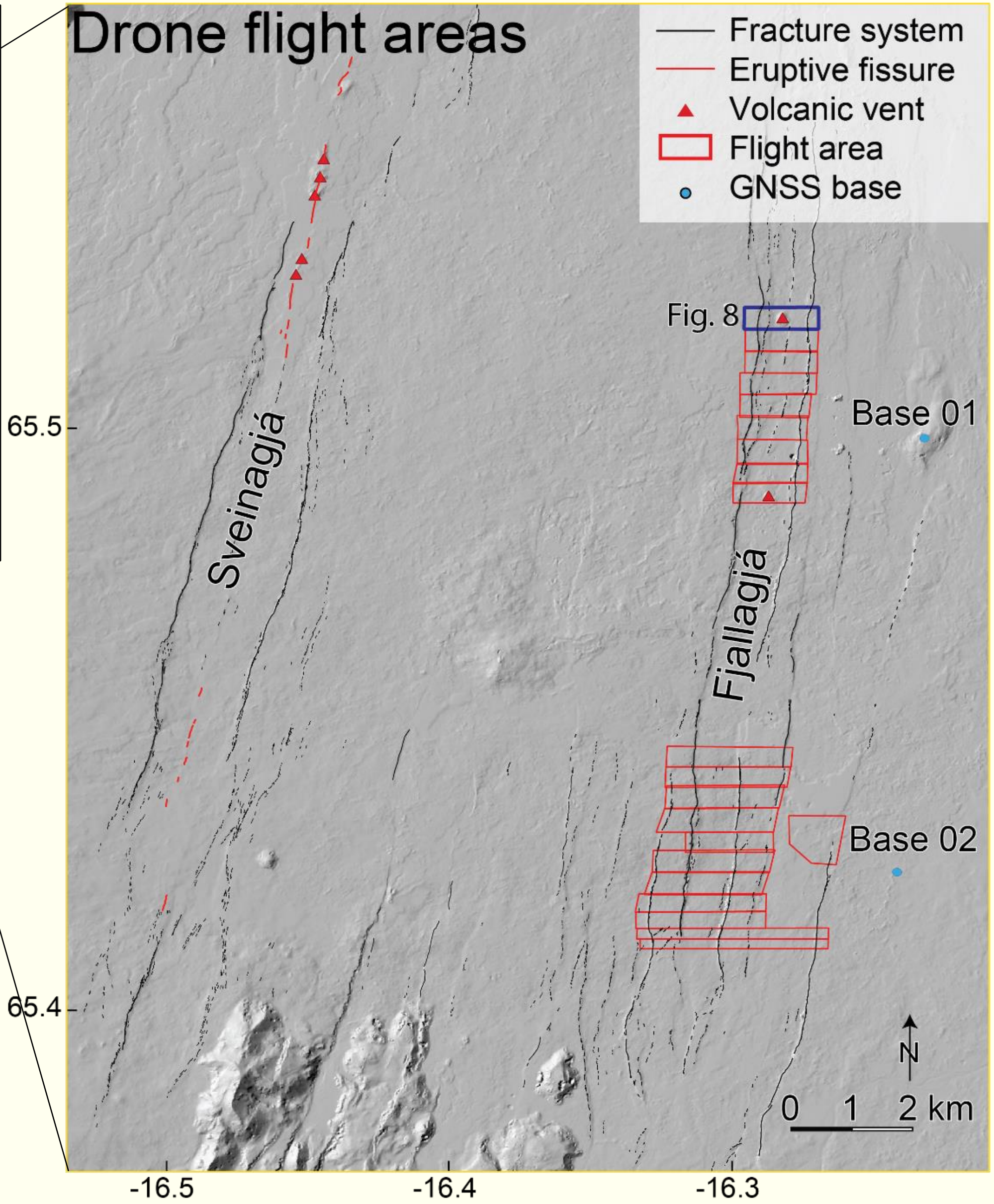


Fig. 3 DEM (ArcticDEM) of the field area, with the outline of the 21 drone flights and the location of the GNSS base. The yellow rectangle in the inset shows the field location.

WingtraOne

Fig. 4 WingtraOne

At **120 m** altitude (in optimal conditions):

- 50 min maximum flight time
- 1.5 cm/px GSD
- 2,1 km^2 coverage

UAV	WingtraOne PPK (fixed-wing)
Drone type	Tailsitter VTOL (Vertical take-off and landing)
Weight (empty)	3.7 kg
Wingspan	125 cm
Max. payload weight	800 g
Radio link	8 km (optimal conditions)
Flight planning software	WingtraPilot
Camera	Sony RX1RII / 35 mm, full-frame, 42 MP
WingtraOne PPK Antenna Module (onboard)	
Constellations	GPS, Glonass
Logging frequency	10 Hz
Mapping accuracy with PPK (w/o GCPs)	Horizontal: down to 1 cm; vertical: down to 2 cm
Operation	
Cruise speed	~ 57 km/h
Wind resistance	Up to 8 m/s on the ground
Temperature	-10 to +40 °C
Max. altitude (a.m.s.l.)	3000 m
Weather	No precipitation, resists light rain
Auto-Landing accuracy	< 5 m

Compared to other UAVs:

- **broader coverage** at high resolution ⇒ less flights needed
- **high resolution** provided by the 42 MP Sony RX1RII camera
- PPK **precise positioning** ⇒ in case of an event, it is possible to carry out a second survey and perform detailed studies of the changes occurred in between

Fig. 5 WingtraOne assisted landing

GNSS base station and geotagging

Fig. 6 Installed Trimble GNSS base station

Trimble R2 GNSS receiver as base station	
Position update rate	1 Hz
GNSS channels	220
SBAS channels	4
Horizontal accuracy	3 mm + 0.5ppm RMS
Vertical accuracy	5 mm + 0.5 ppm RMS
Operating temperature	- 20°C to + 55°C

- GNSS base station + PPK correction = **centimetre-accuracy** of drone images georeferencing
- **no need for ground control points (GCPs)**
- compared to RTK, PPK technology: **no communication needed between the UAV and the base station**

During the survey:

- The Trimble GNSS base station acquires data logged into "Receiver Independent Exchange Format (RINEX)" files
- The UAV, with a **PPK (Post Processing Kinematics)** antenna on board, acquires images and georeferencing data, stored in the camera SD card
- The base station and the UAV do not need to be connected to each other during the flights
- For best results, the **base station should be placed within a 10 km** radius from the flight area

After the survey:

- Geotagging process in within the Windows WingtraHub software, which compares the UAV PPK raw measurements of satellite locations and the raw measurements obtained through the base station.

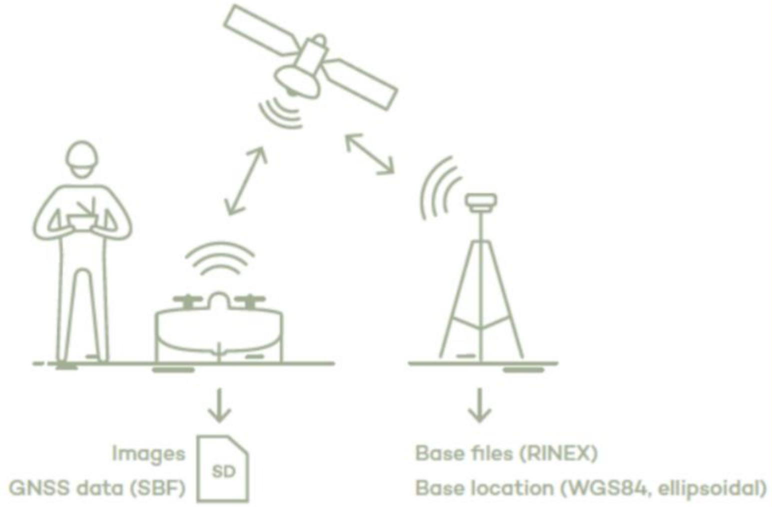
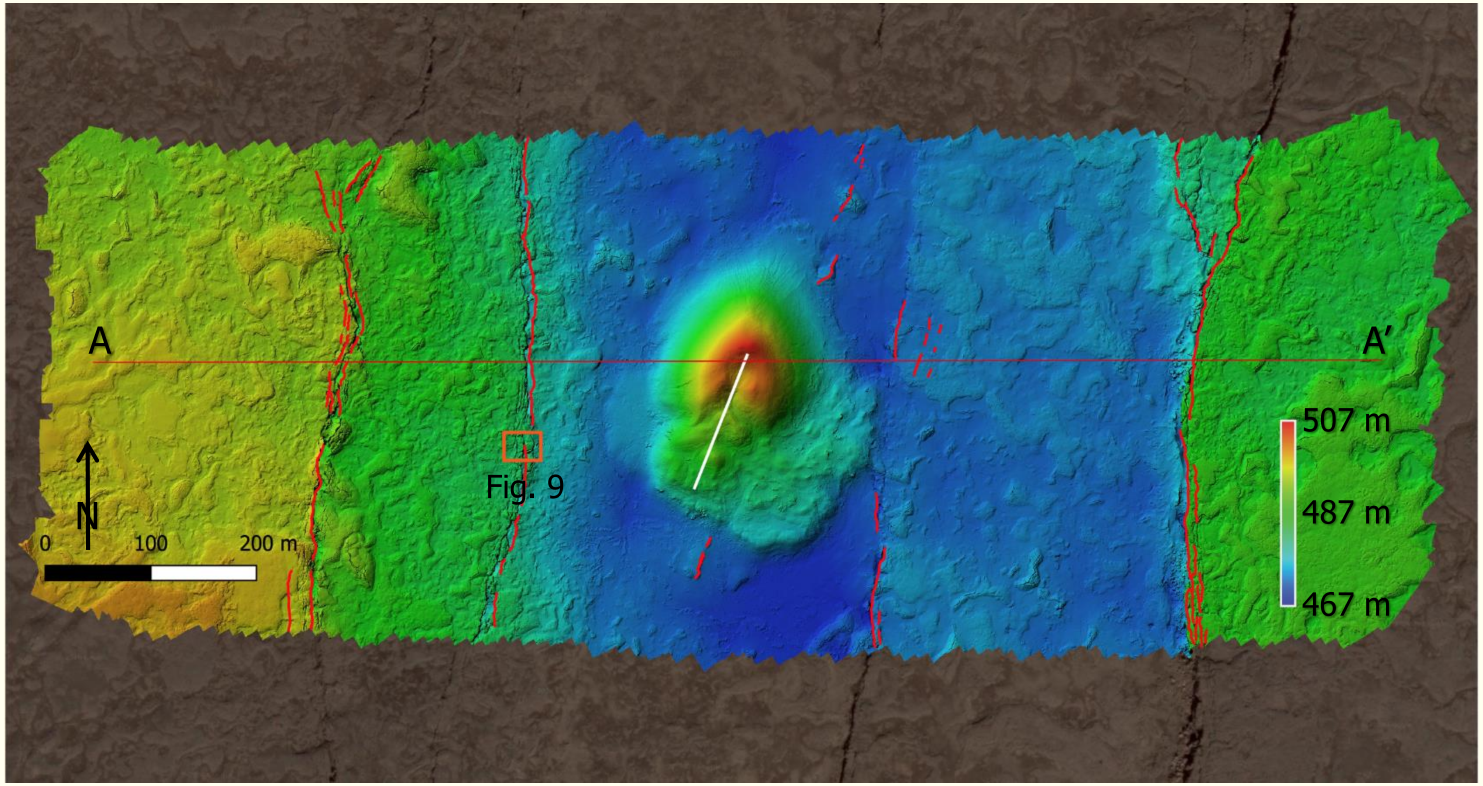


Fig. 7 Data acquired in a UAV survey with PPK technology

Preliminary results



High resolution DEM processing and structures mapping

Fig. 8 DEM (2.2 cm/pix) obtained from the drone photos of the northernmost flight of the field area. The red horizontal line defines the location of the profiles in fig. 10. The location of this DEM is indicated in fig. 3.
In red, preliminary mapping of structures based on the orthomosaic. The white line indicates a trend in the morphology of the vent, suggesting an intrusion oblique to the graben shoulders. It would not be possible to do the mapping at the Google Earth resolution (visible in the background of the image).

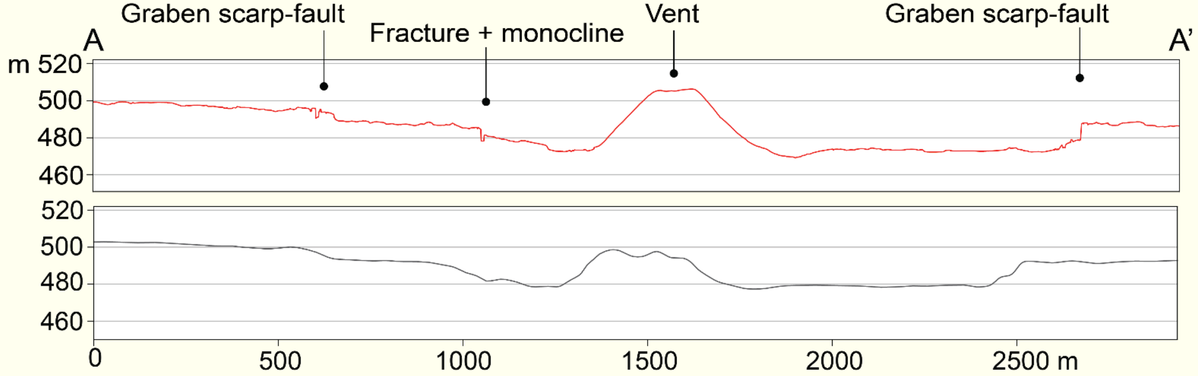


Fig. 10 In red, profile obtained from the 2.2 cm/pix DEM, built on drone images acquired during fieldwork. In grey, same profile based on the 2 m/px ArcticDEM, the highest available resolution so far. Both profiles have a 5X vertical exaggeration.

Measuring structures on the orthomosaic

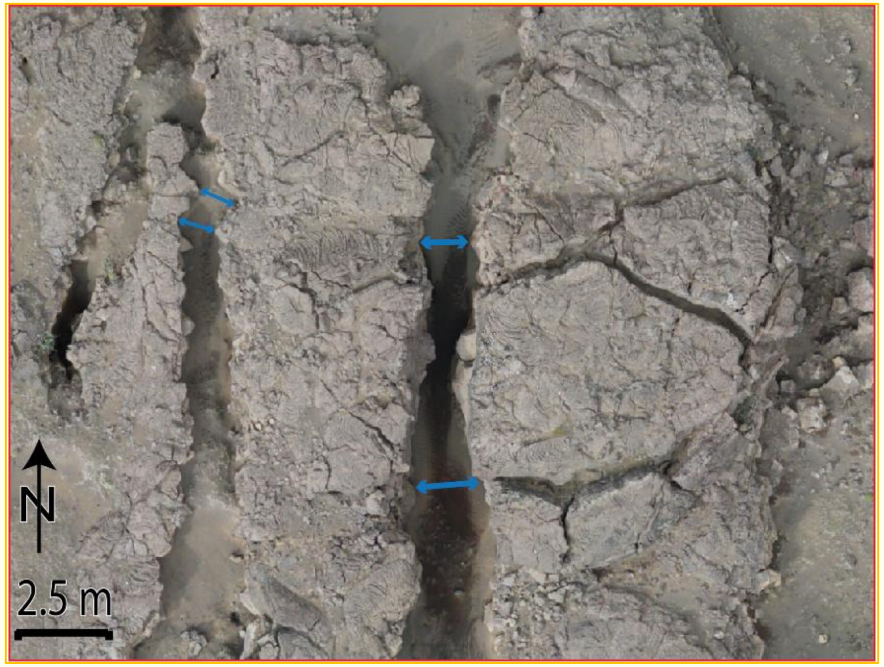


Fig. 9 Orthomosaic (1.1 cm/pix) obtained from the processing of the drone images. In blue, asperity fits. Sample's location indicated in Fig. 8.

References

DeMets, C., Gordon, R.G., Argus, D.F., 2010. Geologically current plate motions. *Geophys. J. Int. 181*, 1–80. https://doi.org/10.1111/j.1365-246X.2009.04491.x

Gudmundsson, A., Bäckström, K., 1991. Structure and development of the Sveinagja graben, northeast Iceland. *Tectonophysics 200*, 111–125.

Thordarson, T., Larsen, G., 2007. Volcanism in Iceland in historical time: Volcano types, eruption styles and eruptive history. *J. Geodyn. 43*, 118–152.

For further information, contact Elisabetta.Panza@unige.ch