

Large-scale destabilization of a basaltic shield volcano (Piton des Neiges volcano, La Réunion Island)

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Piton des Neiges is a highly extinct shield volcano eroded by three deep depressions (Cirques) surrounding the summit of the edifice. Within the Cirques are exposed old basic products from the volcano shield building stage (>2,1Ma – 430 ka). We carried out a structural investigation in the basic deposits of the Cirque of Cilaos (south of Piton des Neiges summit) to constrain the destabilization processes that affected the edifice during its early aerial phase of construction.

The internal structure of the cirque of Cilaos is made of piled basic lava flows and breccias, capped by lavas from the differentiated stage (< 350 ka). The breccias mainly consist in debris avalanche deposits and debris flows containing only basic elements. Two kinds of debris avalanche breccias can be distinguished: the “lower” breccia, with a consolidated green-dark matrix, is widely zeolitised, chloritized and serpentinized and is crosscut by many intrusions (dikes and sills). The “upper” breccia presents a light brown zeolitized matrix, poorly consolidated and poorly intruded. Both avalanches display jigsaw-cracked blocks, up to a few tens of meters in diameter.

Several evidences of brittle deformation (faults and/or intrusions) were recorded within the breccias and the basic lava flows. Paleo-stresses reconstructed from deformation data allow the recognition of two successive episodes of deformation (Figure 1):

- The first, older step of deformation is extensional with a minimum principal stress σ_3 oriented N-S. It is recorded within the “lower” breccia and the underlying zeolitized lava flows which are assumed to be the oldest formations of the Cirque.
- The second, later step of deformation is extensional with σ_3 oriented NW-SE. It is widely expressed in all basaltic formations (lavas and breccias) of the Cirque. It is coeval with strike-slip faulting whose minimum principal stress is also oriented NW-SE. Shear structures and beddings dips within the breccia suggest a runout toward the NW. Intrusions from the basic stage, striking N20-N40 and dipping NW, are also consistent with a flank destabilization toward the NW.

These results in Cilaos show that the dismantling of Piton des Neiges volcano is the consequence of both slow and rapid destabilizations that occurred in at least two episodes:

- (1) a N-S destabilization during the initial eruptive history of the volcano, whose related deposits, zeolitized and chloritized, are still visible at the bottom of the Cirque, in riverbeds.
- (2) a NW rapid collapse producing debris avalanche deposits (that currently cover the main part of the Cirque of Cilaos), accompanied by slow internal deformation that affected the whole stratigraphic sequence.

The temporal evolution of the stress fields recorded in Cilaos can also be observed north of Piton des Neiges, in the Cirque of Salazie. A recent study within debris avalanche deposits attests that the northern flank of the edifice was affected by an extensional deformation (rapid failure combined with slow deformation) in a N-S direction (Famin and Michon, 2010). New deformation data, collected in overlying pahoehoe lava flows (in the northern scarp of the Cirque of Salazie), evidence that this flank undergone a later stage of slow internal deformation in a NW-SE direction.

The combined study of cirques of Cilaos and Salazie reveals that (1) dismantling events on Piton des Neiges volcano are characterized by the combination of episodic catastrophic flank collapses and slow deformation, (2) the stress field evolved from a N-S- to a NW-SE-oriented extension during the shield building stage, perhaps as a consequence of the nearby growth of the Alizés or and/or Piton de la Fournaise volcanoes, and (3) this evolution was a large-scale process that affected the whole edifice.

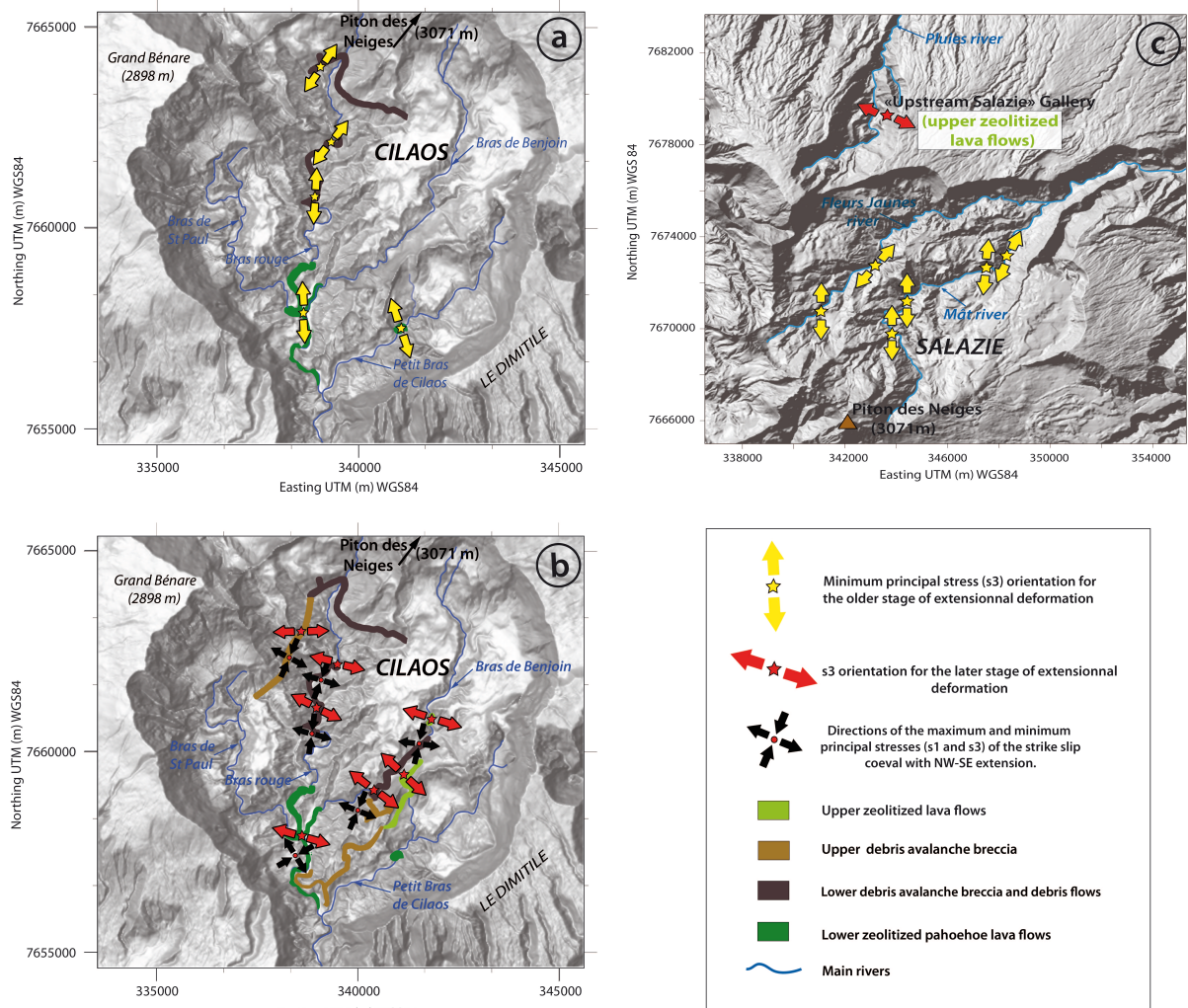


Fig. 1: Successive steps of destabilization of the southwestern and northern flanks of Piton des Neiges volcano, inferred from microstructural studies. a. Older phase of deformation oriented N-S in the Cirque of Cilaos. b. Later phase of deformation oriented NW-SE in the Cirque of Cilaos and coeval with strike-slip faulting. c. Similar N-S to NW-SE stress field evolution in the cirque of Salazie (modified from Famin and Michon, 2010).

- 1 Famin, V. & Michon, L. Volcano destabilization by magma injections in a detachment. *Geology* **38**, 219-222 (2010).