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Unravelling the emplacement dynamics of silicic lava flows: the case of the Grande Cascade trachyte flow (Monts Dore, France)



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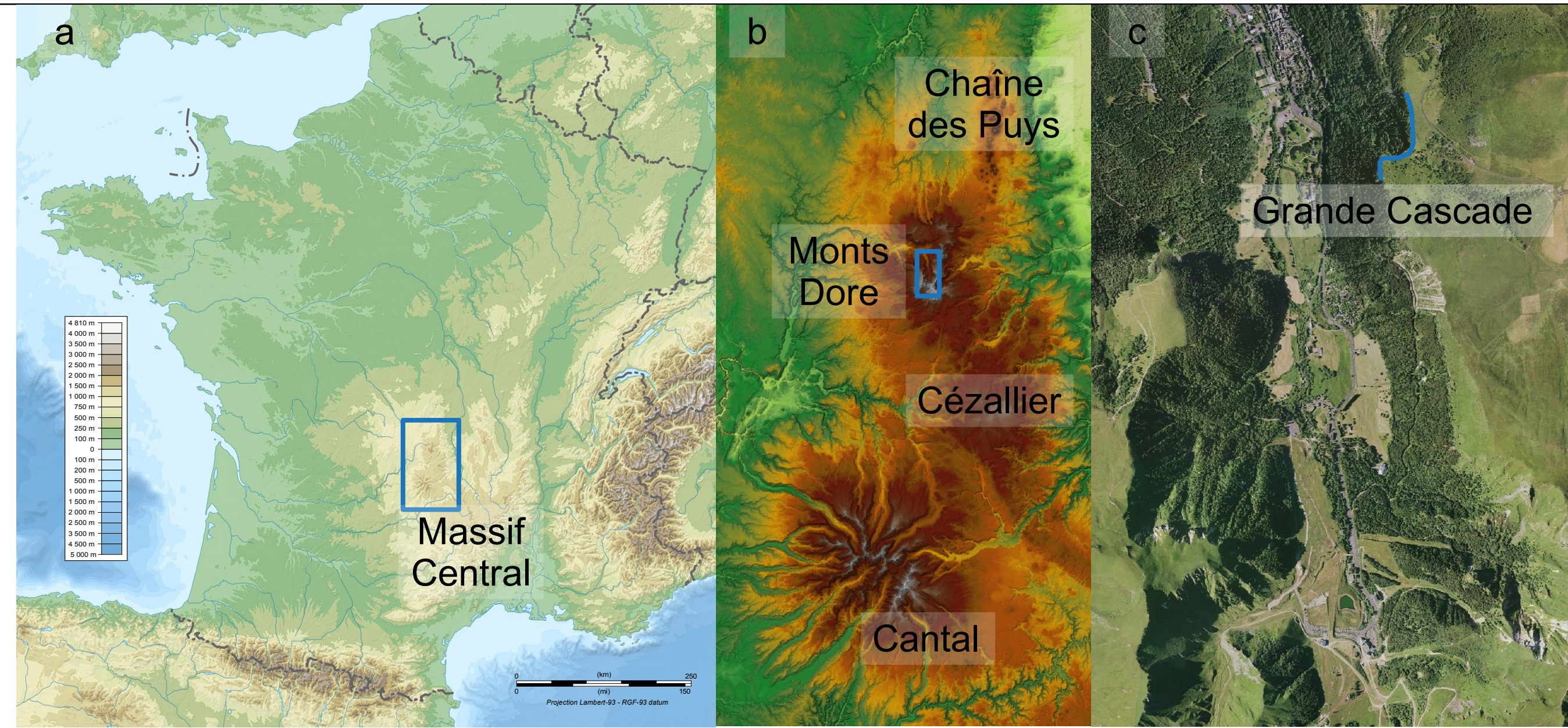
Introduction

Problematic and objective

Silicic lava flows are a rarely observed style of volcanism for which emplacement models remain poorly constrained. Yet they represent a hazard where oversteeping flow fronts can collapse and generate block-and-ash flows as at Santiaguito (Guatemala) in 1986, Unzen (Japan) in 1991, and Sinabung (Indonesia) in 2014. **Our objective is to build new emplacement models for silicic lava flows.**

Context

The Grande Cascade lava flow is located in the Monts Dore massif, the youngest stratovolcano of the French Massif Central, active from 3.09 to 0.23 Ma. The flow has been dated at 0.38 ± 0.02 Ma [1]. It is 20 to 40 m thick and made of trachyte with up to ~40 % sanidine phenocrysts. **The flow can be divided vertically into four facies: (1) a basal breccia; (2) a shear zone; (3) a massive plug; and (4) a foliated surface.**



a: topography of France (NASA/NCEI). b: the four volcanic massifs of northwest Massif Central (CRAIG). c: orthophotograph showing the location of the Grande Cascade in the Dore valley (IGN).

Methods

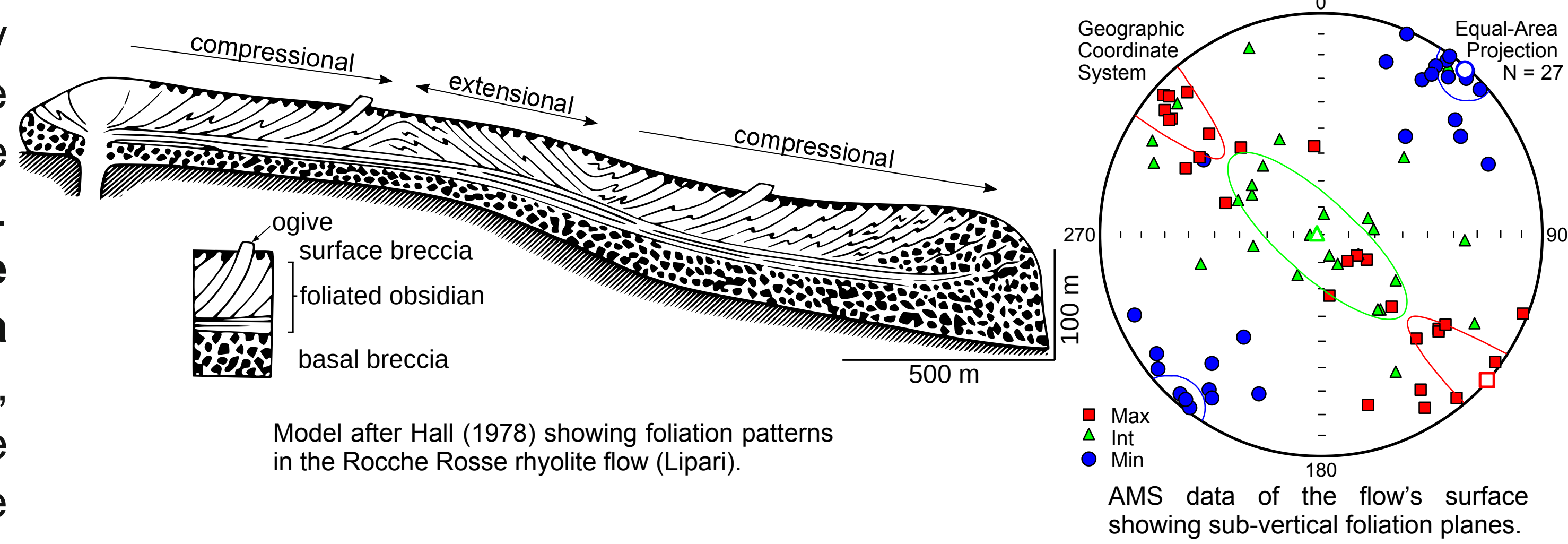
- Structural analysis: mapping and measuring structures.
- Textural analysis: density, vesicularity, crystal orientation...
- Anisotropy of Magnetic Susceptibility (AMS) to know flow directions at a local scale.



The Grande Cascade around 1930.

The surface

The surface of the flow is covered by vegetation, but a few outcrops allow to see parallel foliation planes, with an average inclination of the magnetic foliation of 88.5° . **These vertical structures could be the result of a ramping process due to a compressive regime behind the flow front**, as observed at the nearby puy de Cliegue trachyte flow [2], or at the Rocche Rosse rhyolite flow [3].

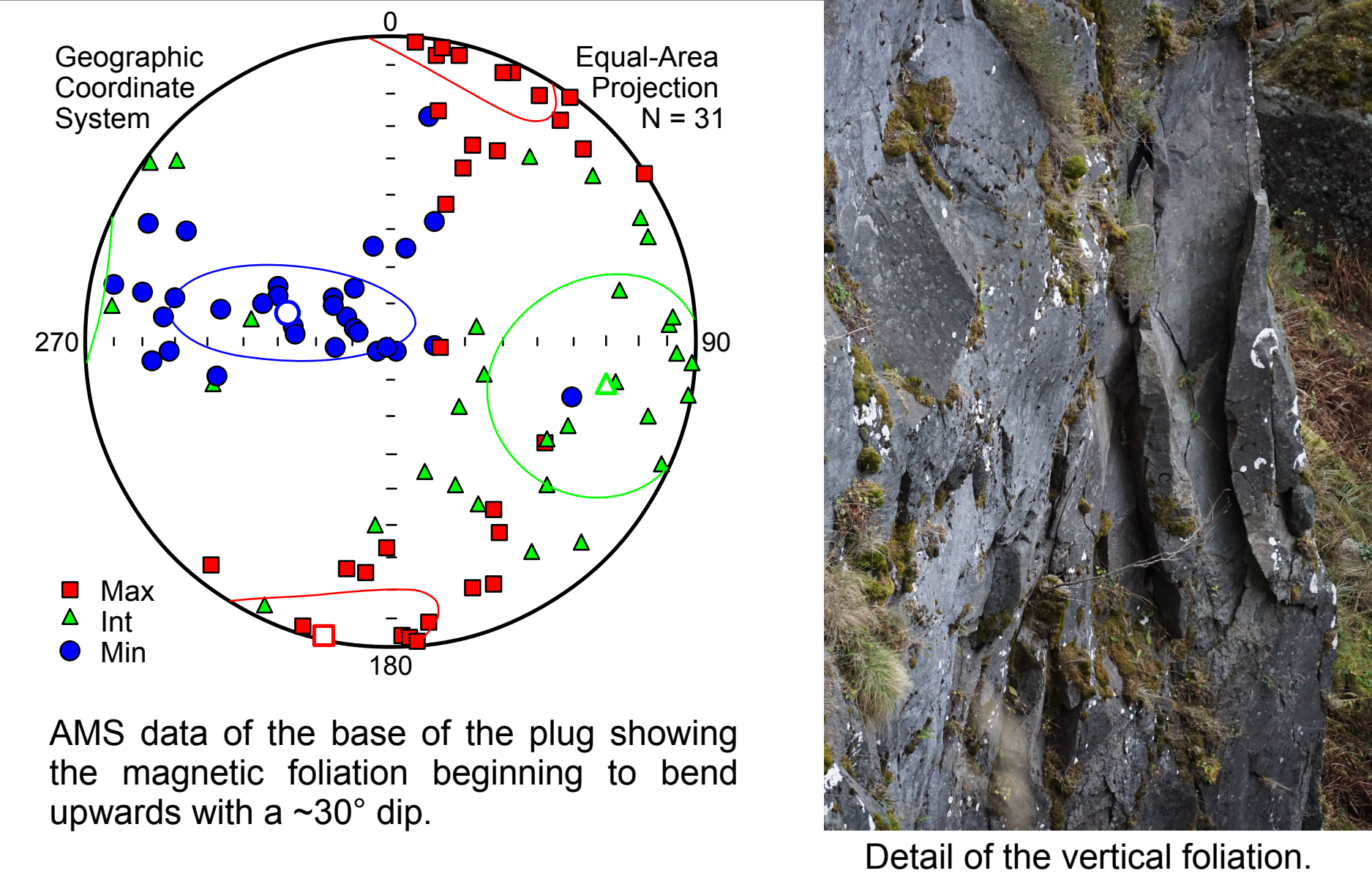


Model after Hall (1978) showing foliation patterns in the Rocche Rosse rhyolite flow (Lipari).

AMS data of the flow's surface showing sub-vertical foliation planes.

The plug

The plug is the dominant facies, making ~85 % of the flow's thickness. There is chemical variation from the bottom (62.5 wt% silica) to the top (66.5 %) of the unit. This might be the result of a mixing process between two magmas, as shown by basic enclaves, banded structures and emulsified textures [4]. Lava deformation has created a foliation within the plug, with 5-20 cm thick slabs detaching from the cliff due to weathering.

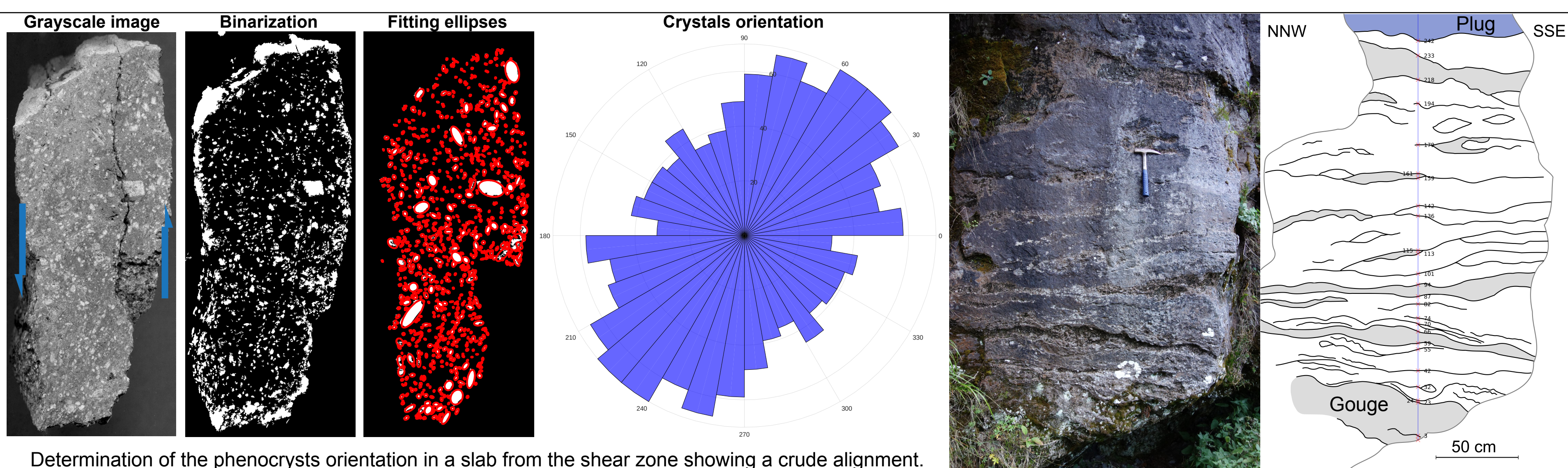


AMS data of the base of the plug showing the magnetic foliation beginning to bend upwards with a ~30° dip.

Detail of the vertical foliation.

The shear zone

The shear zone is 2–3 m thick on average, but it almost disappears locally, where the plug is thinner, thus the vertical stress less intense. The frequency of shear planes tends to decrease from the base to the top of the zone.

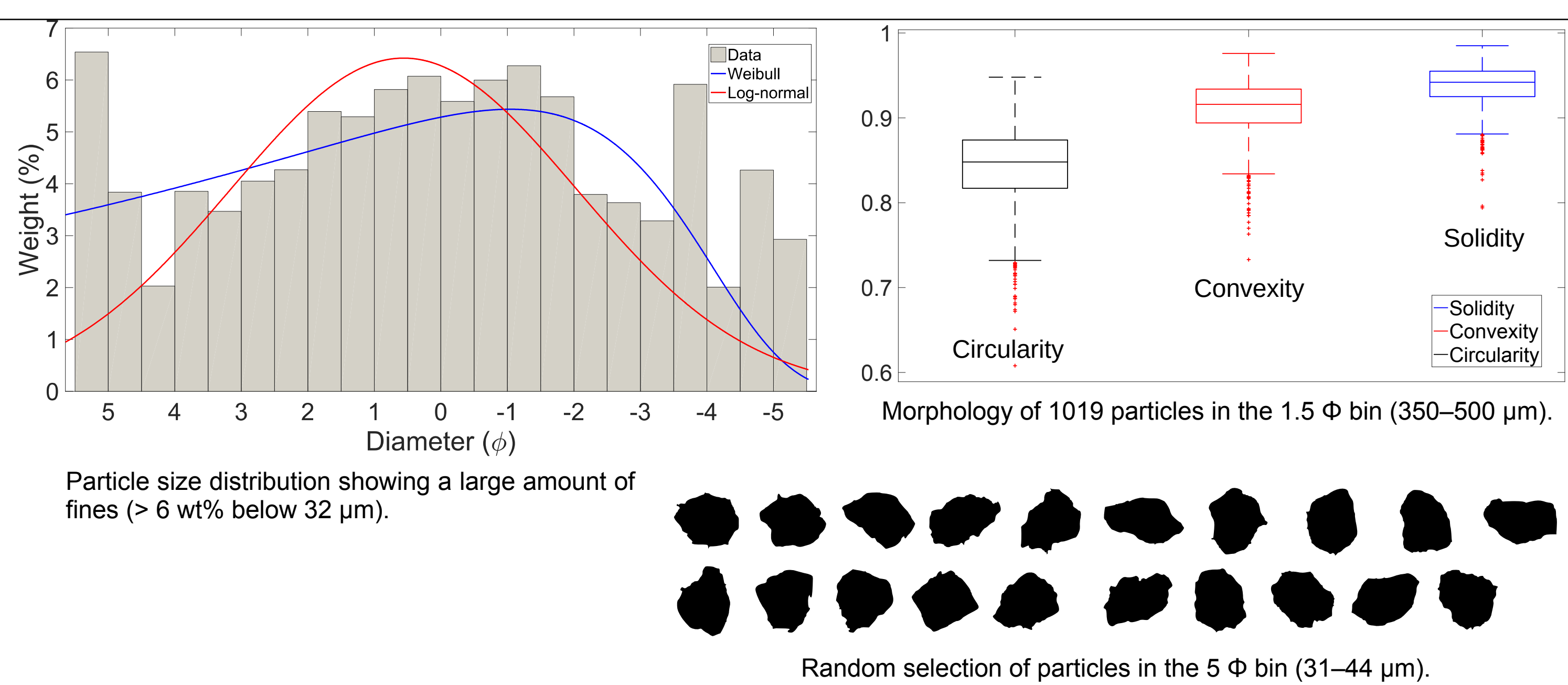


Determination of the phenocrysts orientation in a slab from the shear zone showing a crude alignment.

Measurements of shear planes frequency showing a decrease going upward: one plane every ~7 cm in the lower half, one every ~14 cm in the upper half.

The breccia

Pockets of breccia intermittently crop out at the base of the flow. The contact with the ground is never visible, covered by rubble, but some outcrops expose up to ~3 m of thickness. The breccia is composed by centimetric to decimetric blocks surrounded by a dominant, powdery, grey matrix. Its particle size distribution, particle morphology and componentry all converge towards the hypothesis that the breccia was formed by grinding of the lava under its own weight.



Particle size distribution showing a large amount of fines (> 6 wt% below 32 μm).

Morphology of 1019 particles in the 1.5 Φ bin (350–500 μm).

Random selection of particles in the 5 Φ bin (31–44 μm).

Conclusion

We analyzed the four facies of a thick trachyte flow to infer its emplacement dynamics. We found that its emplacement was driven by deformation, with a solid plug “sliding” over a shear zone and basal breccia, which accommodated most of the stress. The speed and timescale of emplacement, a crucial parameter for hazard assessment, remains unknown. **This study stresses the need to build new emplacement models for silicic lava flows.**

References

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