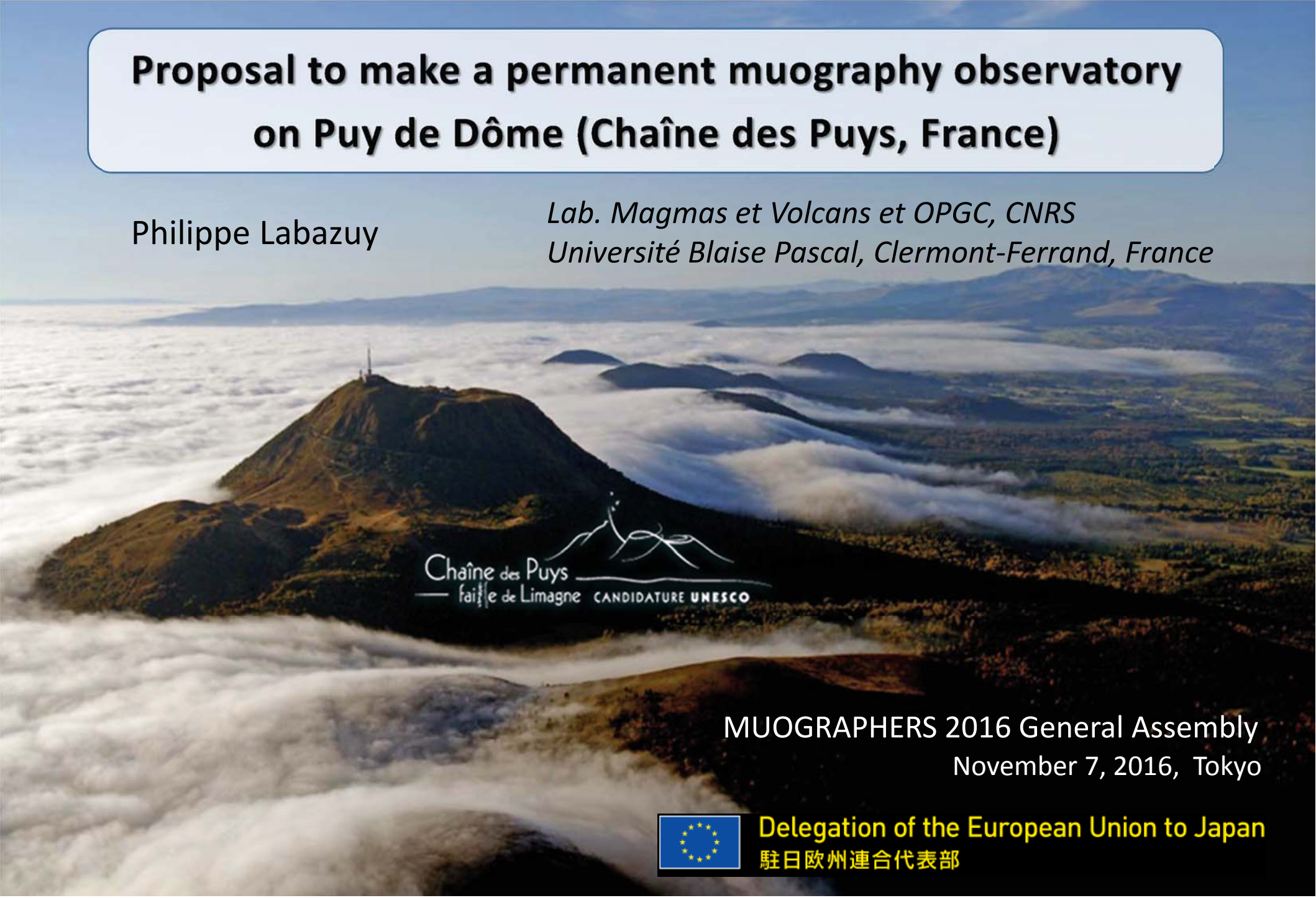
Proposal to make a permanent muography observatory on Puy de Dôme (Chaîne des Puys, France)

Philippe Labazuy

Lab. Magmas et Volcans et OPGC, CNRS
Université Blaise Pascal, Clermont-Ferrand, France



MUOGRAPHERS 2016 General Assembly
November 7, 2016, Tokyo

Delegation of the European Union to Japan
駐日欧州連合代表部

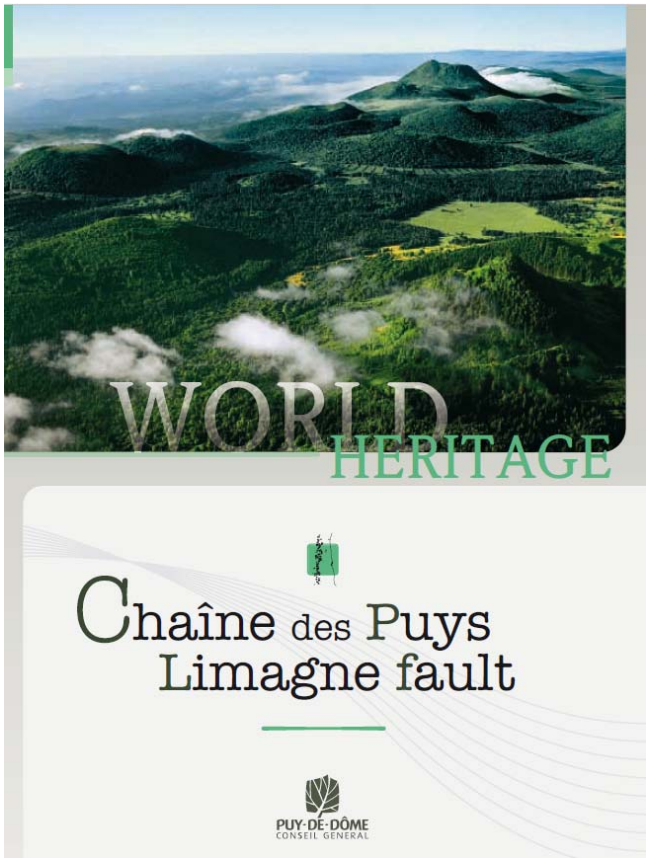
Proposal to make a permanent muography observatory on Puy de Dôme (Chaîne des Puys, France)

- General Framework
- Geological Context
- Geophysics
- Structural model
- Perspectives and issues

Application proposal to the World Heritage List (UNESCO)

Chaîne des Puys and Limagne Fault

A unifying regional project



- Local council of the Puy-de-Dôme,
- Regional Natural Park of the Volcanoes of the Auvergne,
- University of Clermont-Ferrand,
- Local government of the Auvergne region

40 years of collaborative management of this outstanding geological landscape have enabled it to preserve its integrity.

- *1977* : creation of the **Regional Natural Park of the Volcanoes of the Auvergne**
- *2000* : the Chaîne des Puys was added to the national list of the **Natural Monuments and Sites**
- *2008* : status of **GRAND SITE DE FRANCE®**

Main aims of the application to the World Heritage List:

- Make the universal excellence of this site more widely known
- Support and develop national and international scientific research

The Observatoire de Physique du Globe de Clermont-Ferrand (OPGC)

- Observatory of Earth Science (OSU) recognized by the CNRS-INSU and the Blaise Pascal University of Clermont-Ferrand – About 200 people (researchers, technicians, engineers)
- Two research units : the “Laboratoire Magmas et Volcans” (LMV) and the “Laboratoire Météorologie Physique” (LaMP).
- LMV has expertise in the study of magmas and volcanoes, with three research groups: Volcanology; Experimental petrology; Geochemistry

The OPGC chalet at the summit of Puy de Dôme

Monitoring of meteorological and physico-chemical parameters (gases, particles, clouds)

First observatory built in 1876
Major renovation in 2010

Context of the proposal for a permanent muography observatory

➲ Target: Puy de Dôme volcano *(11,000 yrs old)*

- Mature dome not affected by post-eruptive phenomena
- Highly documented through geological studies

➲ Research background

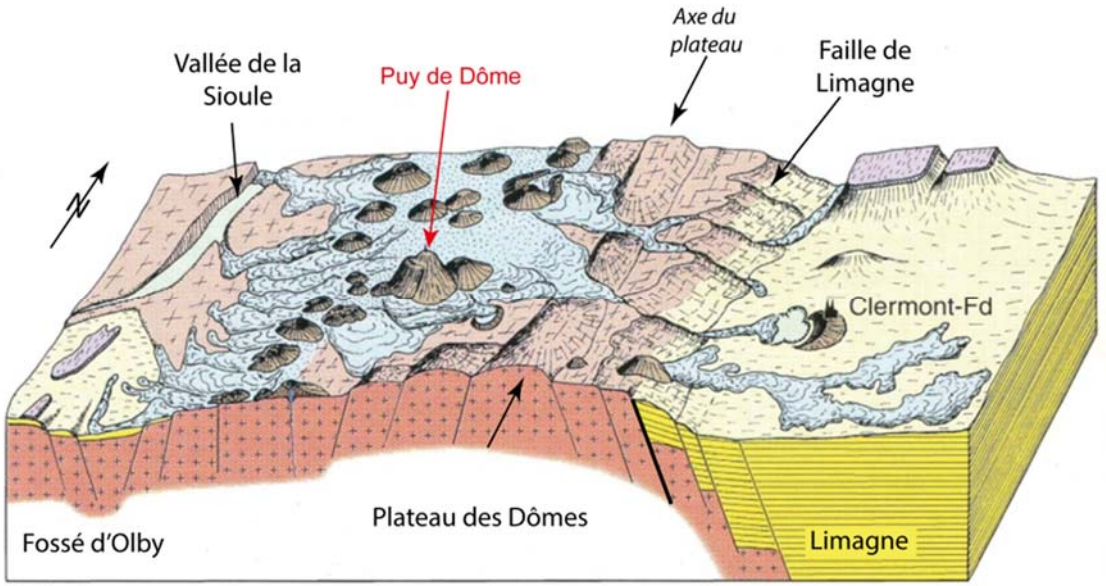
- Morpho-structural analysis of the dome and its environment
- Multi-methods geophysical imagery (resistivity, gravimetry and magnetism)

Existing or planned infrastructures facilities (OPGC)

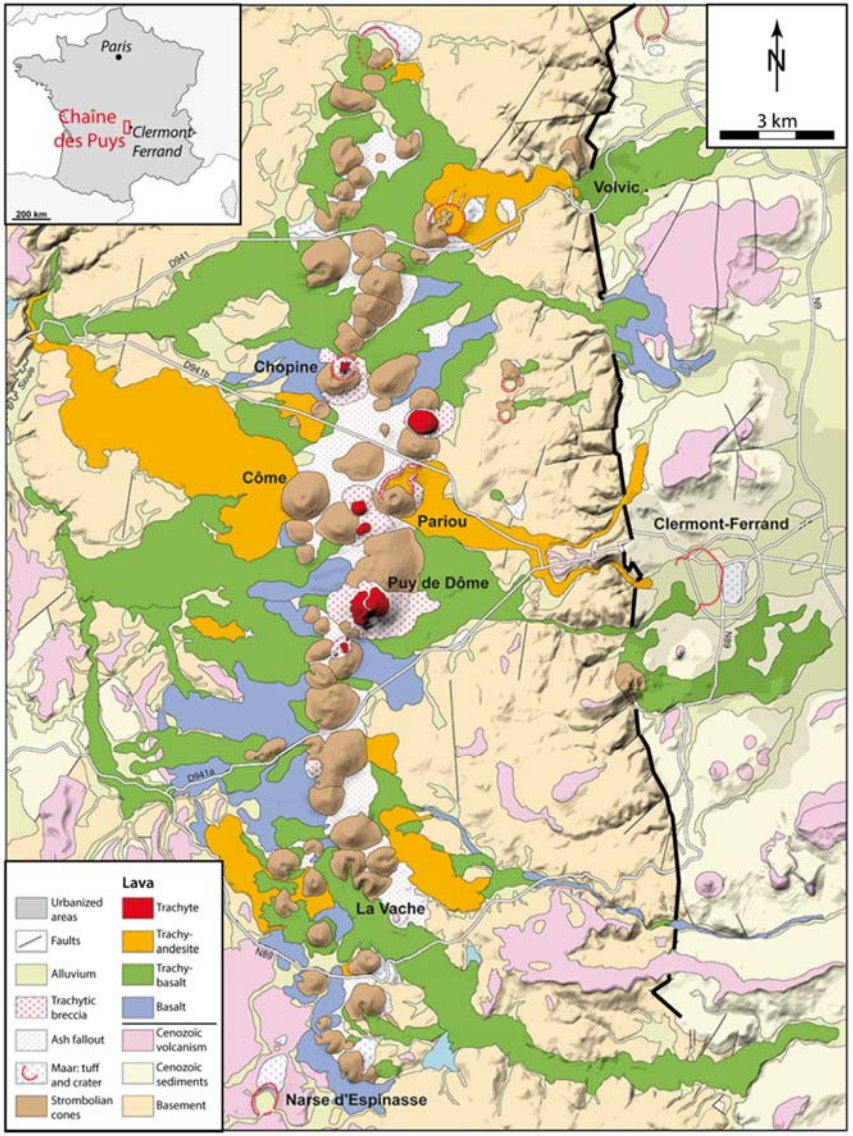
- Access to a detection site located 1. 5km away from the Puy de Dôme volcano
  - *with network connection (Long-range Wifi) and electricity power*
- Access to the Puy de Dôme Observatory (at the summit) with housing facilities, up to 10 persons according to the availability of the infrastructure

The Chaîne des puys volcanic field

- N-S volcanic alignment to the west of the Limagne graben
- 80 - 100 distinct edifices (domes, cones, maars)

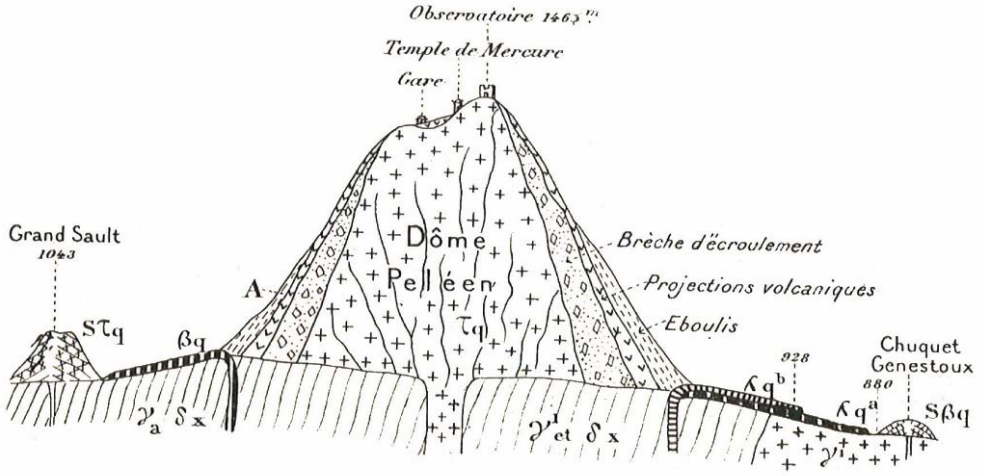


- Eruptive activity: 100,000 to 7,000 years

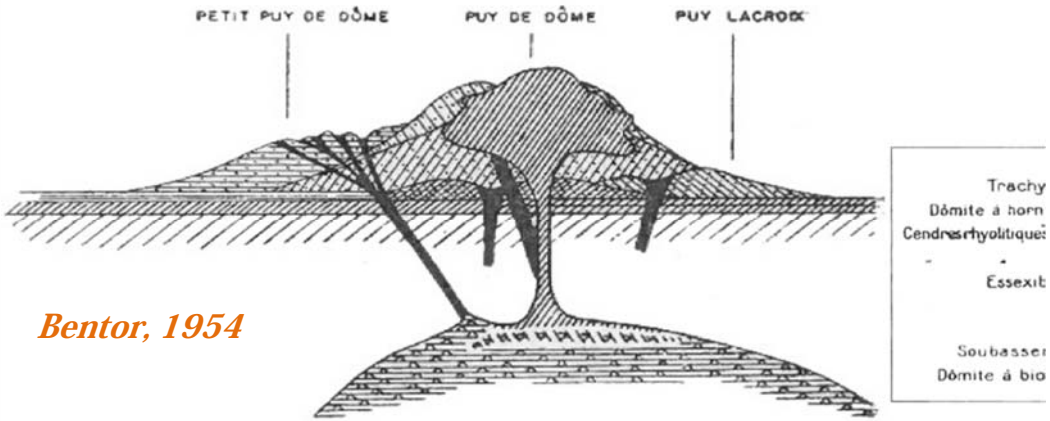


Simplified volcanological map of the Chaîne des Puys (*Boivin et Thouret*, 2014)

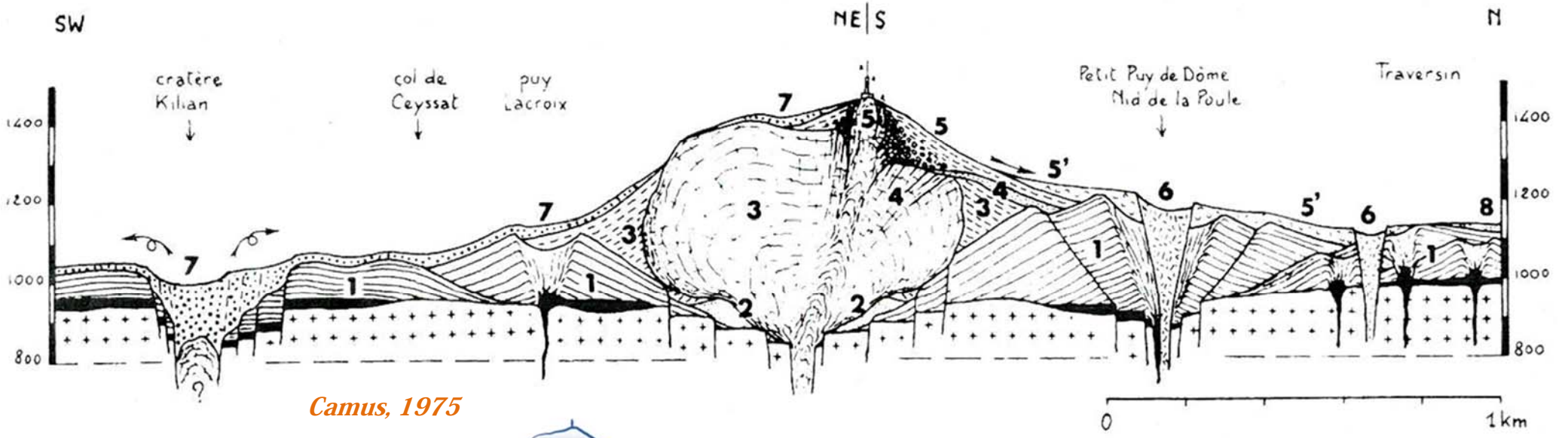
Evolution over time of the geological model of the Puy de Dôme inner structure



Glangeaud, 1913



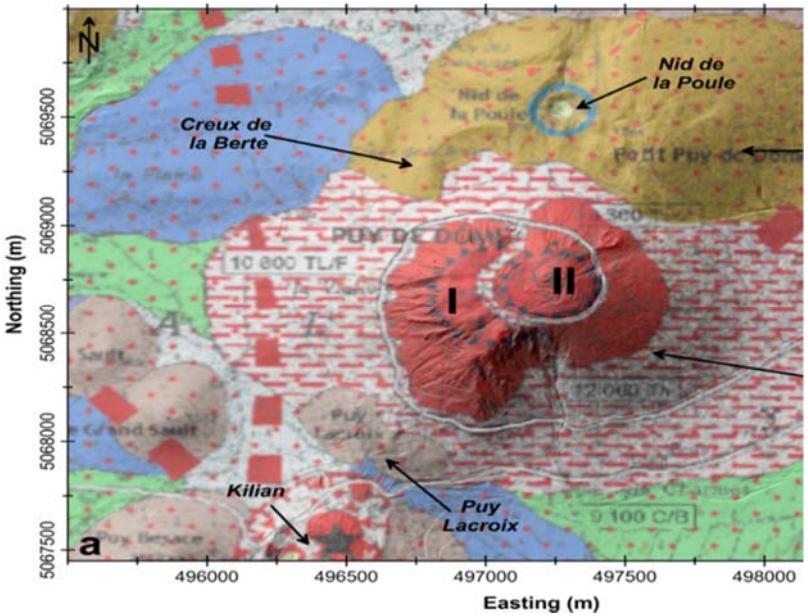
Bentor, 1954



Camus, 1975

The Puy de Dôme volcano

The Puy de Dôme volcano (view from the SE)



Volcanological map (*Boivin et al.*, 2009)

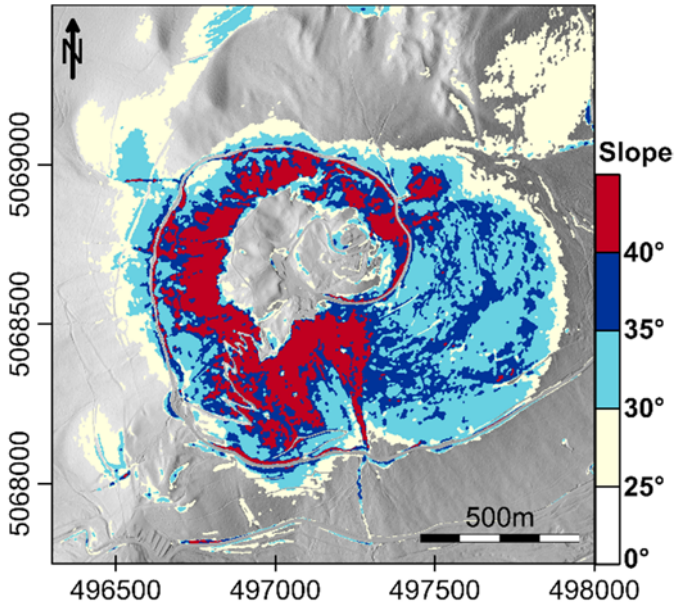
- Trachytic dome (11,000 to 10,700 yrs)
- Surrounded by cinder cones
- Current geological model:
  - *First rough dome (I)*
  - *Collapse*
  - *Second extrusion (II)*
- Intense hydrothermal alteration
  Summit area

Hydrothermal alteration evidences

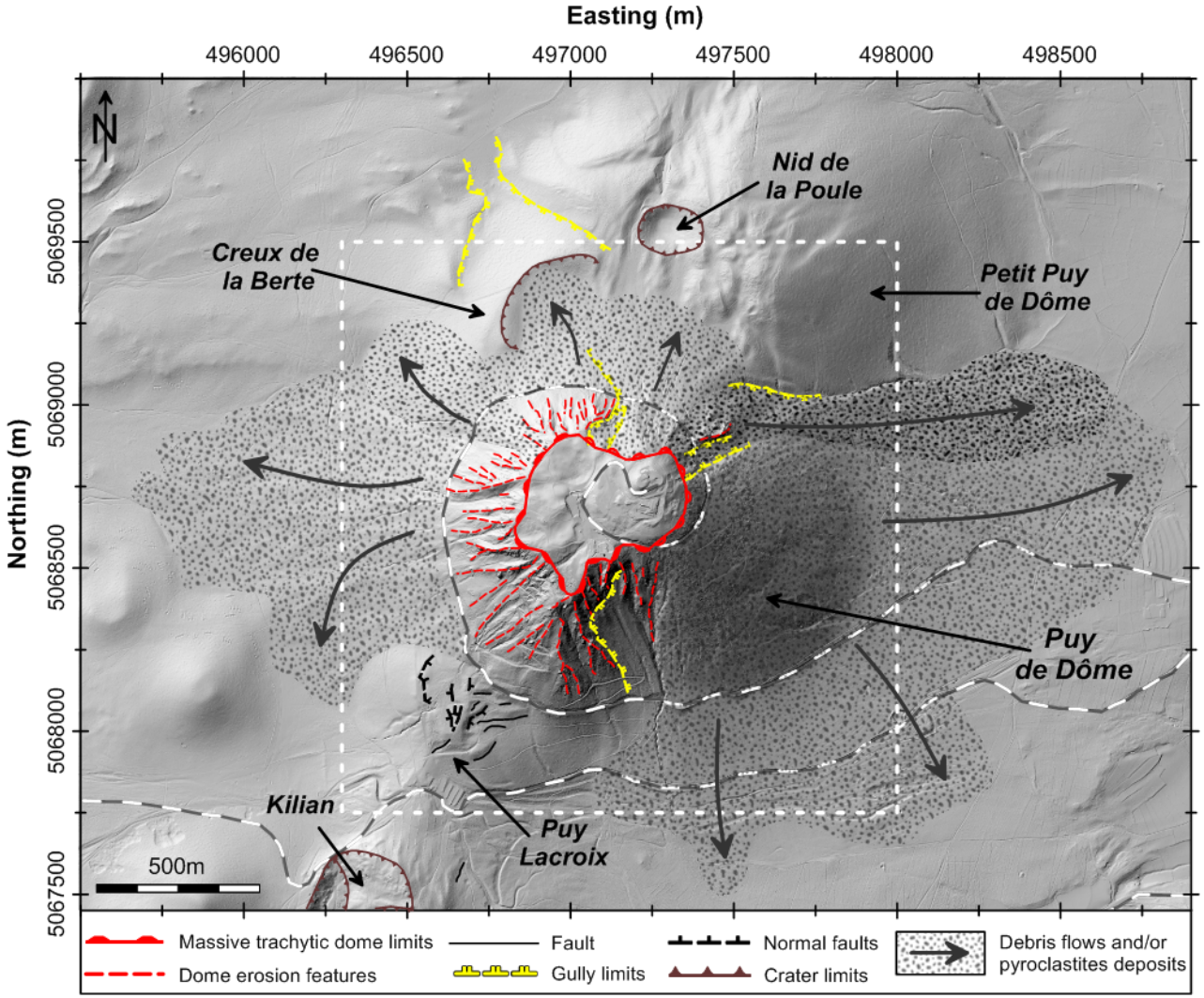
The Puy de Dôme volcano

Two distinct units

(I) Spiky structure, flat summit area
Steep flanks ($> 40^{o}$)



Slopes distribution map



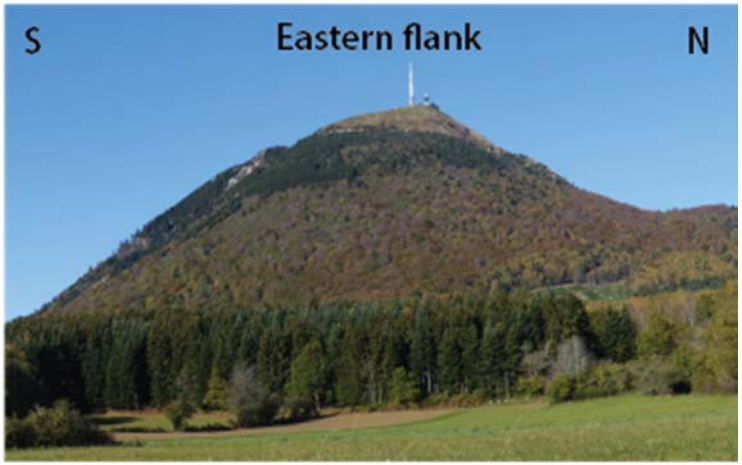
Morpho-structural features on the Puy de Dôme

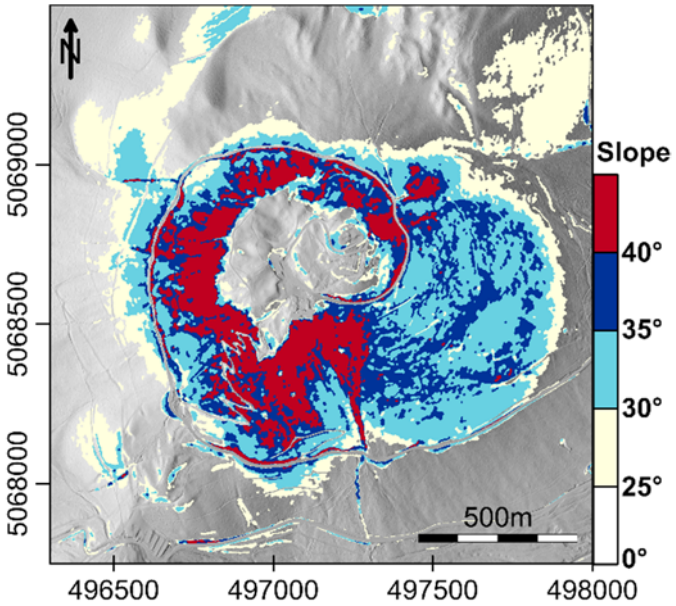
The Puy de Dôme volcano

Two distinct units

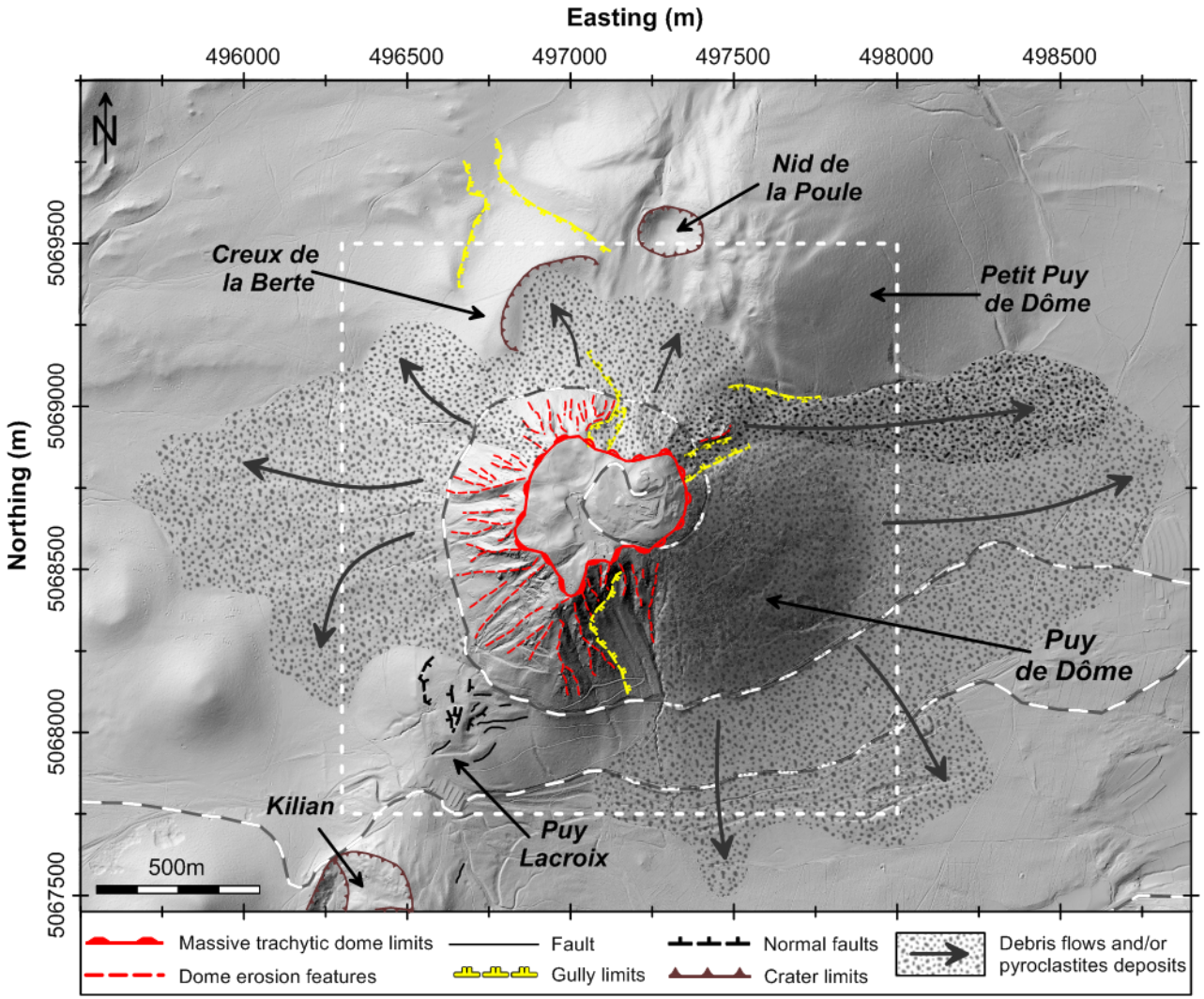
(II) Smooth eastern flank

Steady slope (30 to 40º)



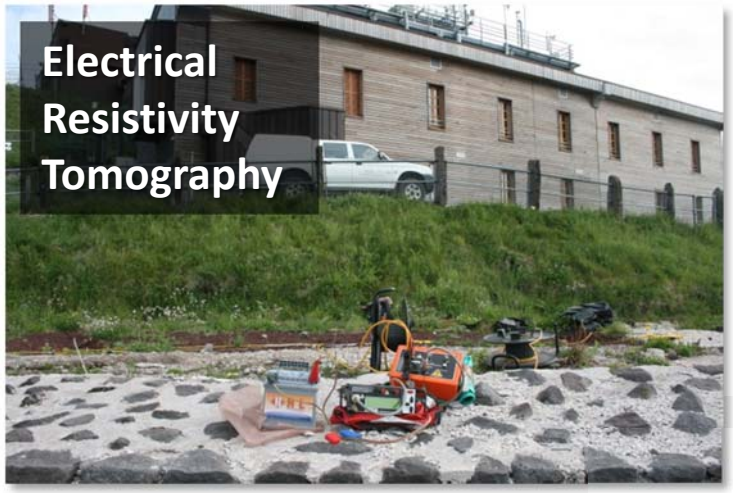


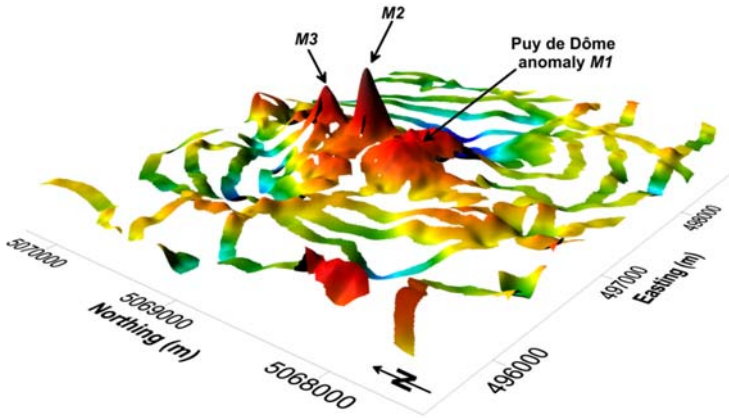
Slopes distribution map



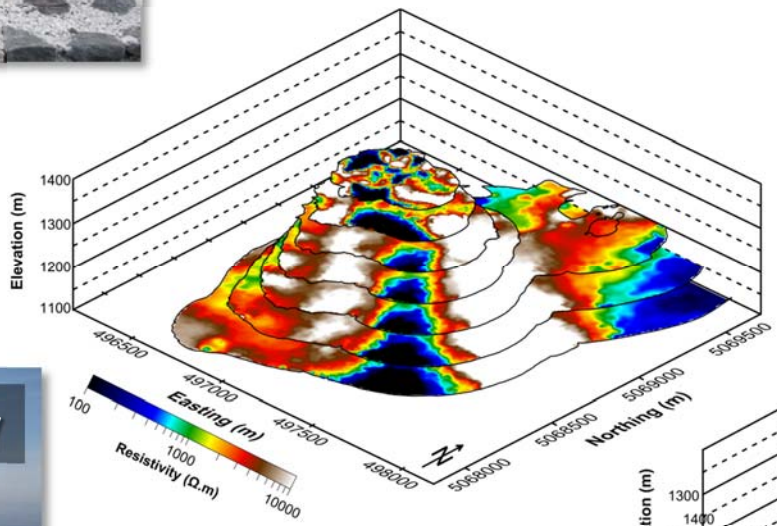
Morpho-structural features on the Puy de Dôme

Geophysical surveys

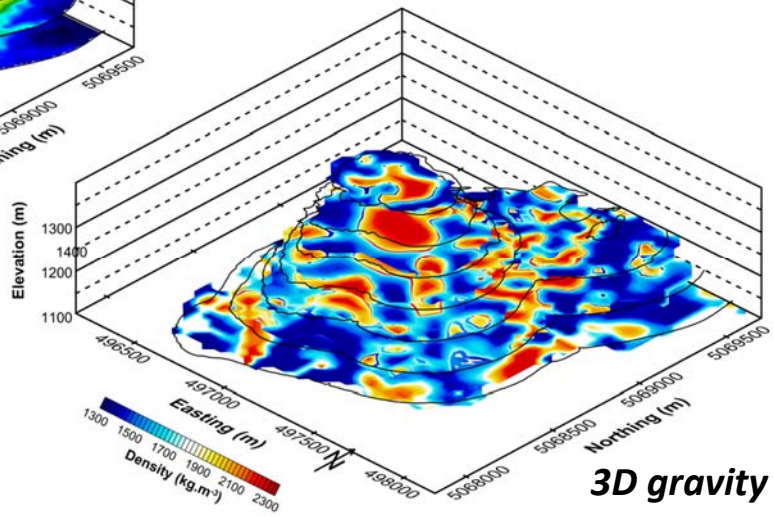




RTP magnetic anomaly map

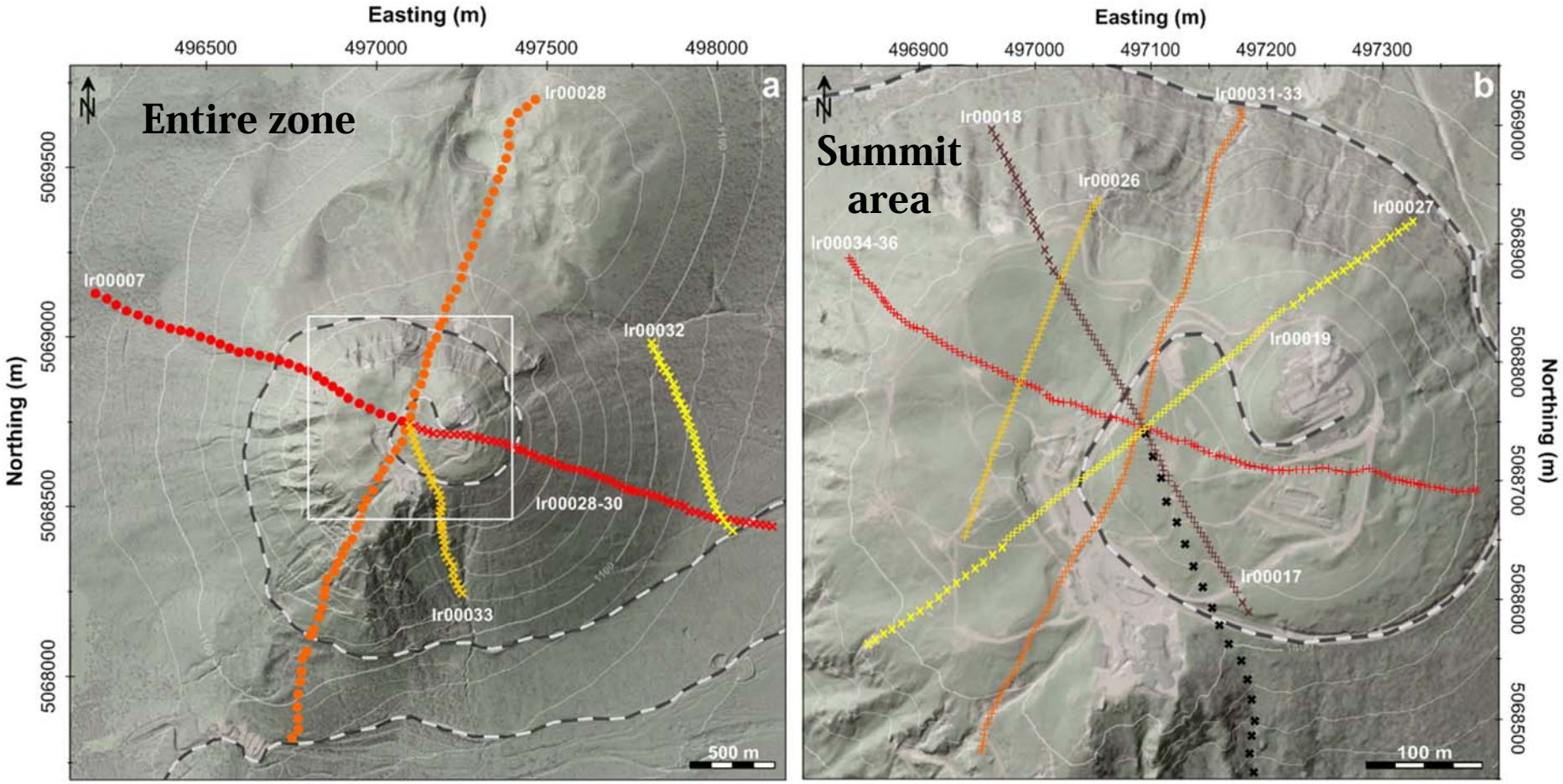


3D ERT inversion model



3D gravity inversion model

Electrical Resistivity Tomography – ERT



Localization of ERT profiles on the Puy de Dôme and its summit area

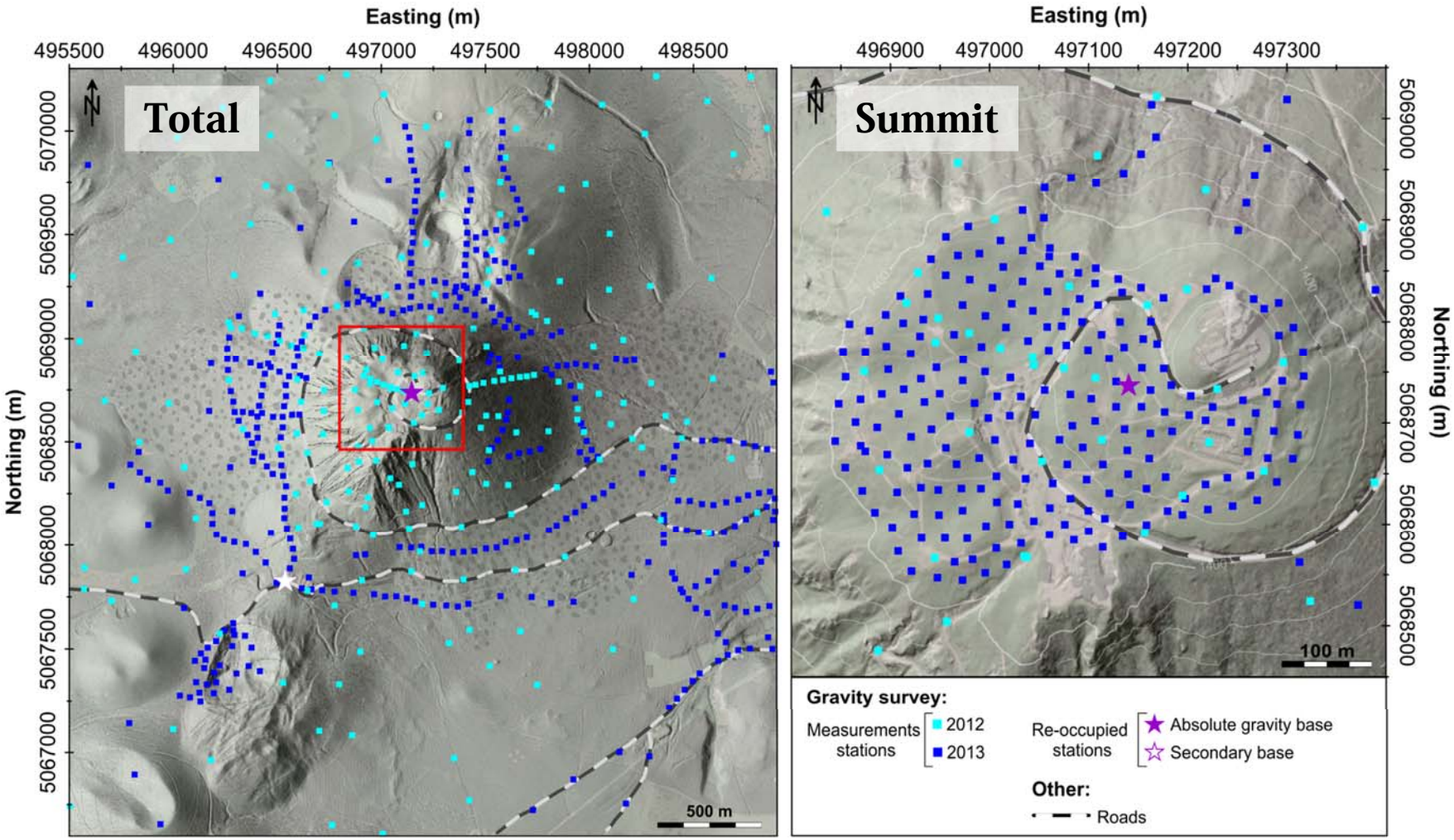
Entire zone → large-scale profiles

- electrode spacing: *35 m*
- depth of investigation: *~400 m*
- length: *~ 2 km*

Summit area → superficial structures

- electrode spacing: *5 m* and *10 m*
- depth of investigation: *100* to *200 m*
- length: *300* to *600 m*

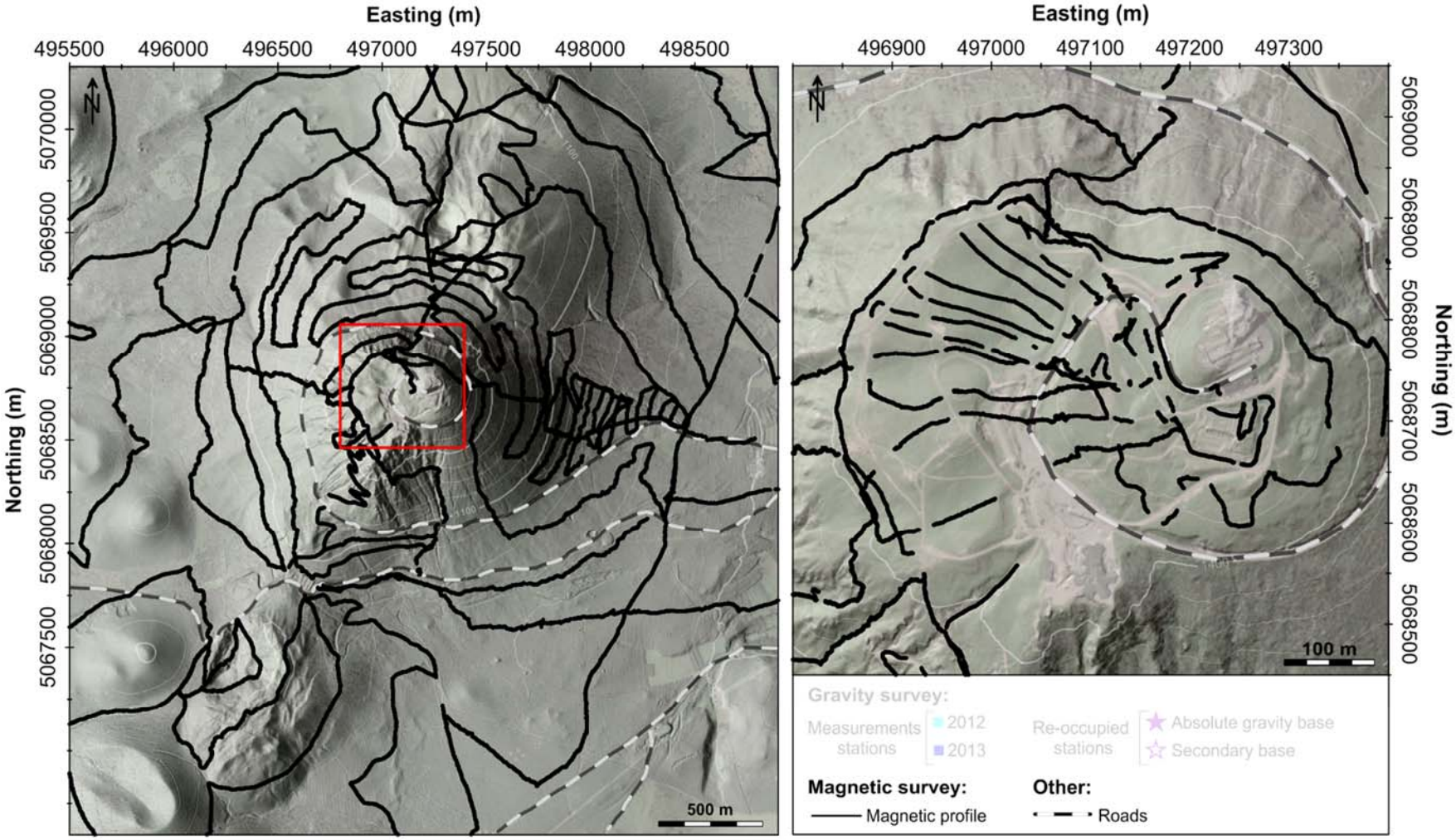
Gravimetry Survey



Localization of the gravity stations

- 1350 new gravity stations
- Differential GPS positioning (σ_z ~ 0.02 m)
- Densification in areas of particular interest (summit area, flanks, deformation areas)

Magnetism Survey

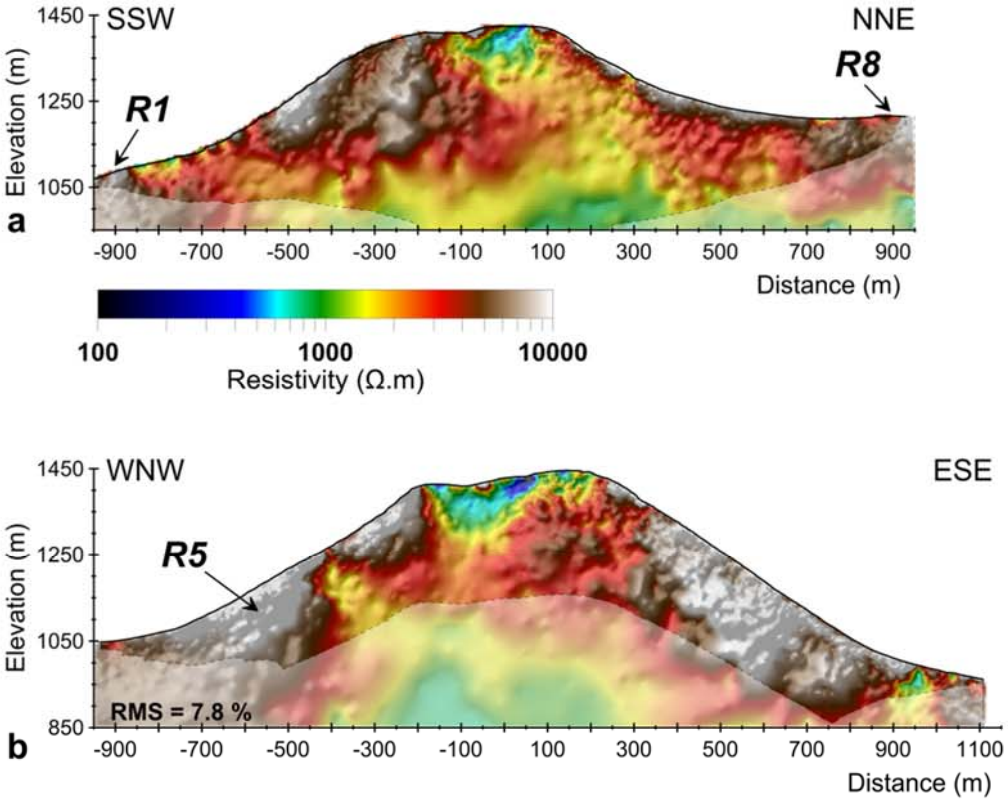


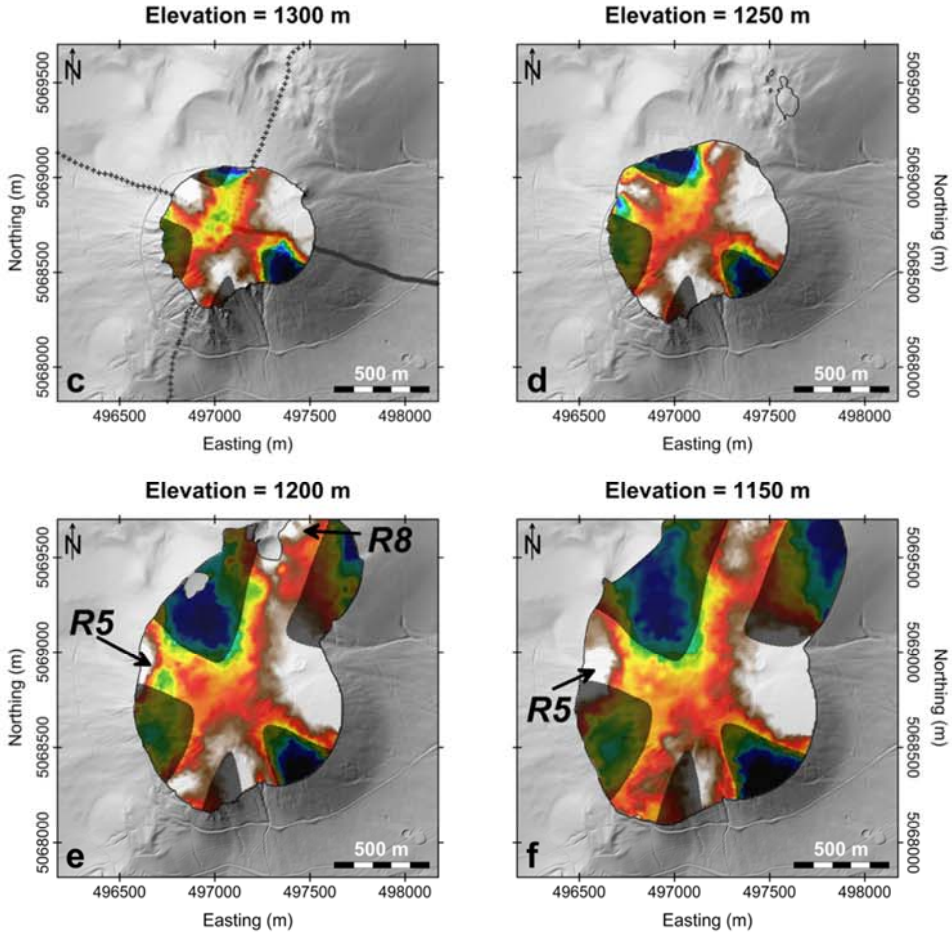
Localization of the magnetic surveys

- **Continuous measurements**
- Simultaneous GPS positioning

Puy de Dôme geophysical structure

3D inversion model of the electrical resistivity distribution

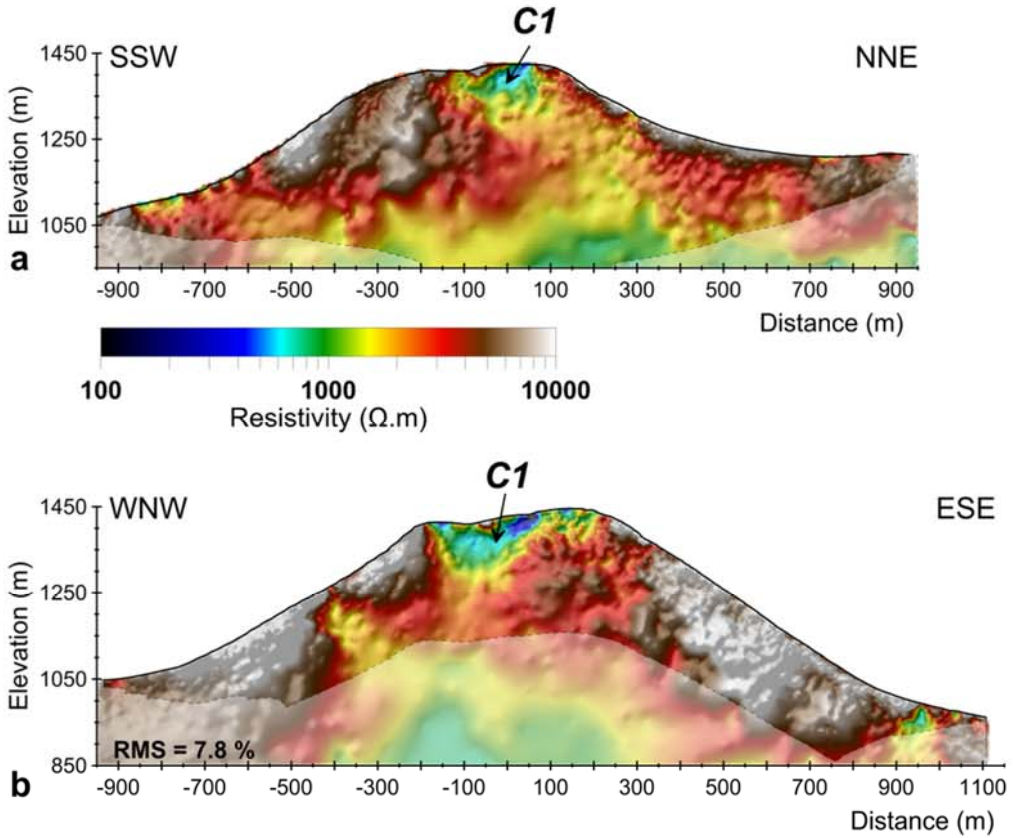


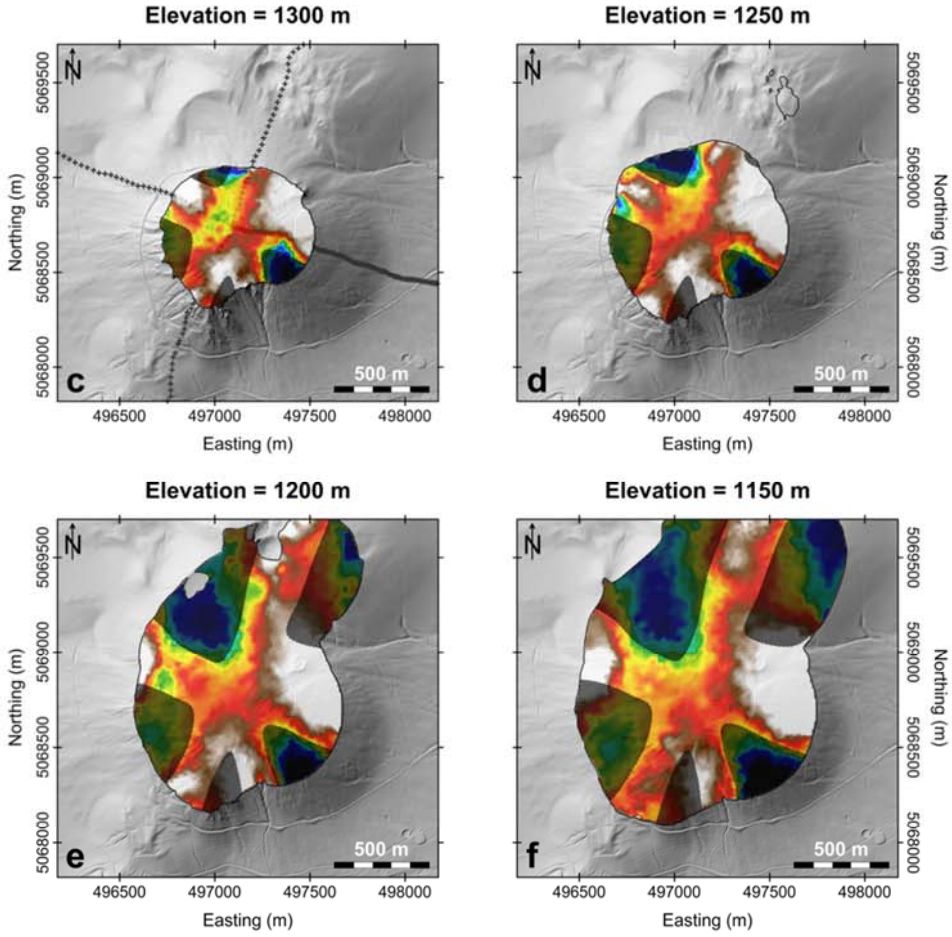


- **Highly resistive** structures
  - → cinder cones *(at the base of the dome)*
  - → lobes of massive lava and lateral intrusions *(inner structure and carapace of the dome)*
  - → *large part of the eastern flank : consolidated and/or welded formations*

Puy de Dôme geophysical structure

3D inversion model of the electrical resistivity distribution

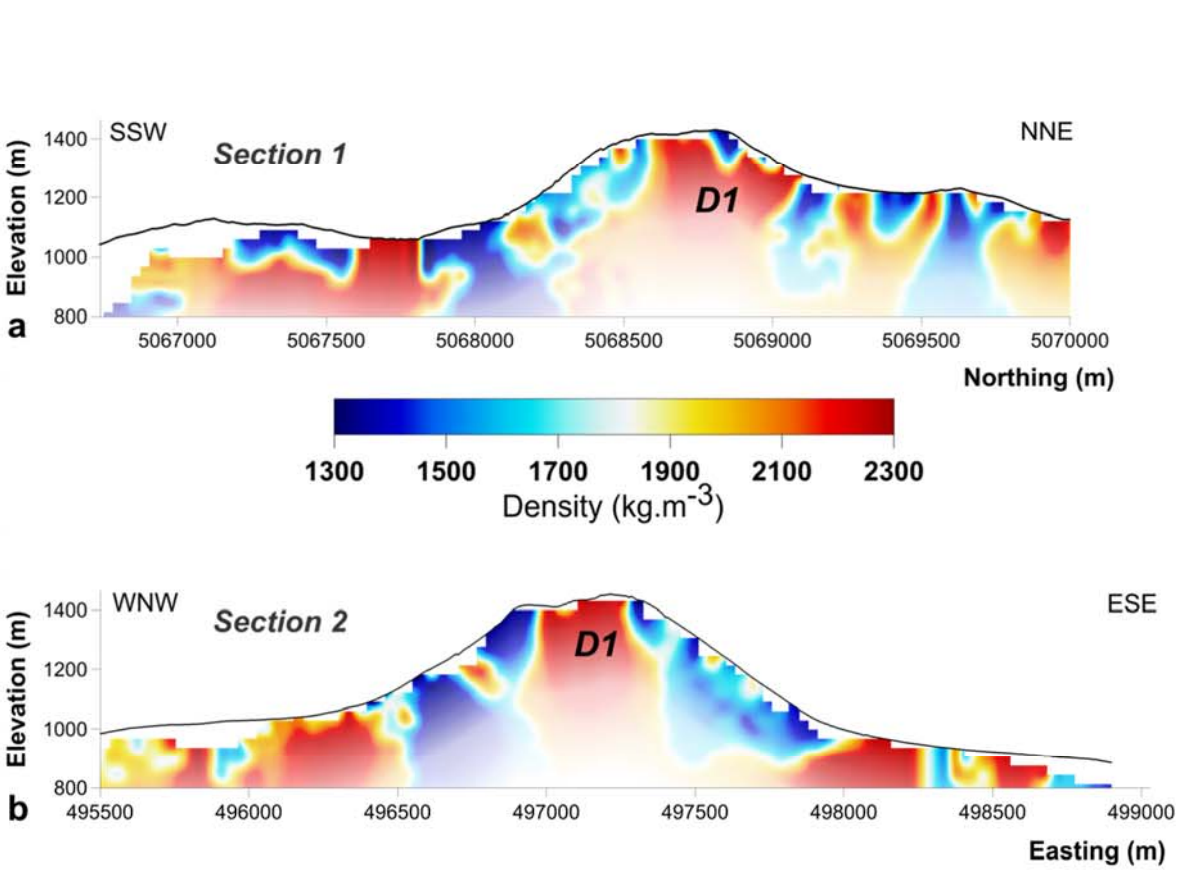


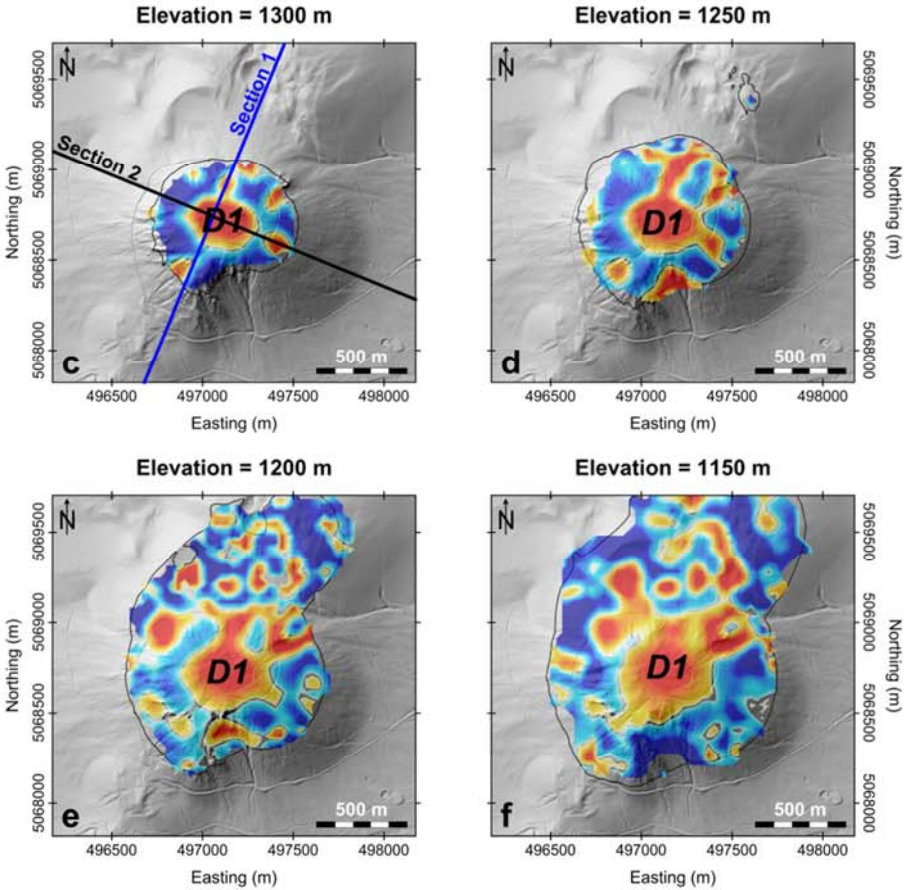


- **Low-resistivity** anomaly (*C1)* in the upper part
  - High hydrothermal alteration and intense fracturing

Puy de Dôme geophysical structure

3D inversion model of the density distribution





➤ **High density** structures

- centered on the dome and rooted at depth (D1)
  - ↳ core of massive trachyte
- pile of basaltic lava flows around the dome

➤ **Low density** structures

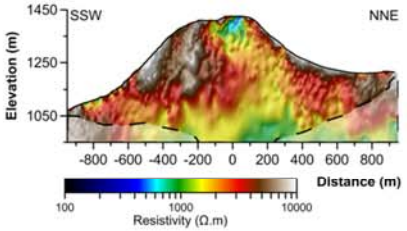
- unconsolidated material / breccia
- cinder cones (at the surrounding)

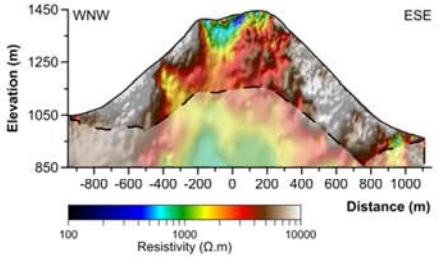
Geological model of the Puy de Dôme volcano

South-North Section

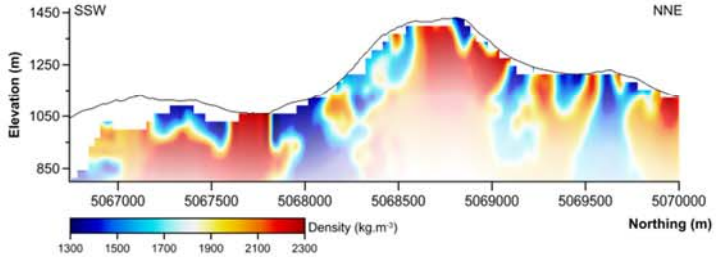
West-East Section

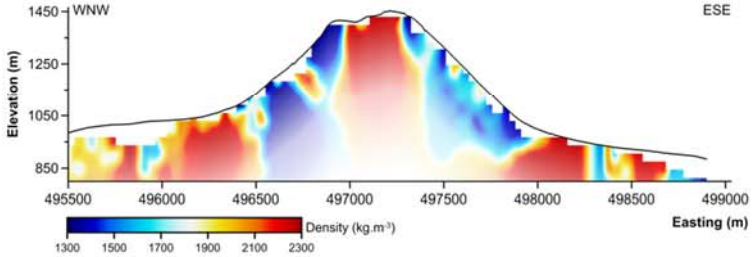
ERT 3D



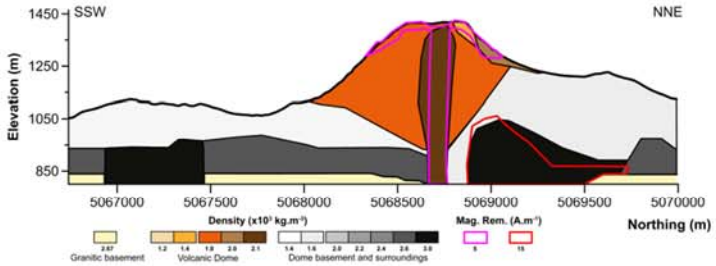


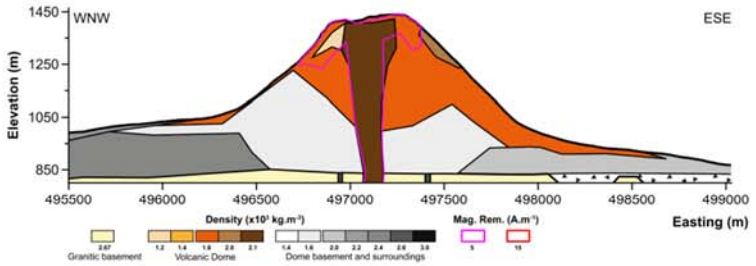
Gravi 3D



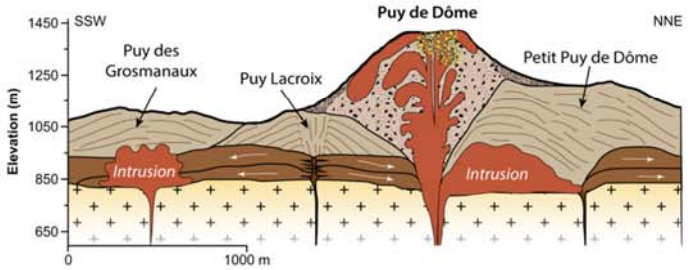


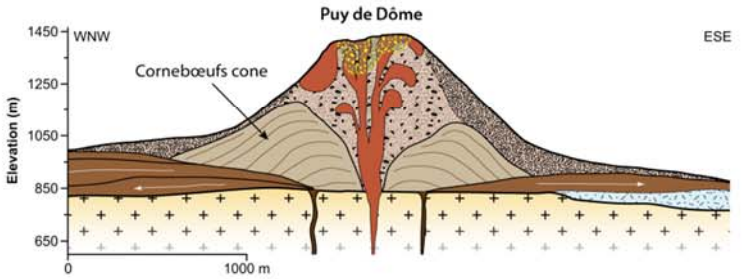
Gravi-Mag 2D



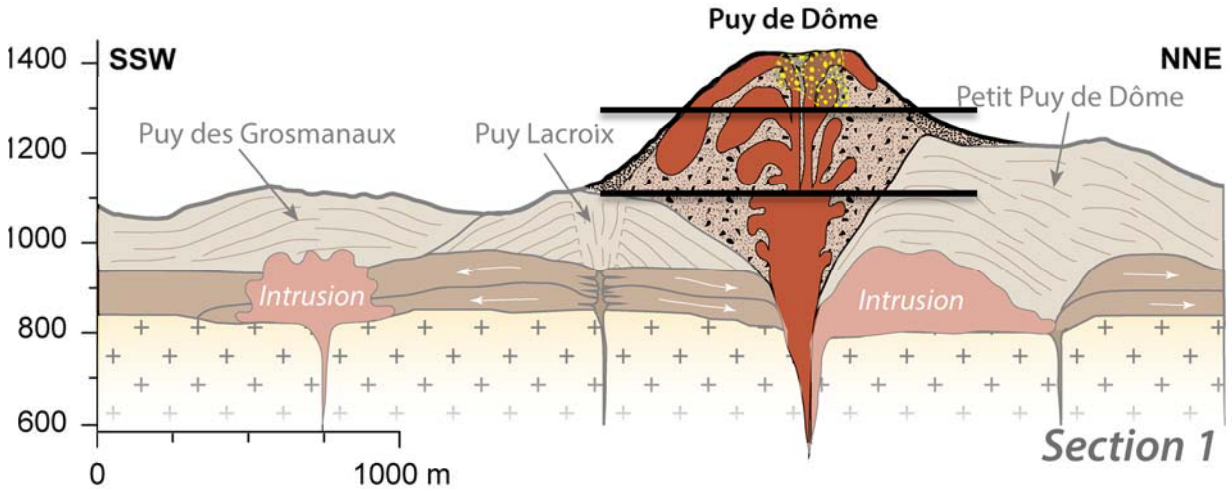


Geological interpretation





Geological model of the Puy de Dôme volcano



Central conduit of trachytic lava

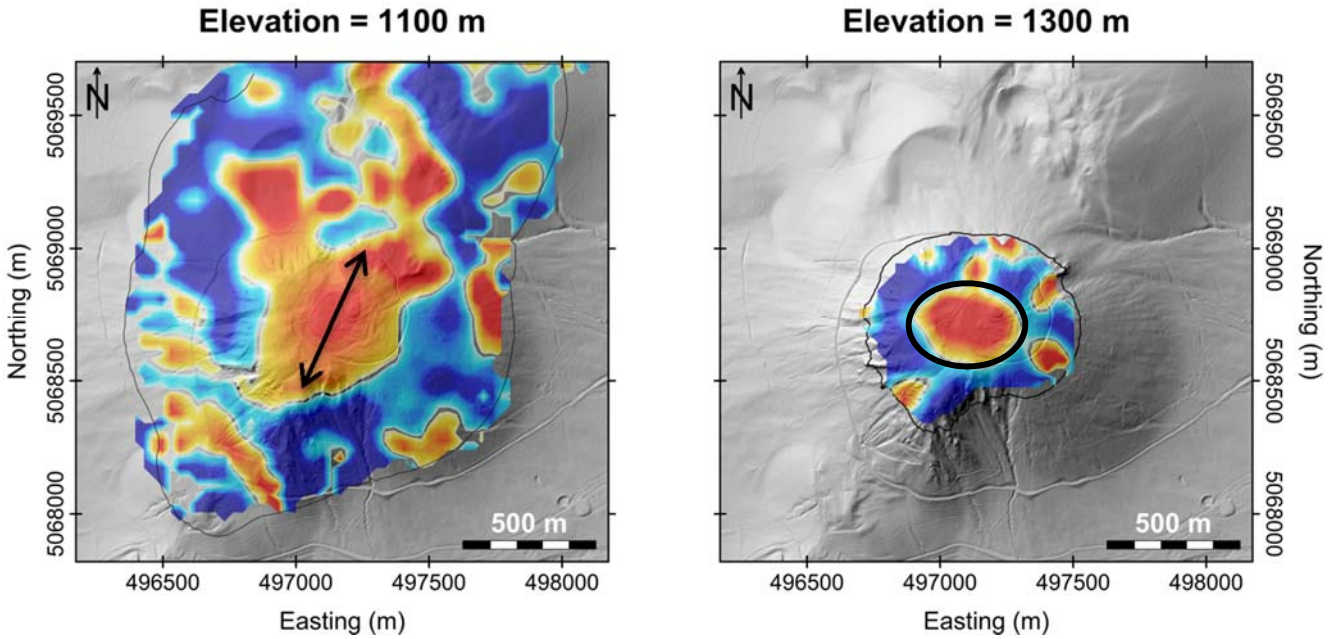
High density and magnetization

↓

Elongated shape at depth

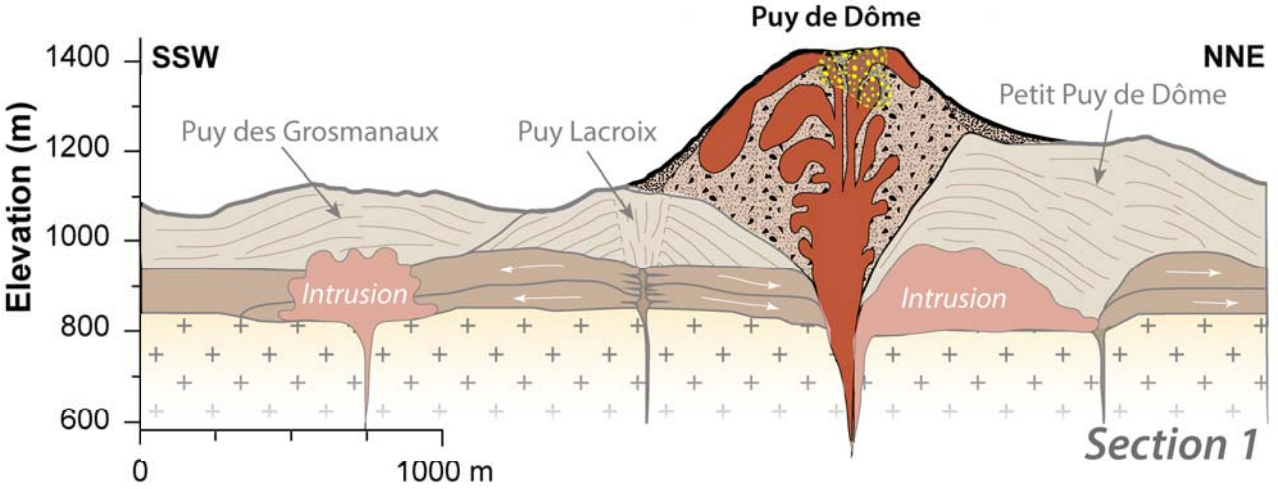
↓

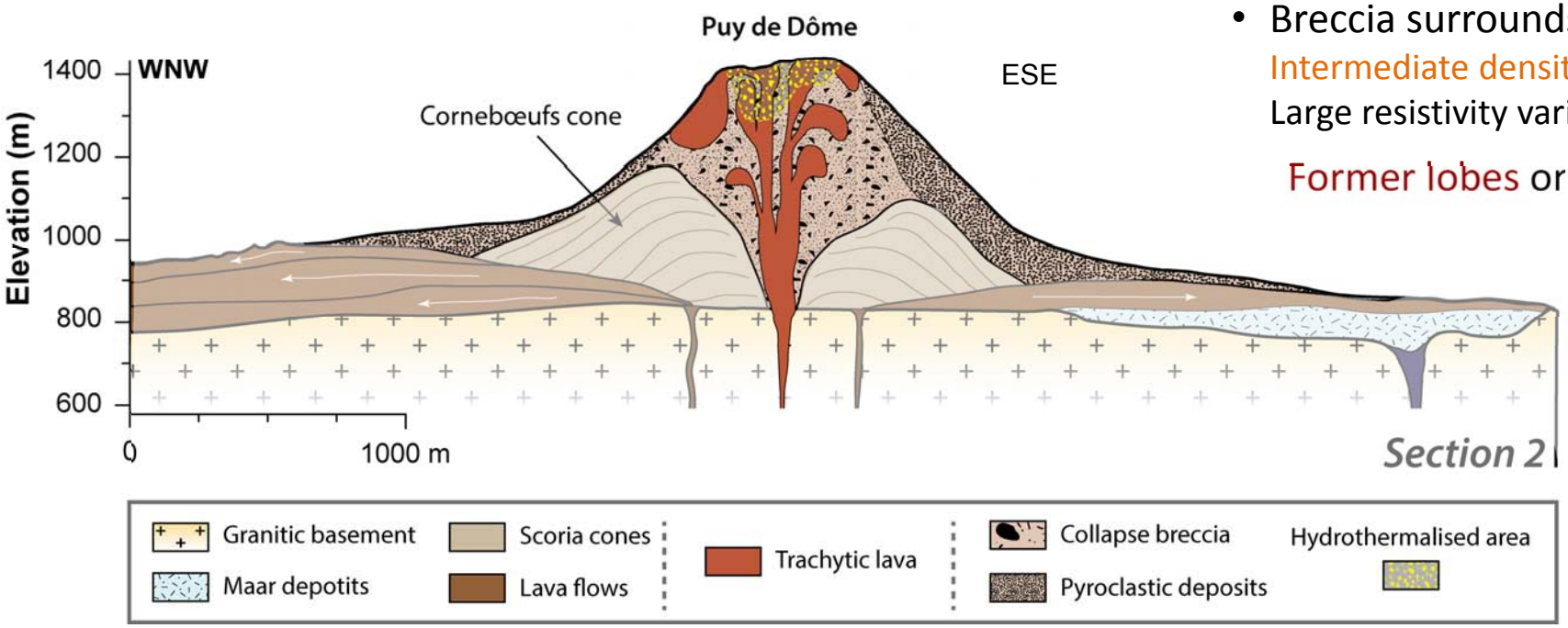
Magma extrusion through a fissure



3D model of the density distribution

Geological model of the Puy de Dôme volcano





- Alteration of the upper part of the conduit (Low resistivities)

  Intense hydrothermal activity

- Superficial lava lobes and spines
  Highly resistive and magnetized,
  Steep slopes

  Rocky carapace

- Breccia surrounds the conduit
  Intermediate density
  Large resistivity variations

  Former lobes or lateral injections

- Eastern flank
  Highly resistive, low density, smooth shape

Highly consolidated pyroclastic deposits

Towards an International Research Infrastructure for Muography experiments

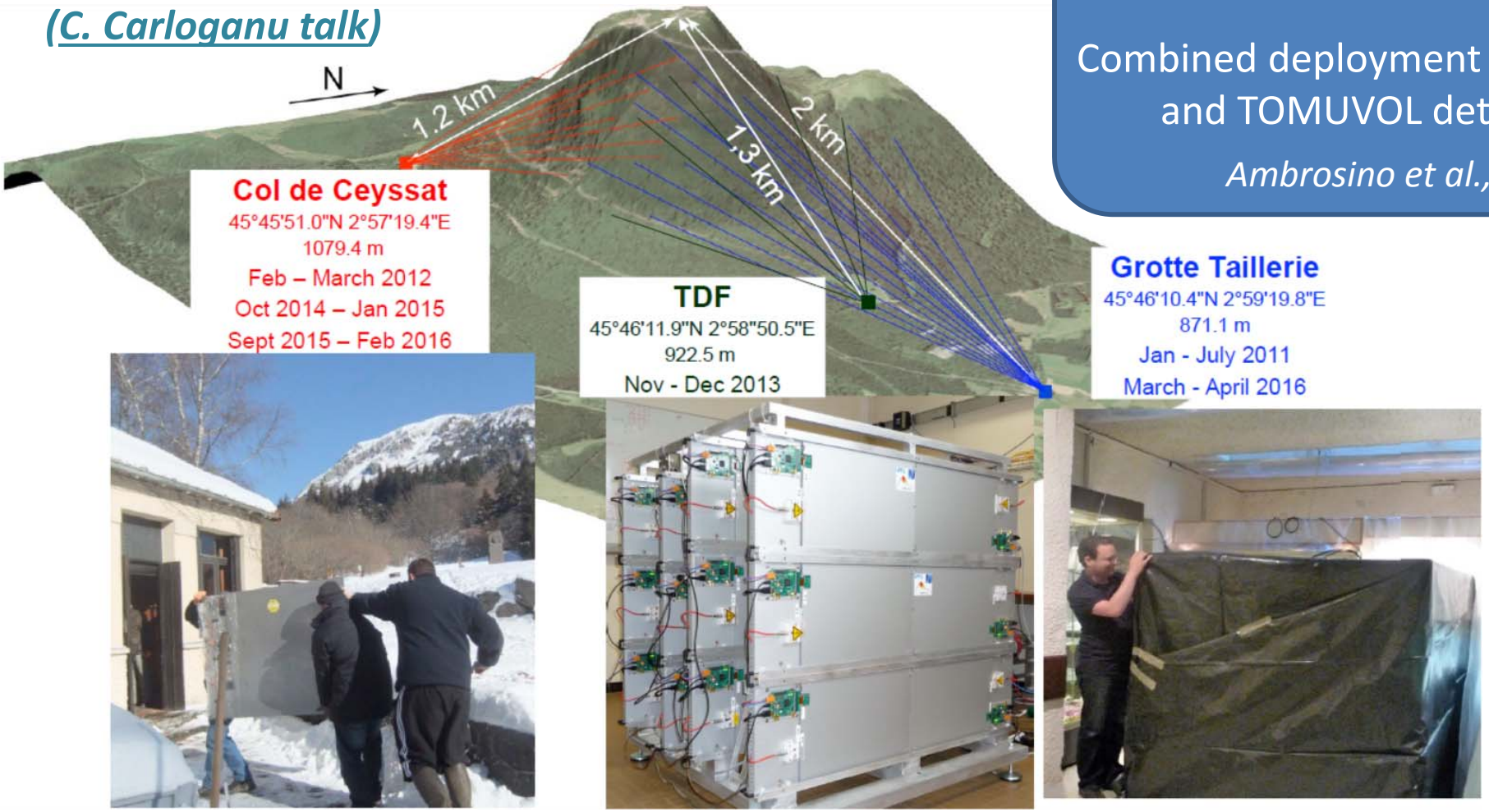
TOMUVOL experimental sites

(C. Carloganu talk)

Italian MU-RAY collaboration
6 months survey in 2013

Combined deployment of MU-RAY and TOMUVOL detectors

Ambrosino et al., JGR (2015)



Puy de Dôme and Chaîne des Puys, major tourist attractions

Vulcania

Theme Park for exploring volcanoes

www.vulcania.com

344,000 visitors in 2015

PANORAMIQUE DES DOMES

Access to the summit by rack-railway

439,000 passengers in 2015

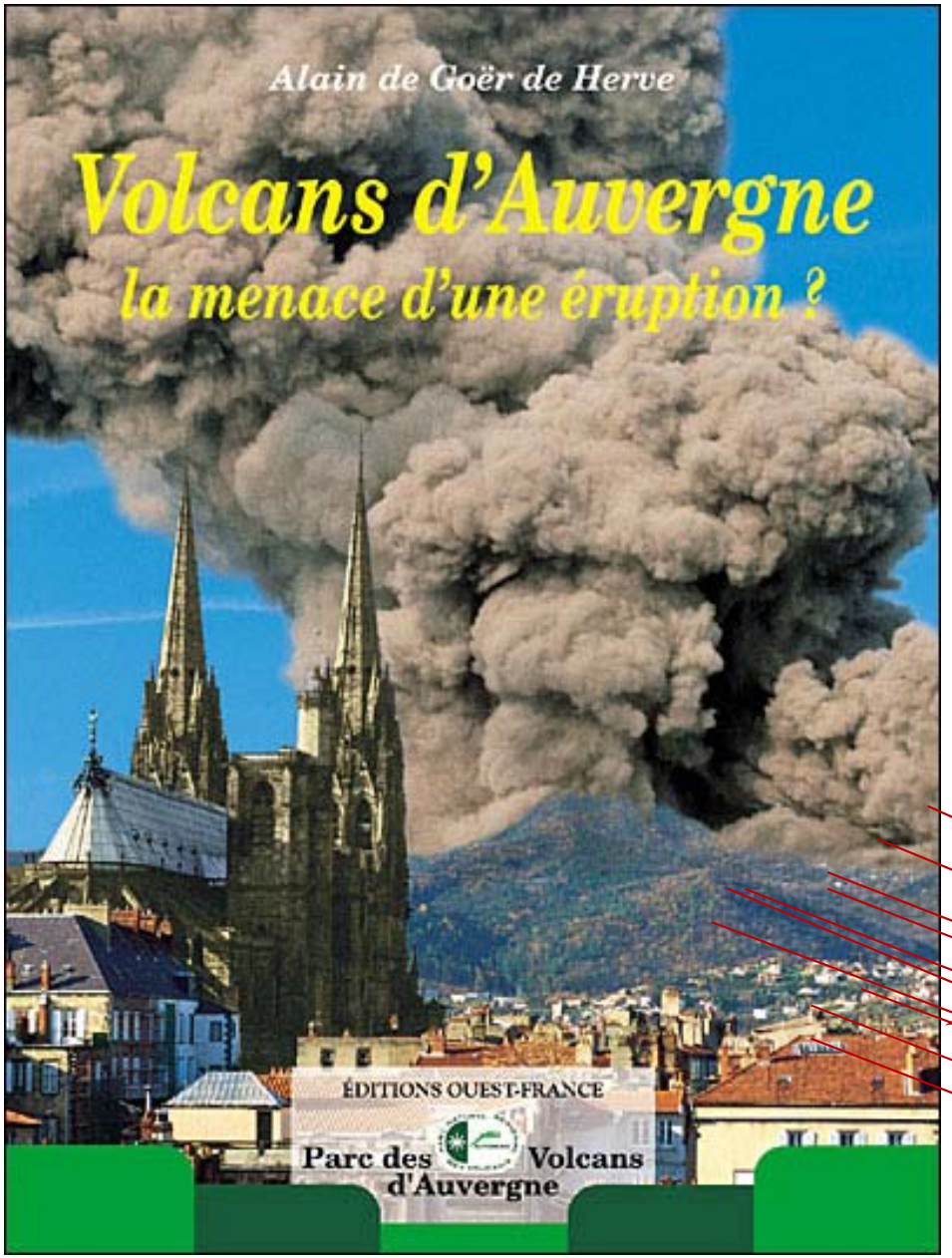
+ 150,000 hikers on the Puy de Dôme tracks in 2015

Proposal to make a permanent muography observatory on Puy de Dôme (Chaîne des Puys, France)

In the framework of the G-Endeavor H2020-INFRAIA project (C. Bozza talk)

French partners : LPC and IPNL (CNRS/IN2P3); ISTerre Grenoble (CNRS/INSU)

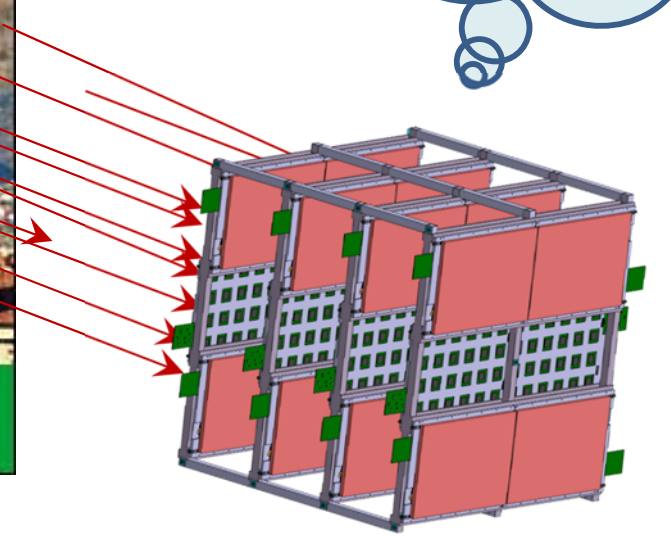
- Access to a building infrastructure attached to the Observatoire du Puy de Dôme (*OPGC, Blaise Pascal university and CNRS*) in the near vicinity of the lava dome.
- The Puy de Dôme has interesting characteristics to carry out muography experiments.
  - *Geology and high resolution geophysical surveys have revealed that the interior of the edifice is complex and highly heterogeneous.*
  - *Moreover, the dimensions of the edifice are moderate enough to expect that a large part may be investigated with atmospheric muons.*
- Experiments for the qualification of detectors designed for imaging large volcanoes. Comparison may be carried out with different geophysical methods. *- datasets available -*
- Possibility to make calibration and inter-calibration of detectors.
- Exhibition facilities for general public information and scientific diffusion.
  Vulcania, Panoramique des Dômes, Volvic, etc.



Thank you for your attention

ご清聴ありがとうございました

… Waiting for the next eruption!



Muon telescope