How do cirques form in ocean island volcanoes: the case of Piton des Neiges (Reunion island, Indian Ocean)

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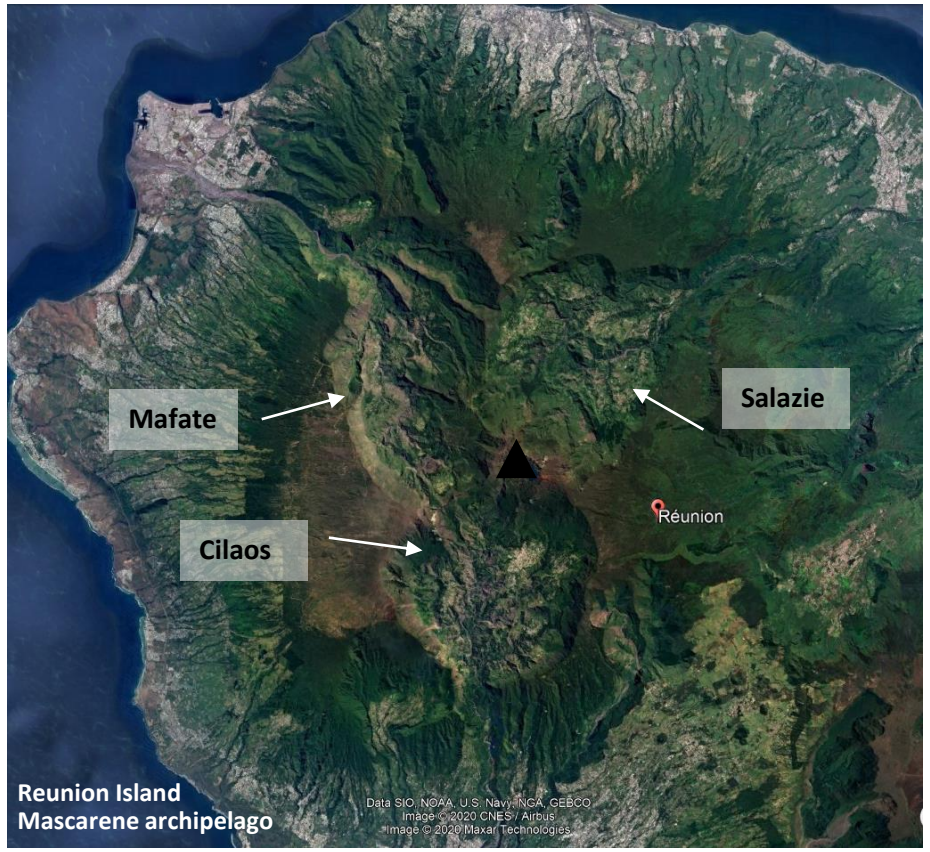
How to explain these volcanics geomorphologies ?



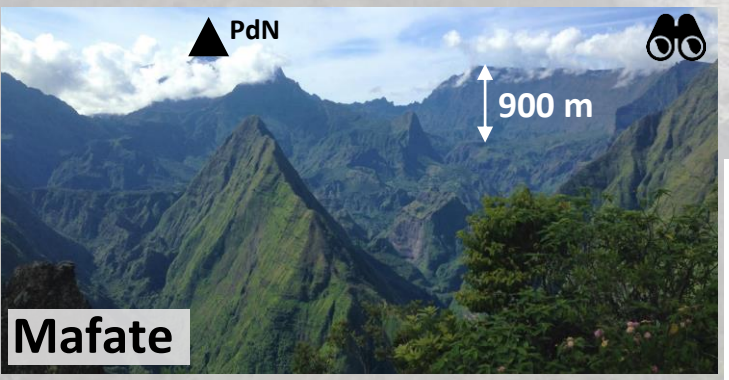
Cirques morphologies in many islands…
(barrancos, amphitheater-headed valley, erosive caldera …)

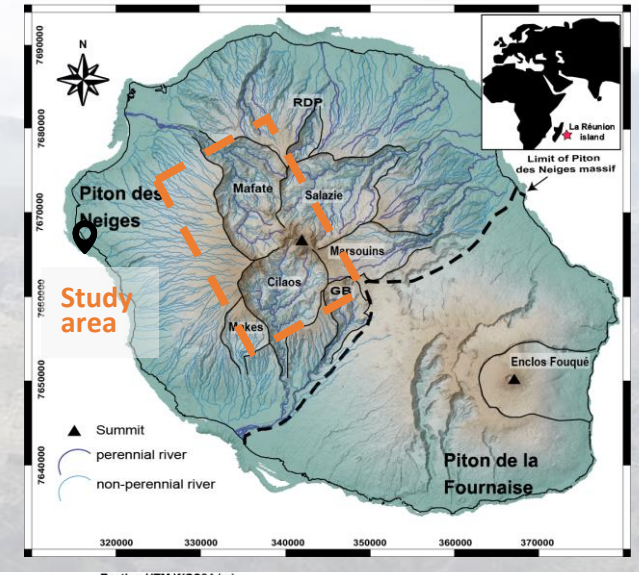
Reverted funnel-shapes are observed on many volcanic islands worldwide.

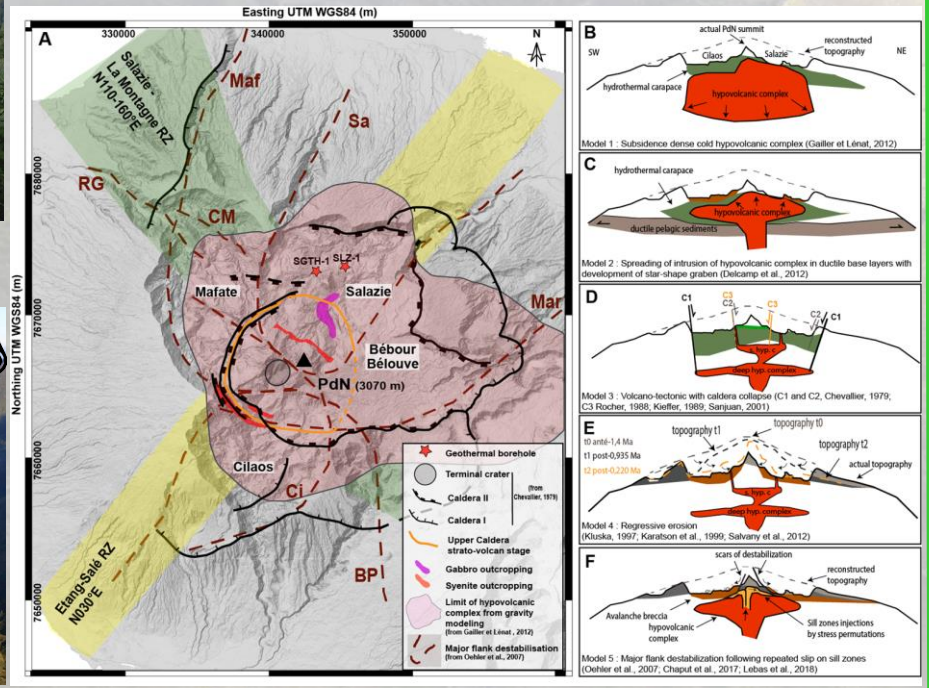
- → **These geomorphic structures have been interpreted in many ways and have been subject of a long debate.**
- → **(1) Erosion by large landslides or classic regressive erosion (Colmenero et al., 2012; Lomoschitz et al., 2002; Masson, 1996 ; Salvany et al., 2012 ; Palacios, 1994) ; (2) volcano-tectonic control: caldera, rift zone, spreading (Mathewson, 1970 ; Delcamp et al., 2012 ; Borgia et al. 2000 ; Carracedo, 1994 ; Hildenbrand et al. 2008)**
- → **Review and classification : Karatson et al., 1999**

→ **So, what kind of model could be proposed for Reunion Island ?**

Case study







What is the focus of the study ?

The oldest and highly eroded volcano of Reunion island : **Piton des Neiges**

Cirques? What are their features ?

Cirques = large **watersheds** of Piton des Neiges (Mafate, Salazie, Cilaos) each of which is drained by a perennial river. They are in **the inner part of the edifice** around the summit (3070 m).

Cirques = a geomorphological structure with a **reverted funnel-shape**, a basal floor with irregular topography bounded by large rock scarps.

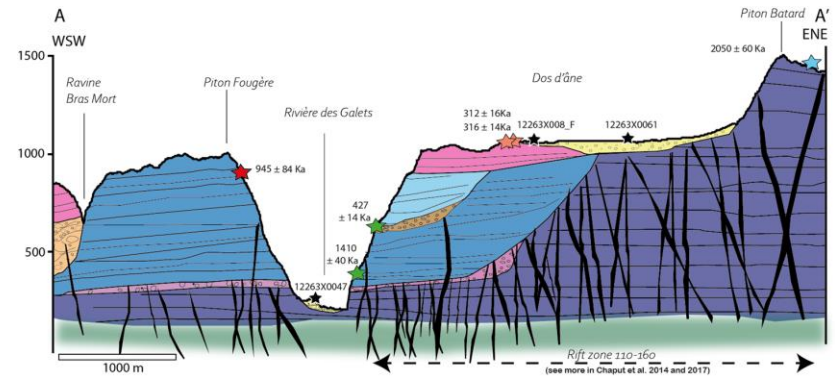
Previous works in Reunion Island
→ lots of models
→ NO CONSENSUS

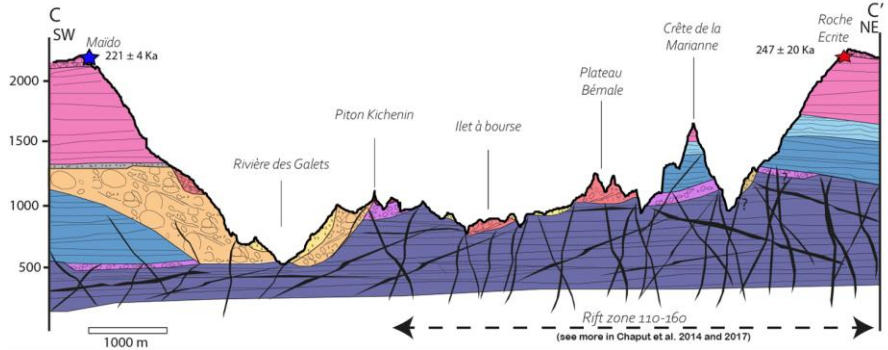
How to answer ?

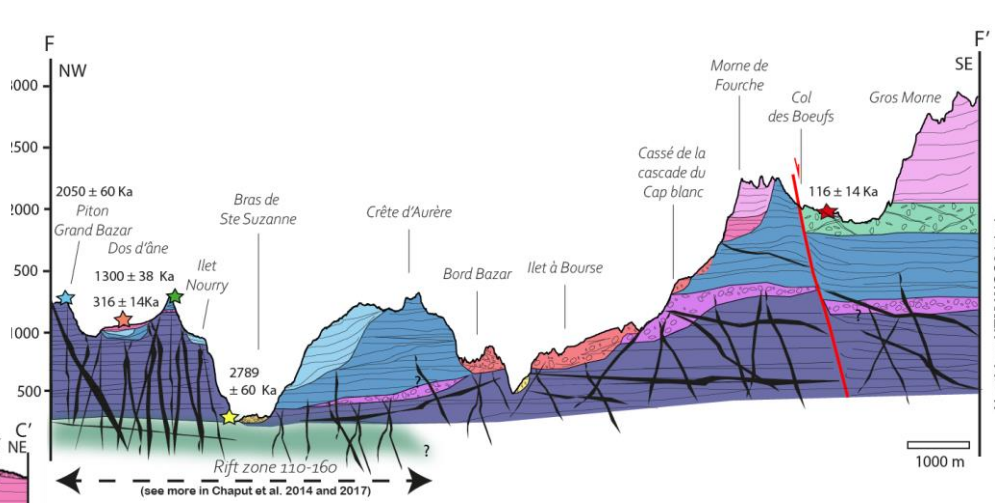
Geological mapping | Detailed field surveys

Aerial photogrammetric acquisition

Mafate





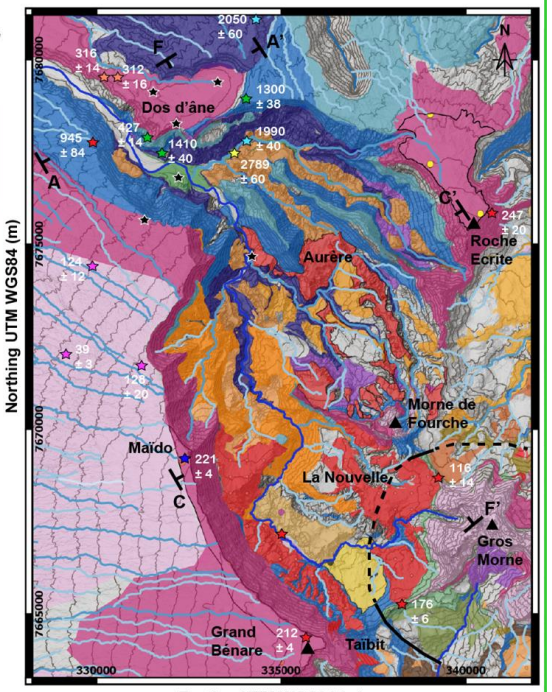


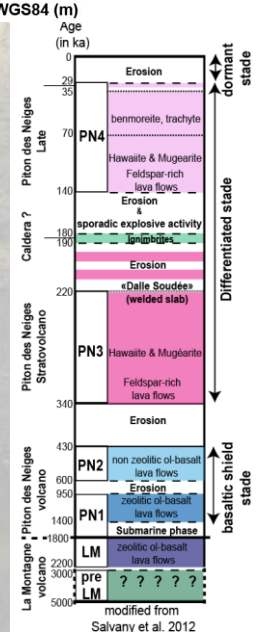
differenciated lava flows PN4
dépôt de la dalle soudée PN3
differenciated lava flows PN3

non-zeolitic ol-basalt lava flows - PN2
zeolitic ol-basalt lava flows PN1
zeolitic ol-basalt lava flows hightly intruded - LM
volcanic breccia pre - LM ?

breccias from rework and actual landslides chaotic and «powdered» basic breccias filling the current valleys
«Kerval» ignimbrite
debris avalanche deposits basic and differenciated breccias Aurère / Tamarins-Kerval
«Les Orangers» debris avalanche deposits basic breccias
debris avalanche deposits basic breccias inter LM-PN1
boreholes

Kluska, 1997
Salvany, 2009
Gillot et Nativel, 1982
Quidelleur et al., 2010
Famin, 2019
Kieffer et al., 1993
Deniel et al., 1992





Northern & Eastern parts : no breccia

- Enclosed scarps = lava shield building
- No vertical movement but rift zone influence
- Very few and no large breccias deposits
- Paleo-valley & classic regressive erosion pattern & relief inversion

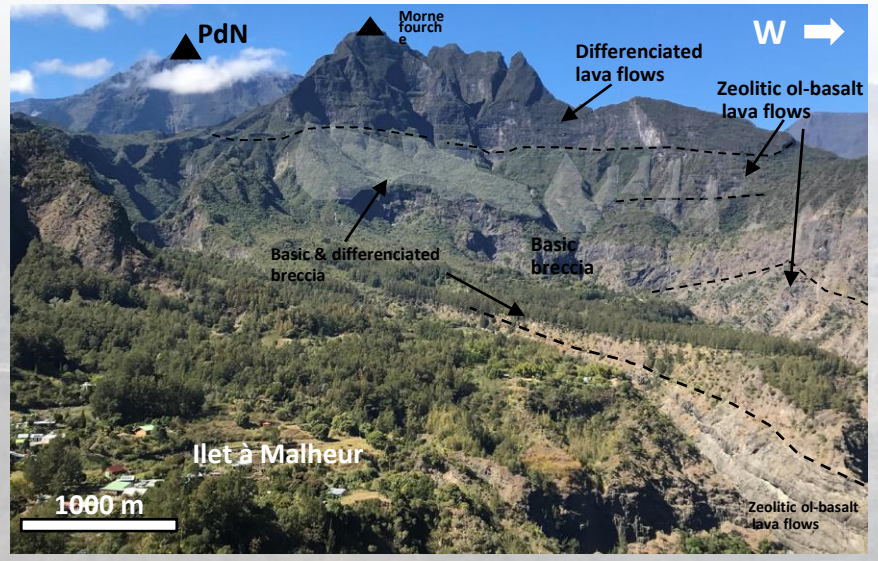
Southern & Western parts : large volcaniclastic breccias

- Large Orangers breccia deposit = volcaniclastic breccias filling
- horseshoe-shaped depression opened to the NW
- No vertical movement
- Geomorphology of this part is more flat and recurrent landslides occured

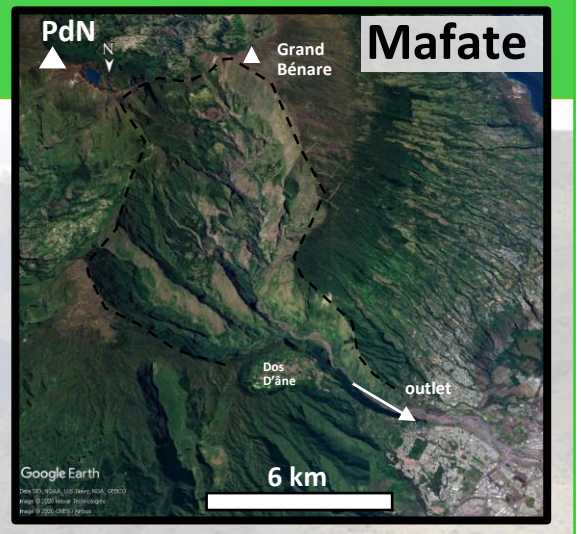
Caldera influence only in the southernmost inner part

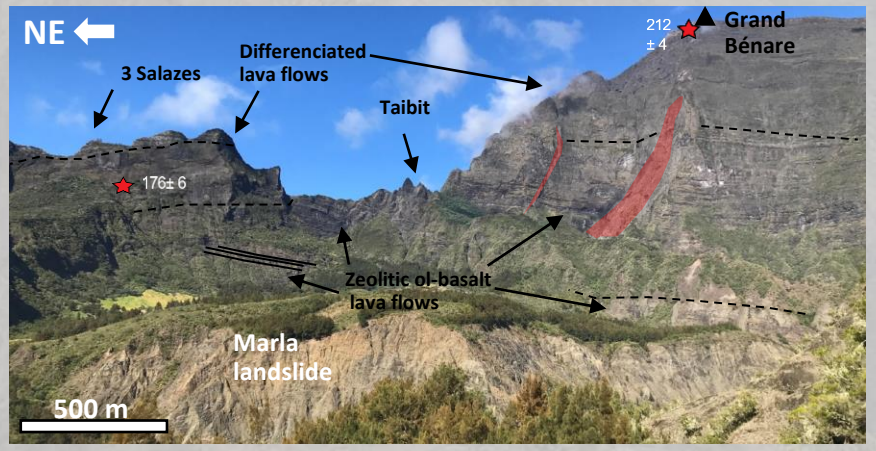
- Vertical movement (normal fault) & ignimbritic deposit
- No faults from basaltic stage caldera

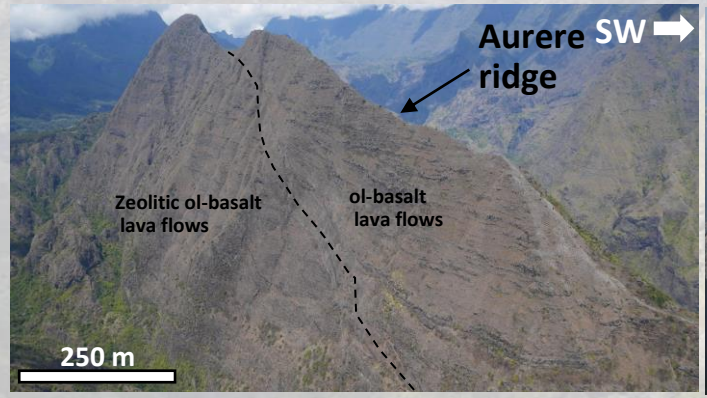
Mafate

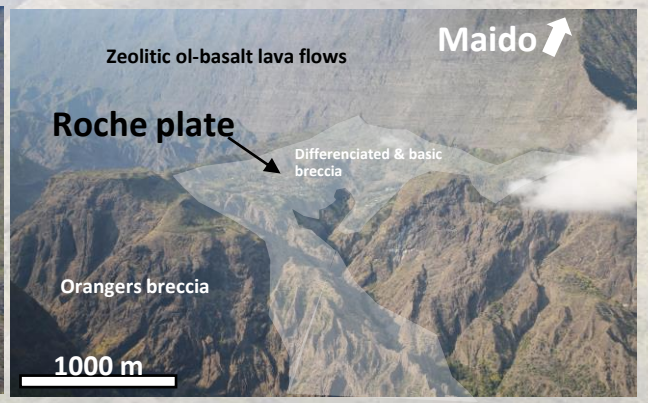

PdN
Morne fourche
W
Differenciated lava flows
Zeolitic ol-basalt lava flows
Basic & differenciated breccia
Basic breccia
Ilet à Malheur
1000 m
Zeolitic ol-basalt lava flows

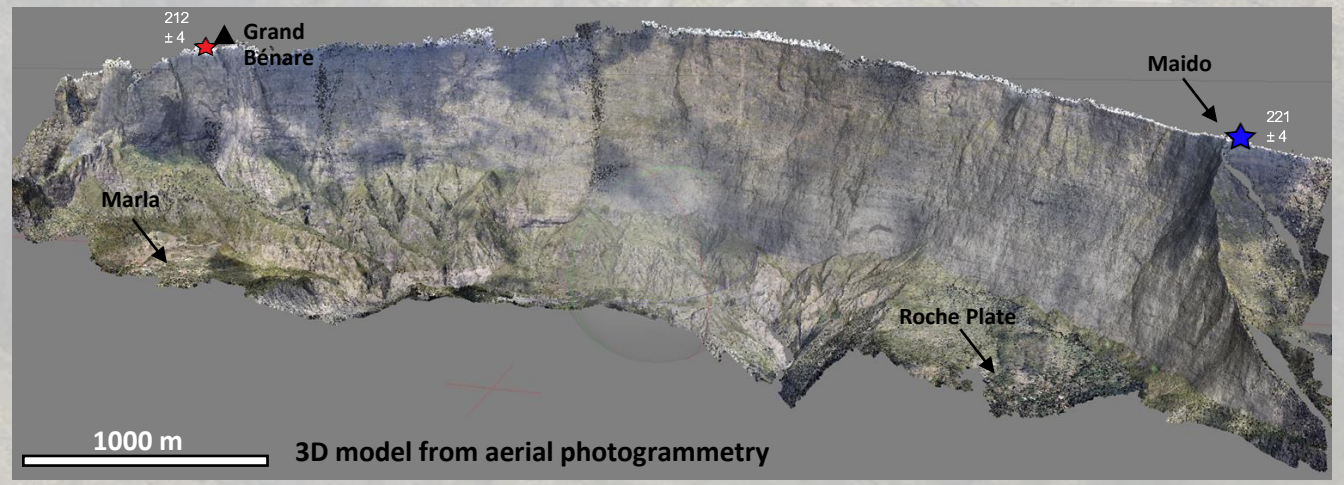

1300 ± 38
Poorly intruded lava flows
NE
Poorly intruded lava flows
Highly intruded lava flows
Rift zone N120-140°E
500 m
(from Chaput et al., 2014)


PdN
N
Grand Bénare
Mafate
Dos D'âne
outlet
Google Earth
6 km

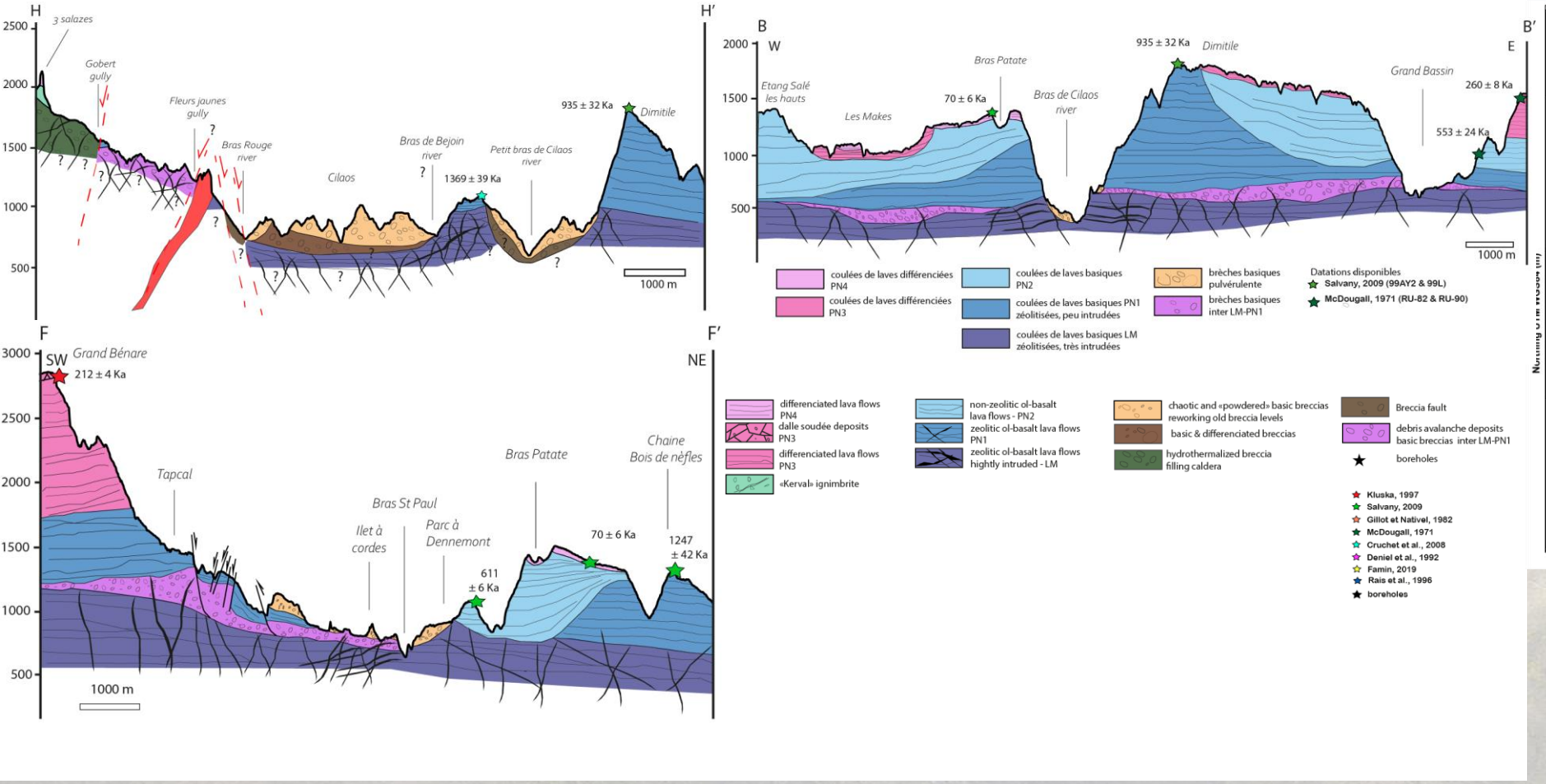

NE
212 ± 4
Grand Bénare
3 Salazes
Differenciated lava flows
Taibit
176± 6
Zeolitic ol-basalt lava flows
Marla landslide
500 m

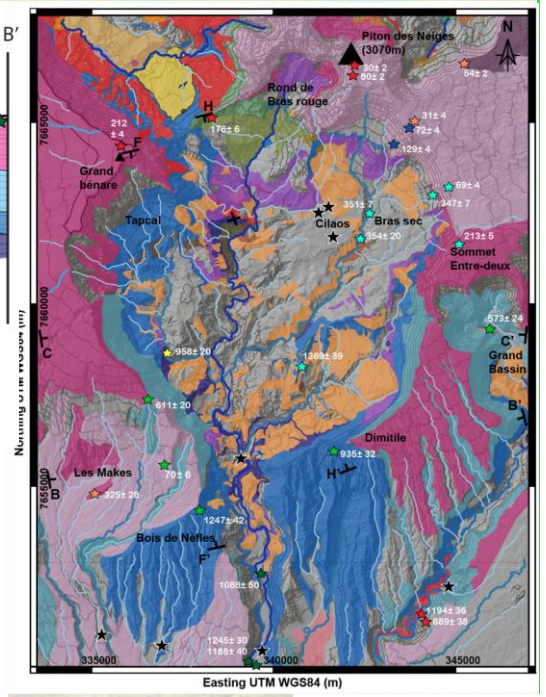

Aurere ridge
SW
Zeolitic ol-basalt lava flows
ol-basalt lava flows
250 m

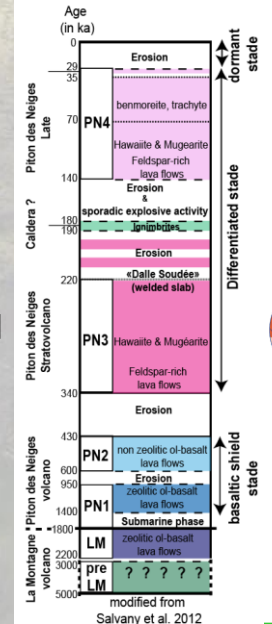

Zeolitic ol-basalt lava flows
Maido
Roche plate
Differenciated & basic breccia
Orangers breccia
1000 m


212 ± 4
Grand Bénare
Maido
221 ± 4
Marla
Roche Plate
1000 m
3D model from aerial photogrammetry

Cilaos







Southern & Western parts :

- Enclosed scarps = lava shield building
- No vertical movement in the scarps
- Breccias deposits
- Paleo-valley in flank and in scarps of the cirque filled by lava flows

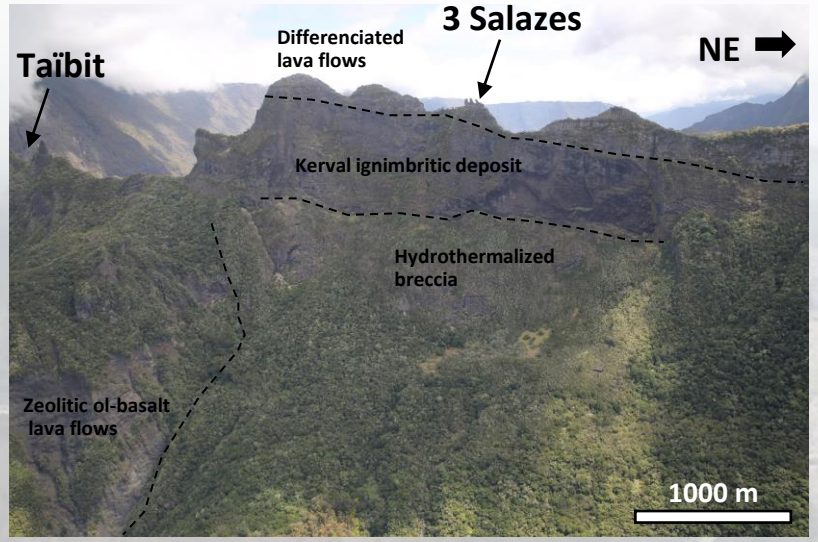
The inner part : large volcaniclastic breccias

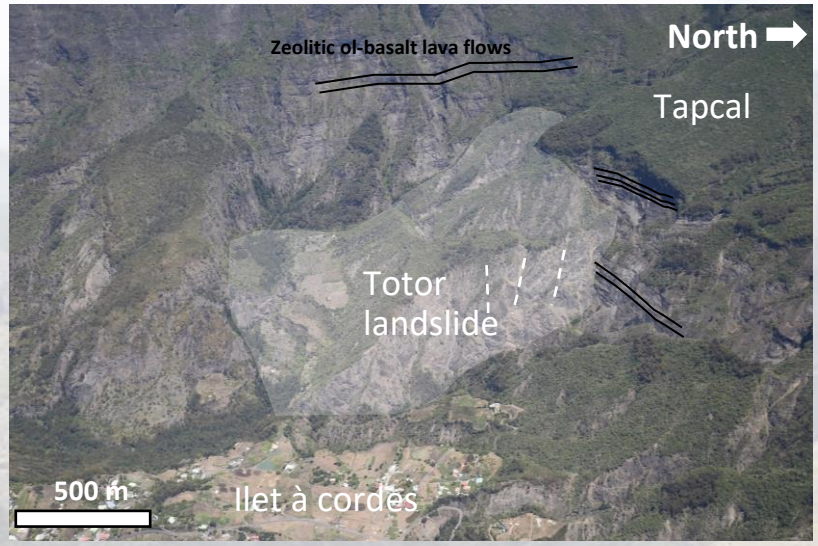
- Large breccia deposits = volcaniclastic breccias filling (intra-caldera breccias and volcaniclastic breccias)
- Vertical movement in the inner part
- Close to the actual cirque walls no vertical movement but landslides occur

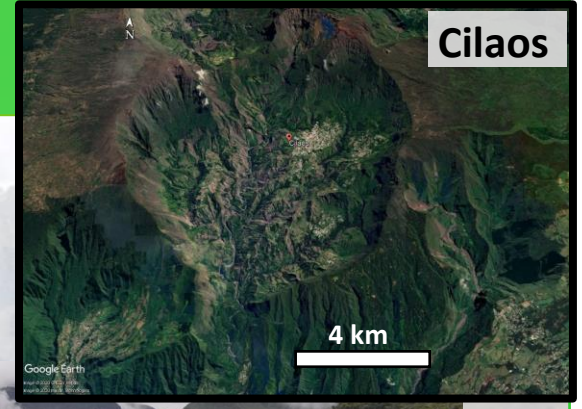
Caldera influence only in inner part

- Vertical movement (normal fault) & ignimbritic deposit & hydrothermalized breccia

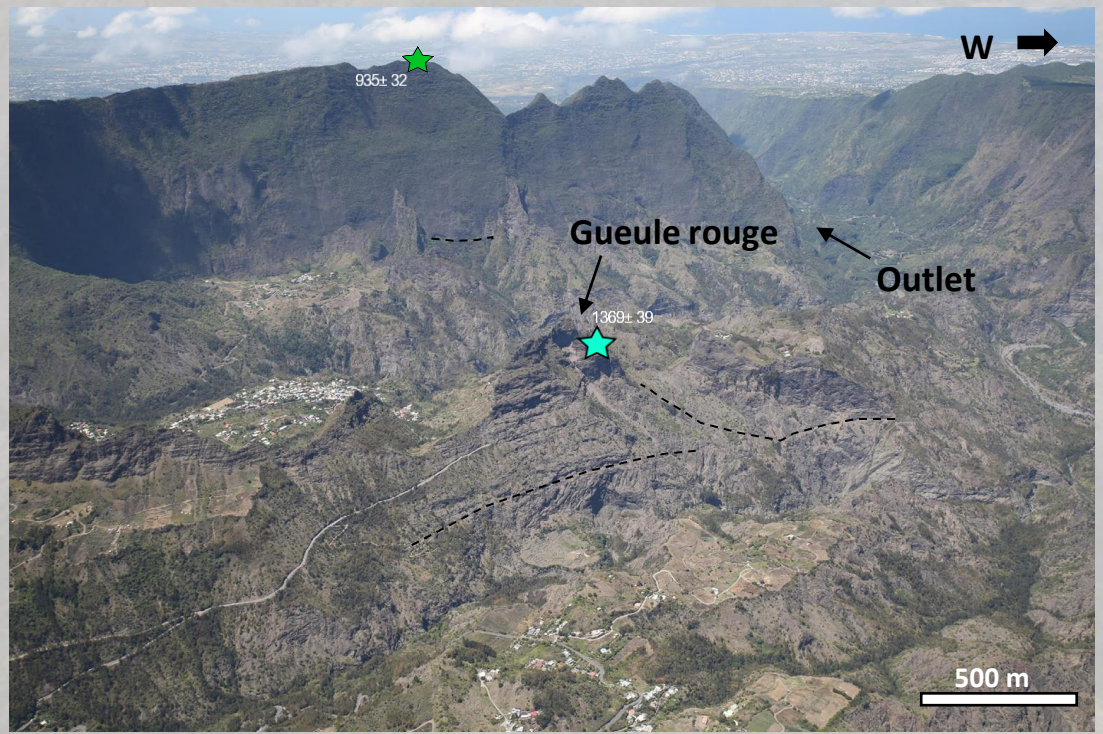
Cilaos

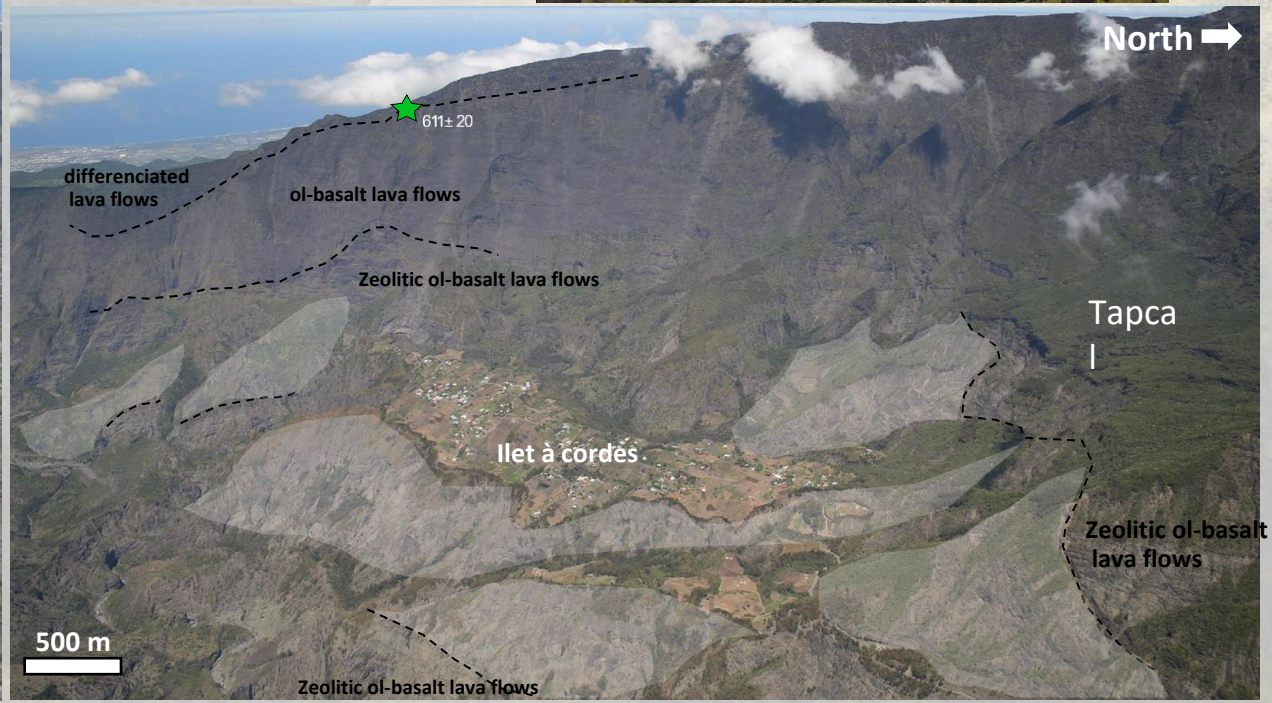

Taïbit
Differenciated lava flows
3 Salazes
NE
Kerval ignimbritic deposit
Hydrothermalized breccia
Zeolitic ol-basalt lava flows
1000 m


Zeolitic ol-basalt lava flows
North
Tapcal
Totor landslide
500 m
Ilet à cordes


Cilaos
4 km


East
La chapelle
syenite
breccia
breccia
100 m


W
935± 32
Gueule rouge
Outlet
1369± 39
500 m


North
611± 20
differenciated lava flows
ol-basalt lava flows
Zeolitic ol-basalt lava flows
Tapca
l
Ilet à cordes
Zeolitic ol-basalt lava flows
500 m
Zeolitic ol-basalt lava flows

Conclusion

Mafate

- Result 1: NE part of the cirque = no breccia ; Enclosed scarps = lava shield building

→ Normal regressive erosion with paleo-valley and relief inversion

- Result 2: SW part of the cirque = Orangers breccia outcropping (several hundred meters thick). These breccias come from large flank collapse well known and filling a horseshoe-shaped structure opened to the NW.

→ Minor reverted funnel shape and widening in a funnel shape

→ **We interpret the flank collapse and its large deposits of the Orangers breccia (debris avalanche) as playing a major role to enhance erosion and shape the Mafate cirque. This new model is a combined model of Salvany et al. (2012) and Oehler et al. (2008).**

Cilaos

- Result 1: Caldera influences only in the NW part of the cirque, in its inner part.
- Result 2: Volcaniclastic breccias are several hundred meters thick in the inner part of the cirque and thin out toward the outer flanks.
- Result 3: Basal volcaniclastic breccias play a major role in the erosion, by offering a weaker mechanical resistance (ex: Totor landlside).

→ **We interpret basal volcaniclastic breccia (=weak layer) as playing a major role to enhance erosion of Cilaos cirque.**

Reverted funnel shape of the cirques are erosional structures mostly guided by breccias of past dismantling episodes

See more about hydrothermal system and sheet intrusions in Chaput et al., 2017 ; Famin et al. 2016 ; Chaput et al., 2014 ; Famin et Michon, 2010

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