Internal structure of a complex lava dome and its surroundings inferred from gravity and magnetic data

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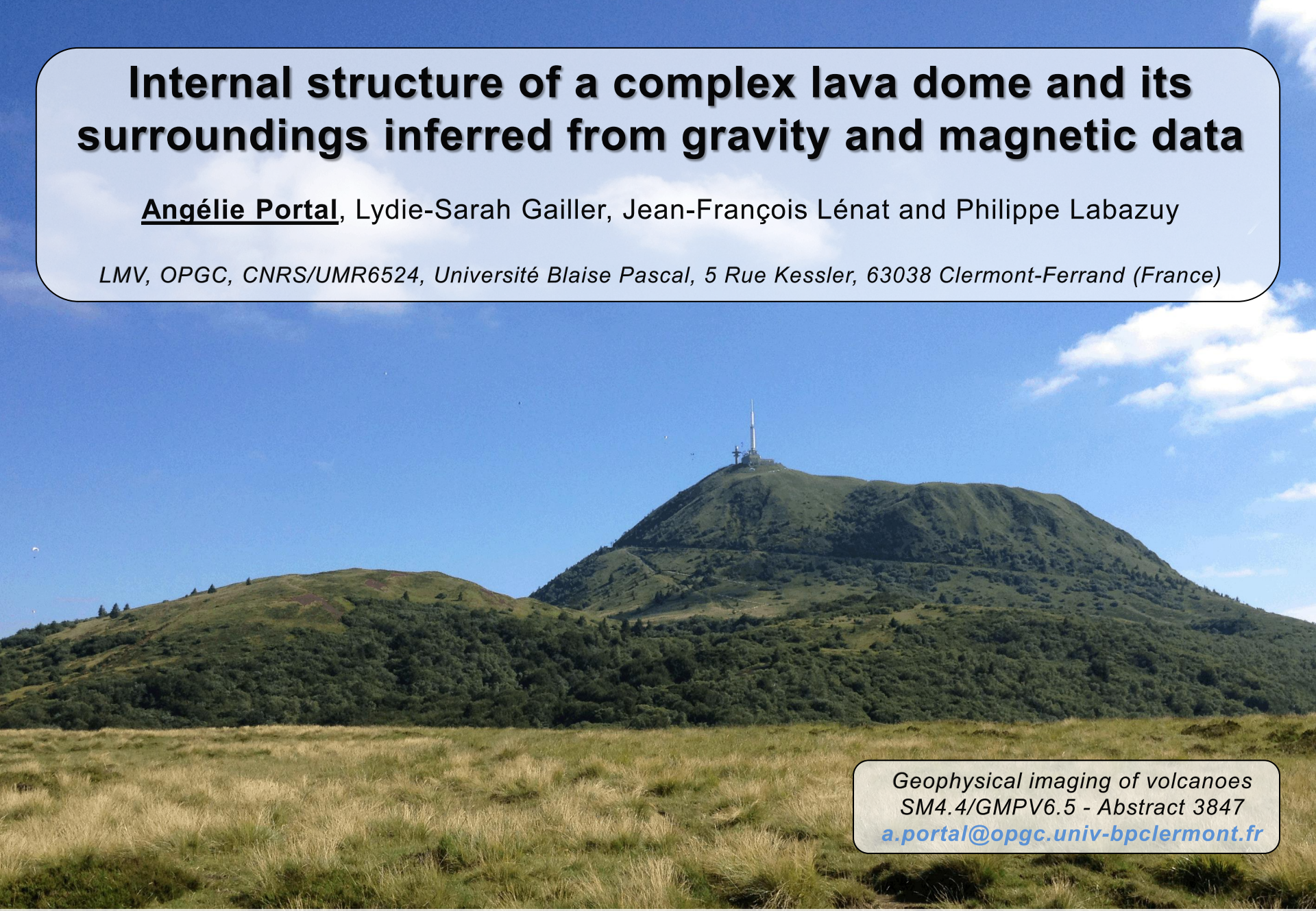

Geophysical imaging of volcanoes
SM4.4/GMPV6.5 - Abstract 3847
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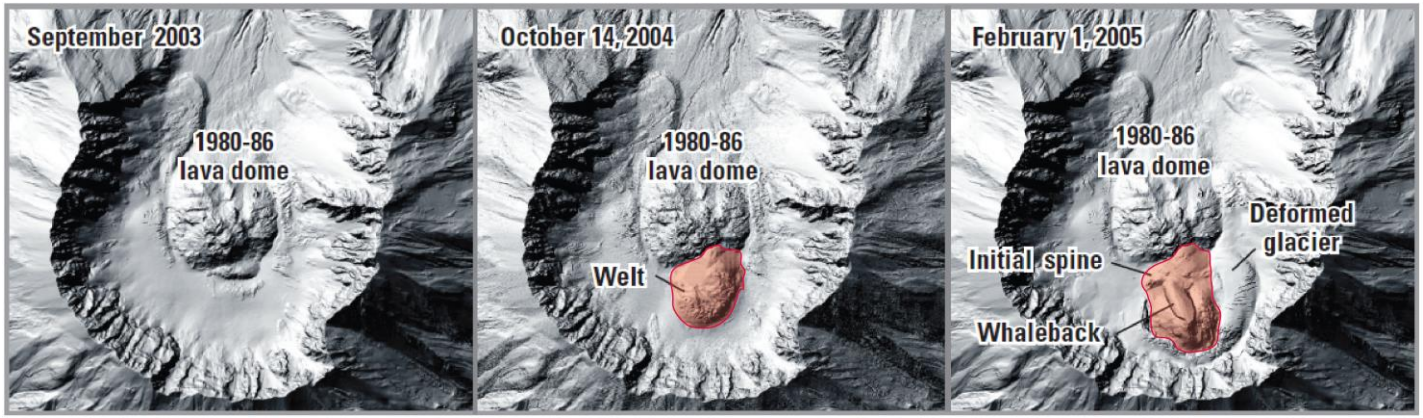
➢ General context

Growth of volcanic domes is a multiphase process:

- extrusion phases



2005 lava dome growth inside the Mount St. Helens crater (modified from Major and al., 2005)

- volcanic explosions and dome collapses

2009 Soufrière Hills eruption

2014 Sinabung dome collapse

General context

- intense hydrothermal and fumarolic activity

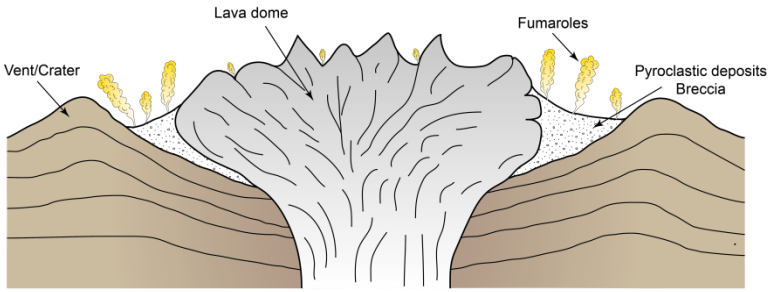
Soufrière de Guadeloupe (2010)

Kelud lava dome (2008)

Fuego de Colima (2001)

Resulting inner structure is complex:

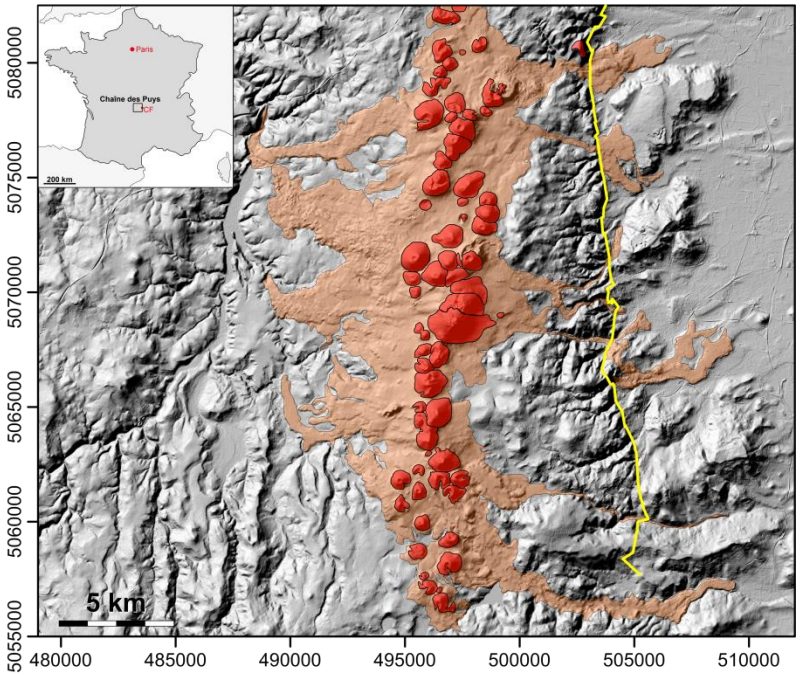
- massive lava parts,
- pyroclastic deposits and breccia,
- talus.



Modified after Wohletz (1992)

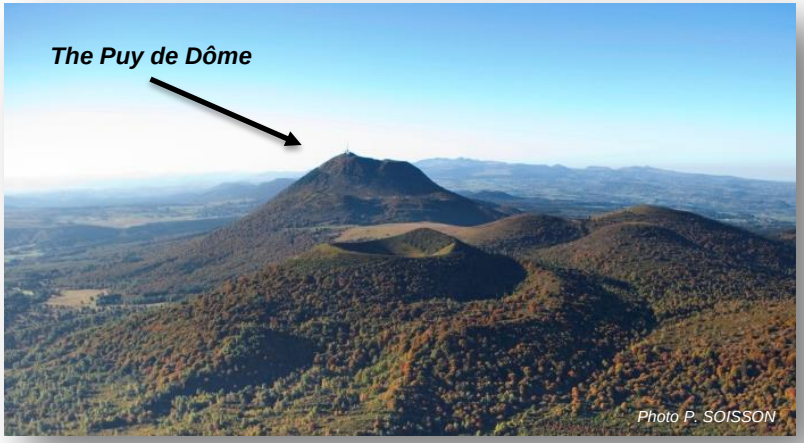
➢ The Chaîne des Puys volcanic field

- Volcanic ~N-S alignment
  West of the Limagne graben
- More than 100 volcanic edifices
  (lava domes, strombolian cones, maars).



➢ The Puy de Dôme volcano

- 11,000 yrs old trachytic lava dome
- huge edifice as compared to other volcanic edifices



View from the North

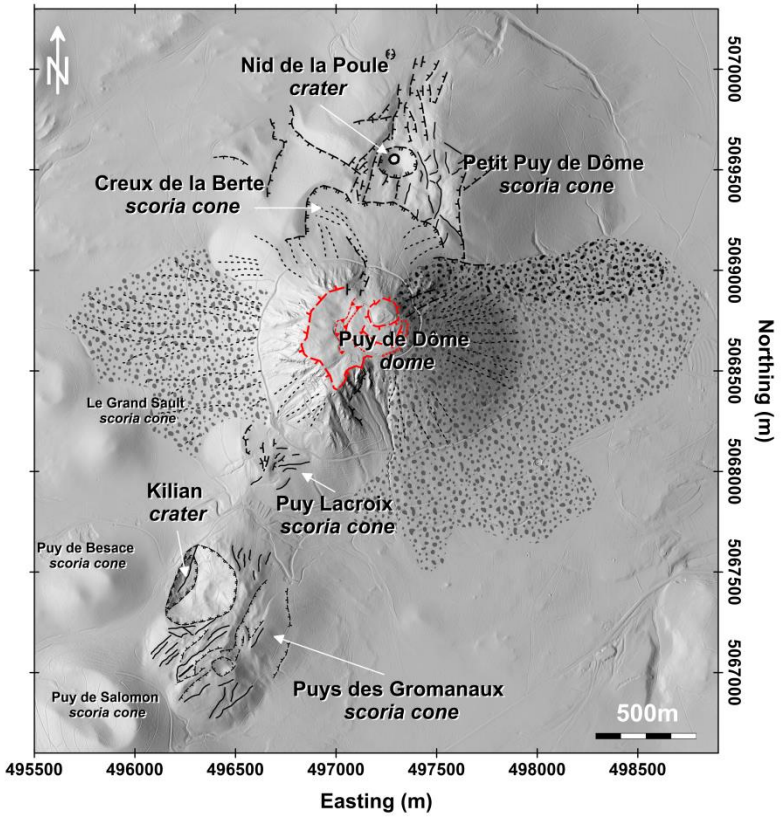
Puy de Dôme western flank

➢ The Puy de Dôme volcano

- Flat summit area
- Block and ash avalanche deposits fans toward West and East
- 2 zones showing deformation structures (N and S of the dome)

↳ underlying intrusion?
(van Wyk de Vries and al., 2014)

Structural analysis



➢ The Puy de Dôme volcano

- Flat summit area
- Block and ash avalanche deposits fans toward West and East
- 2 zones showing deformation structures (N and S of the dome)

  ↳ underlying intrusion?
  (van Wyk de Vries and al., 2014)

- High slopes (>40°): limited to the summit part

  ↳ solid carapace

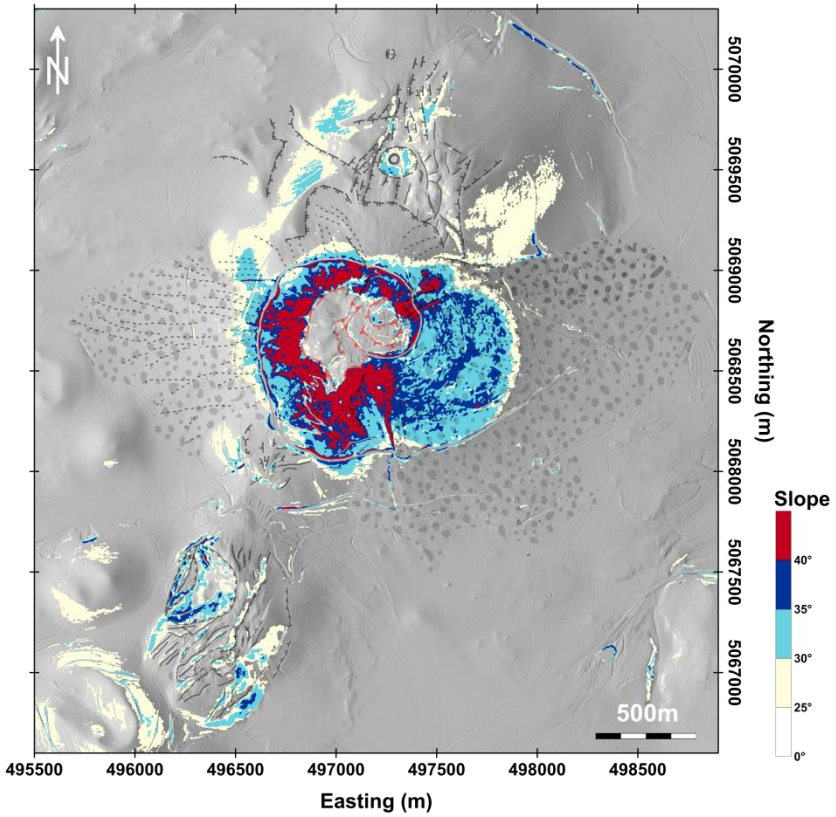
- Intermediate slopes (35°-40°)

  ↳ solid carapace covered by Puy de Dôme deposits

- Low slopes (30-35°)

  ↳ unconsolidate materials

Slope analysis



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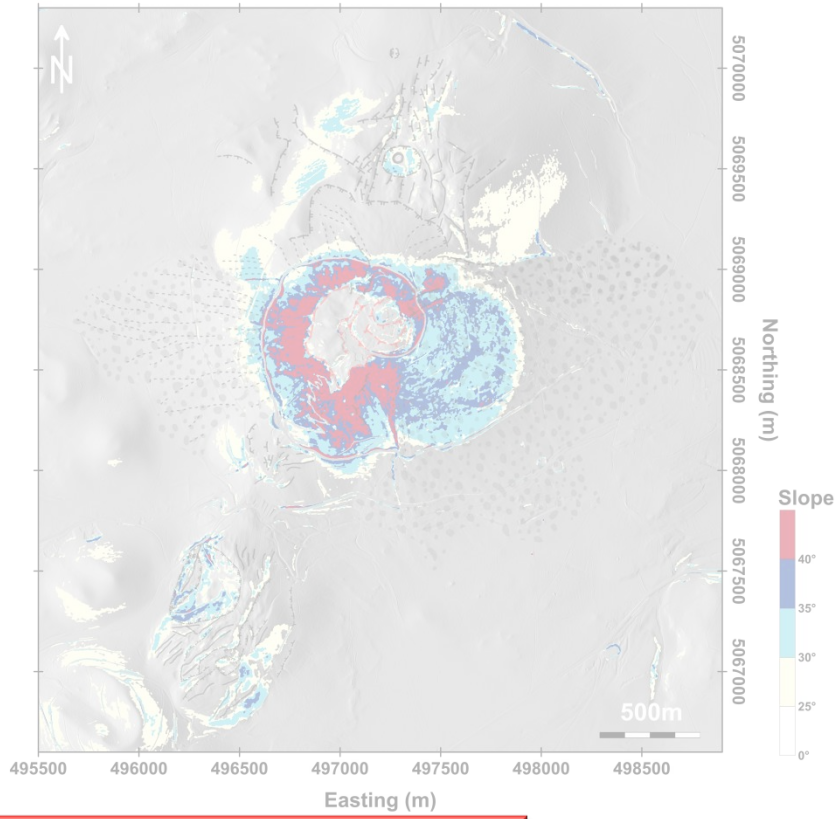
Slope analysis

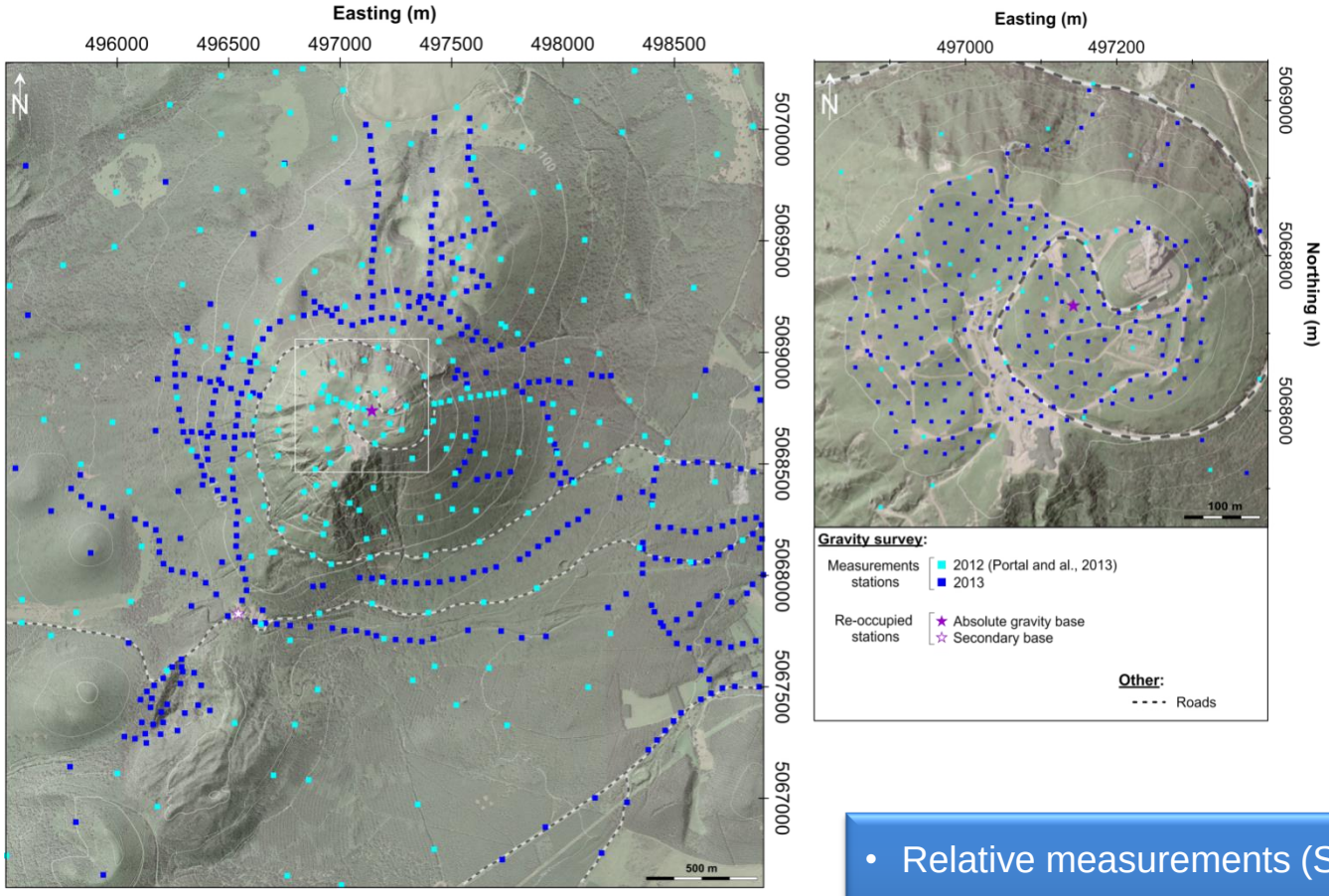


Objectives

✓ **Provide geological model of the Puy de Dôme inner structure**

✓ **Constrain the relation between the dome and its surroundings**

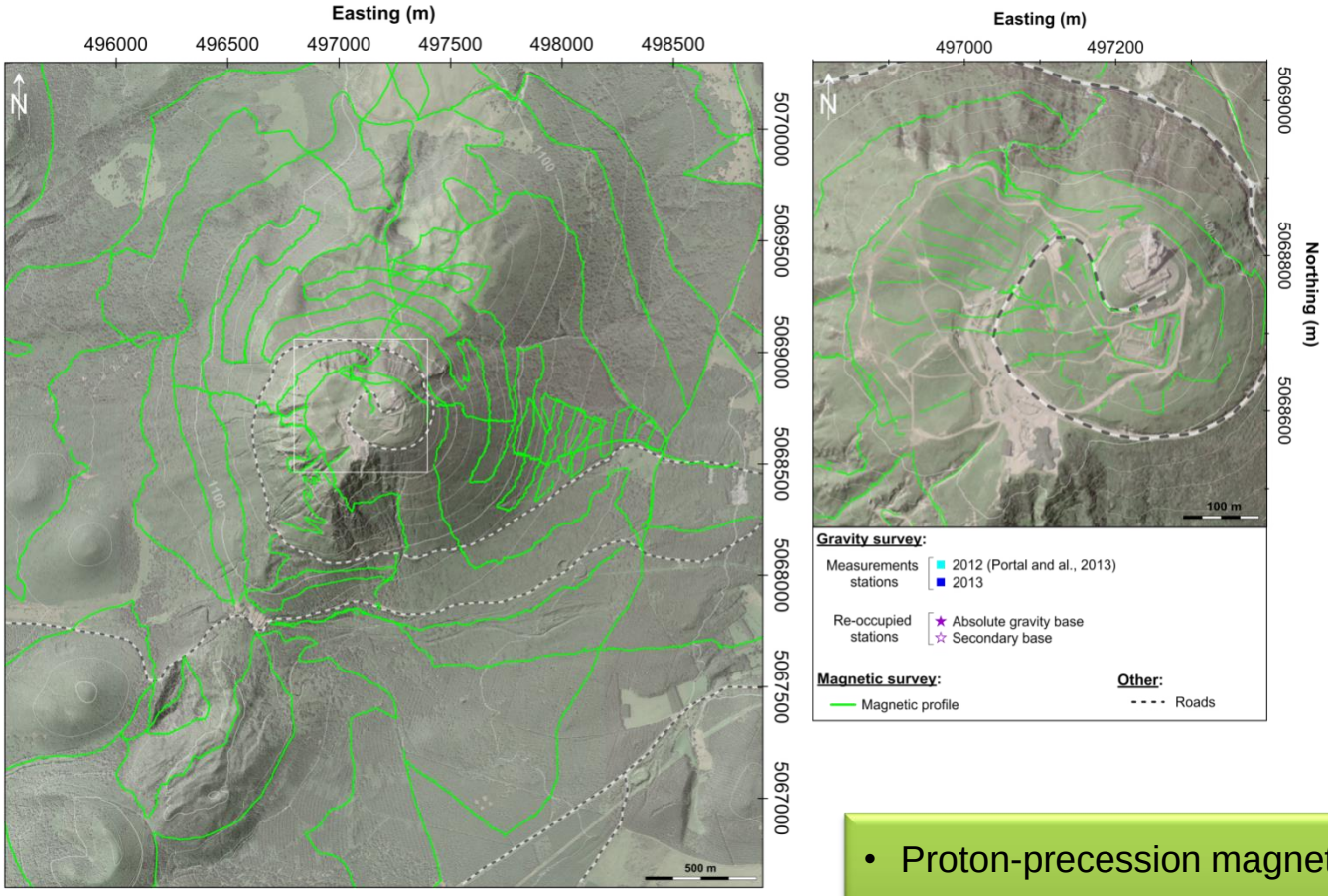
Gravity measurements



Gravity measurements location map

- Relative measurements (Scintrex Autograv CG-5)
- 1350 gravity stations
- Precise DGPS positioning

➢ Magnetic measurements

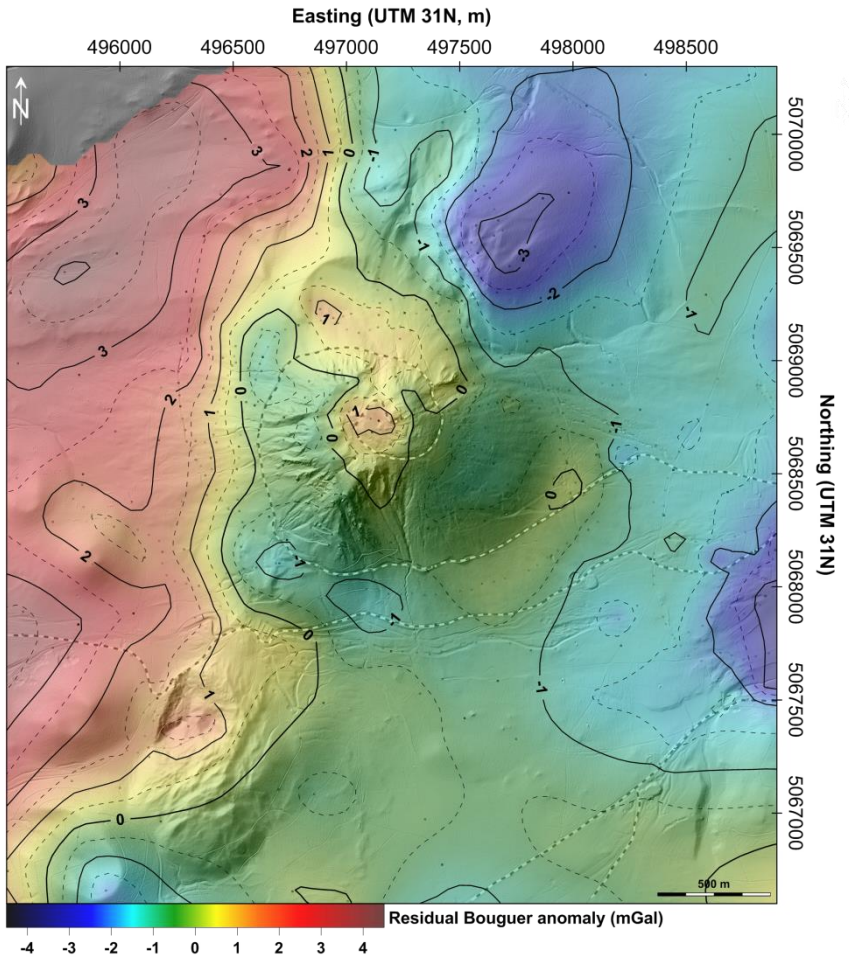


Magnetic surveys location map

- Proton-precession magnetometer (Overhauser)
- 0.5s sampling interval
- Simultaneous GPS positionning

➢ Bouguer anomaly map

- Density correction $\rho_{corr} = 1.8_{*}10^{3}$ kg.m^{-3}
- Regional trend = 2nd degree polynomial surface



Bouguer anomaly map

- Density correction $\rho_{corr} = 1.8_{*}10^{3}$ kg.m^{-3}
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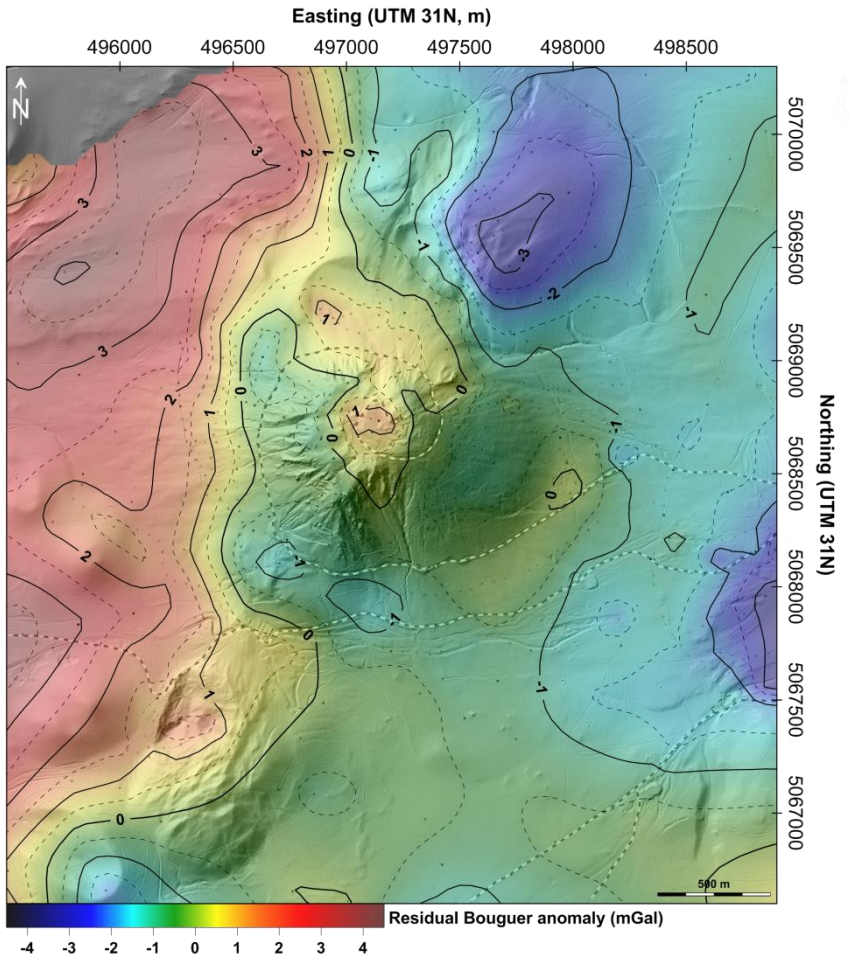
- Qualitative interpretation
  - Negative Bouguer anomaly values

    ↳ Scoria cones/maar (low density structures)



Bouguer anomaly map

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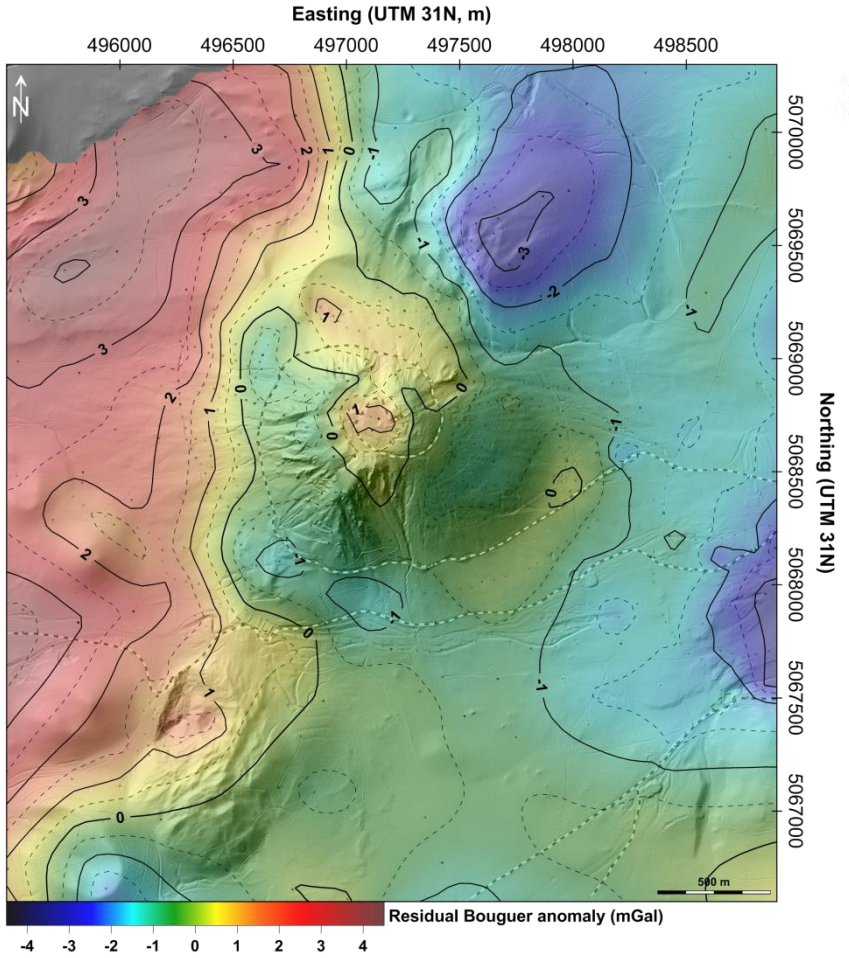
- Qualitative interpretation
  - Negative Bouguer anomaly values
    - ↳ Scoria cones/maar (low density structures)
  - Positive anomalies
    - ↳ Lava flows ?



Bouguer anomaly map

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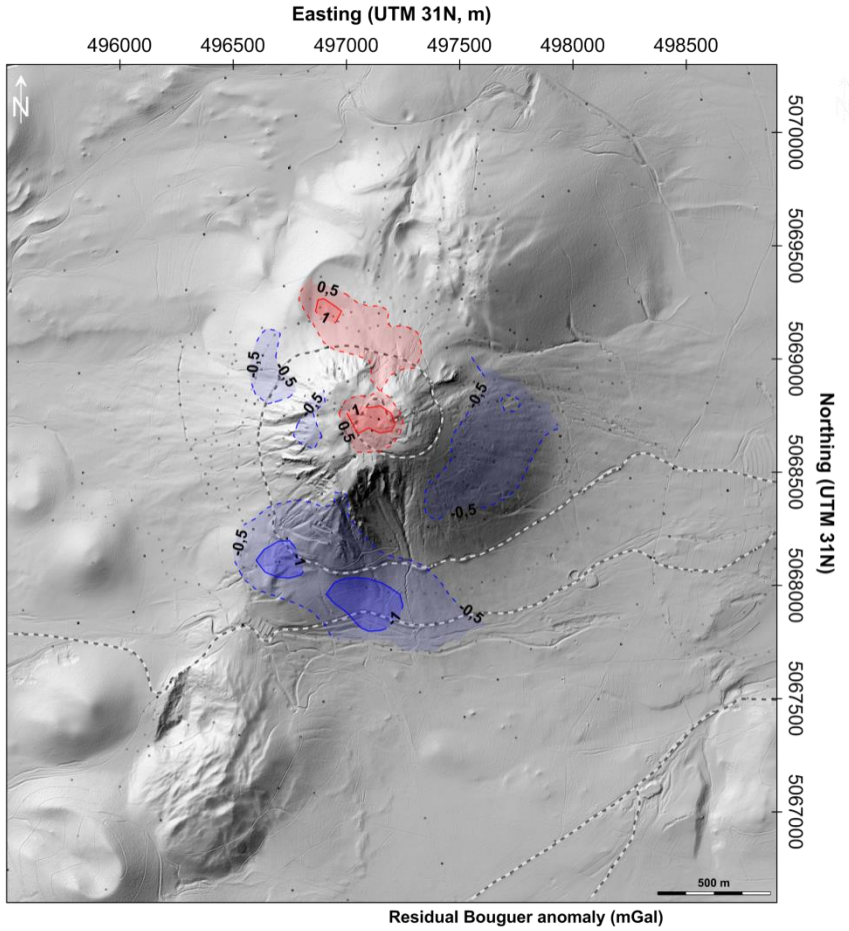
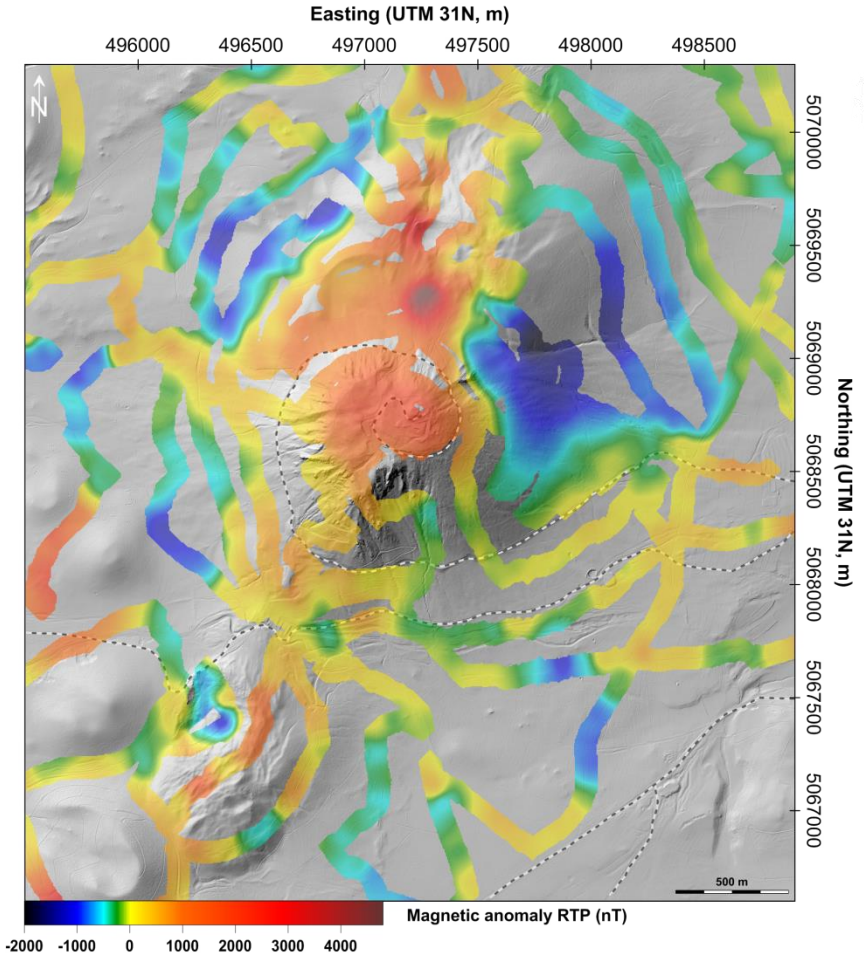
- Qualitative interpretation
  - Negative Bouguer anomaly values
    - ↳ Scoria cones/maar (low density structures)
  - Positive anomalies
    - ↳ Lava flows ?
  - Puy de Dôme: complex anomaly
    - Central positive anomaly → dense rock core
    - Negative anomaly toward S
      - ↳ underlying Puy Lacroix scoria cone
    - Positive anomaly on the northern flank



➢ Magnetic anomaly map

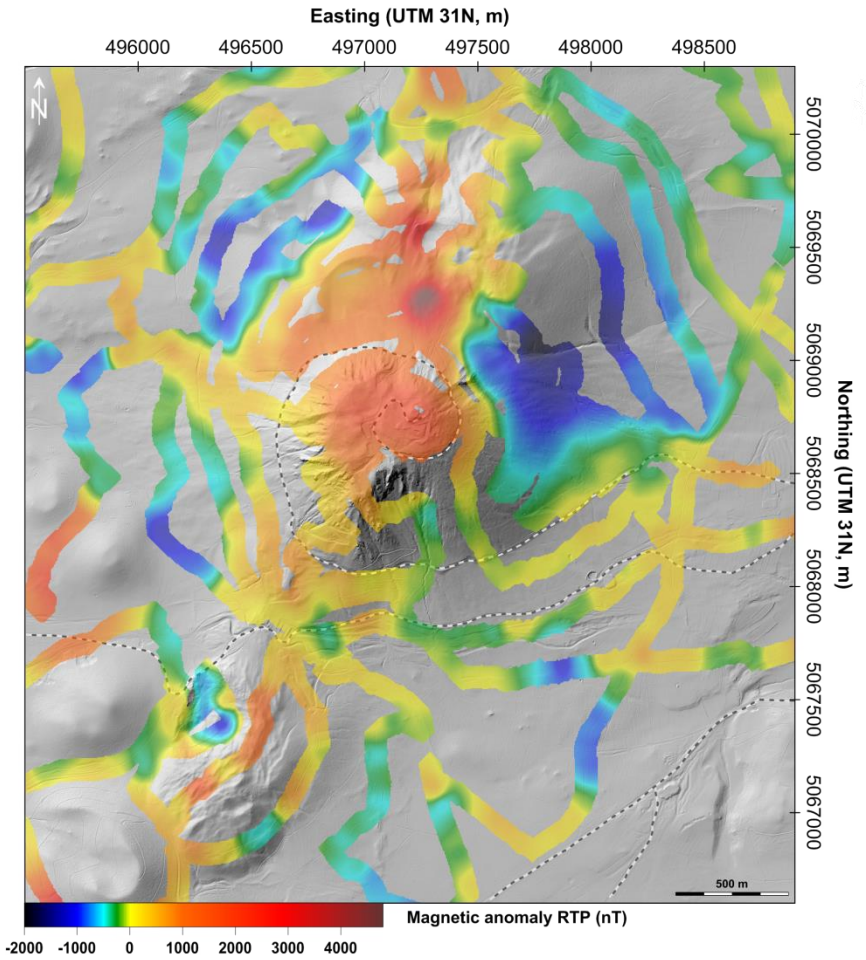
- Reduction to the magnetic pole (I=60°, D=0)



Magnetic anomaly map

- Reduction to the magnetic pole (I=60°, D=0)

- Qualitative interpretation
  - Negative anomaly on both sides of the PdD

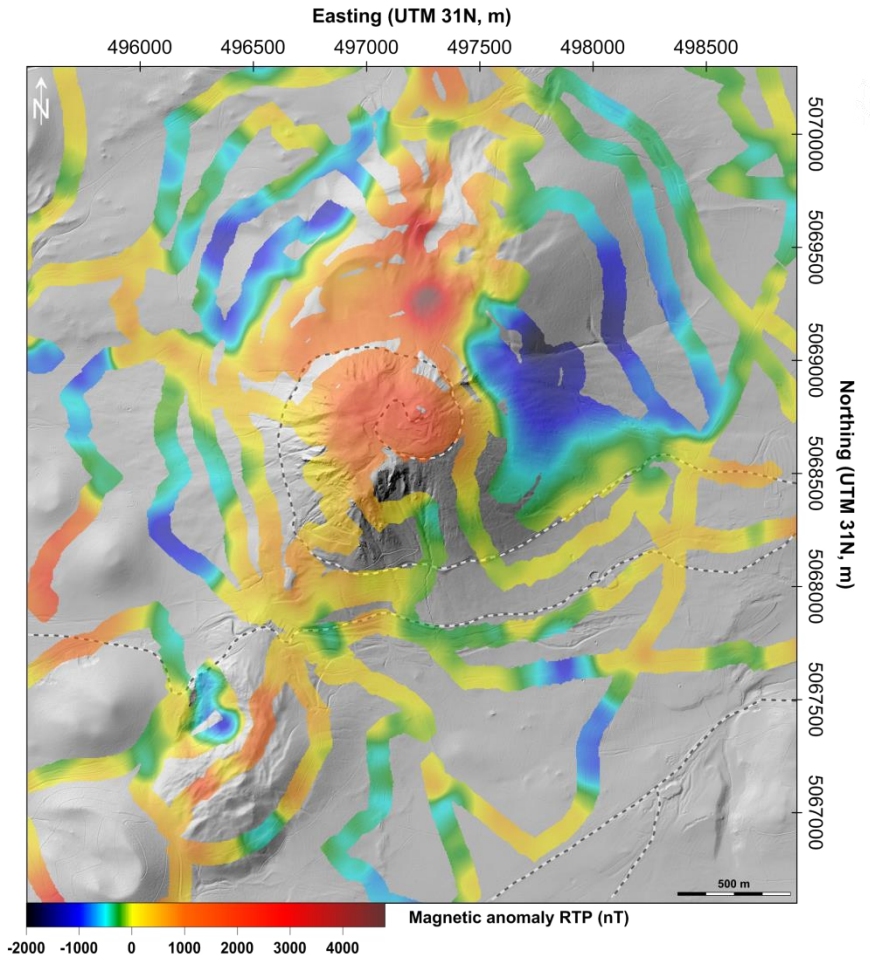


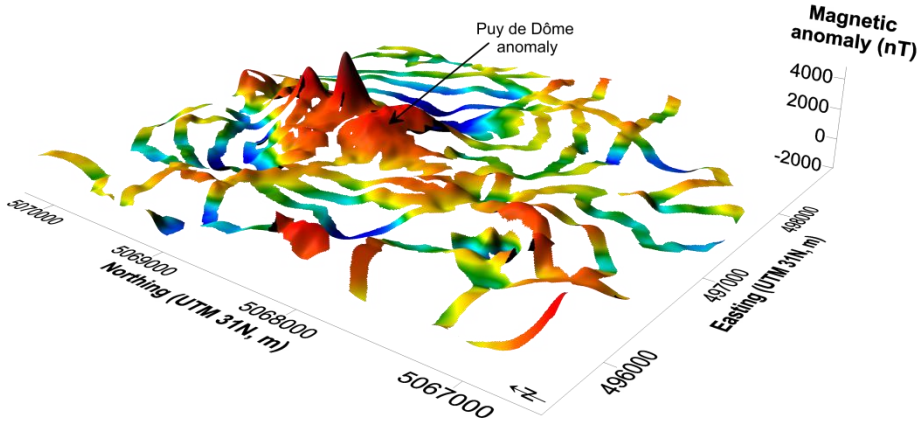
Magnetic anomaly map

- Reduction to the magnetic pole (I=60°, D=0)

- Qualitative interpretation
  - Negative anomaly on both sides of the PdD
  - Positive anomaly of the dome itself

    ↳ Lava dome massive core ?
  - 2 high anomalies (>3000 nT) northward to the PdD





3D representation of the magnetic anomaly

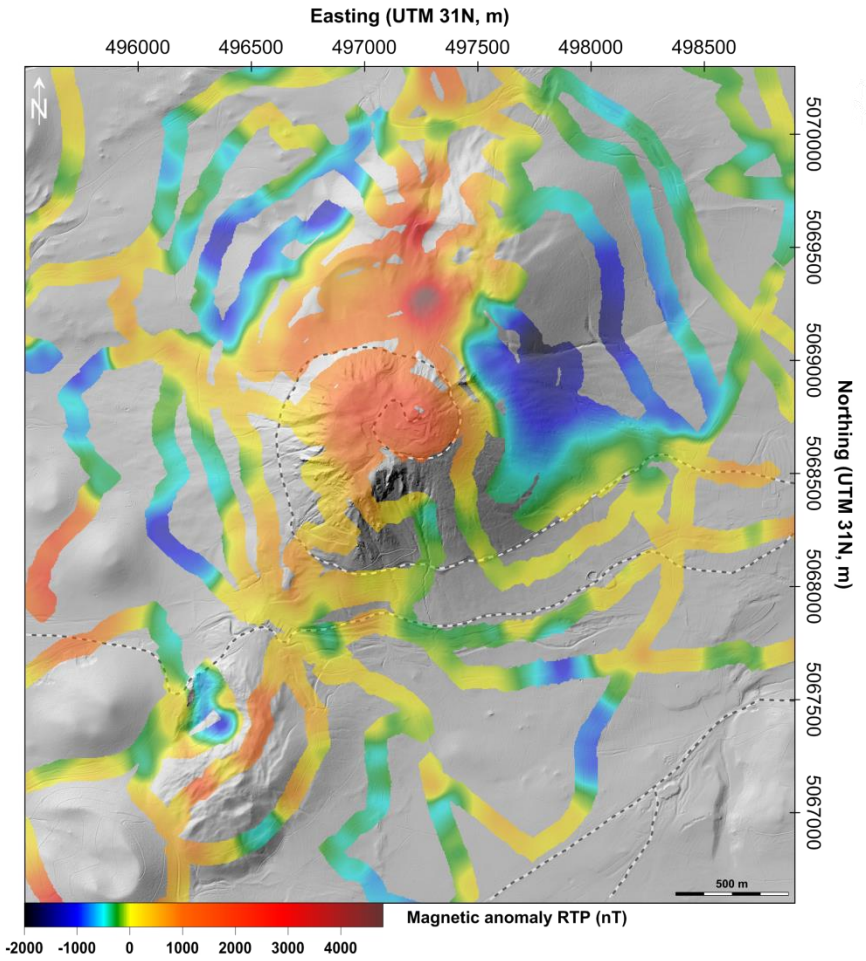
➢ Magnetic anomaly map

- Reduction to the magnetic pole (I=60°, D=0)

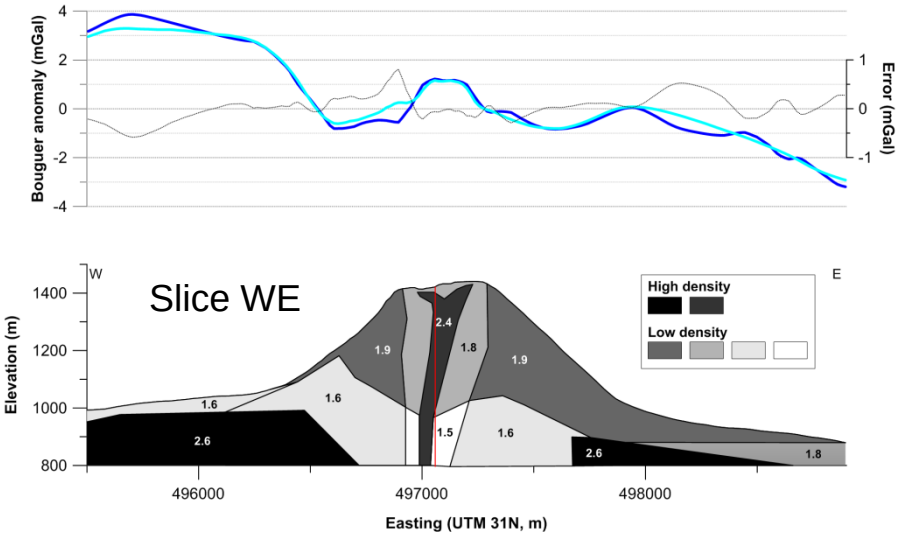
- Qualitative interpretation
  - Negative anomaly on both sides of the PdD
  - Positive anomaly of the dome itself

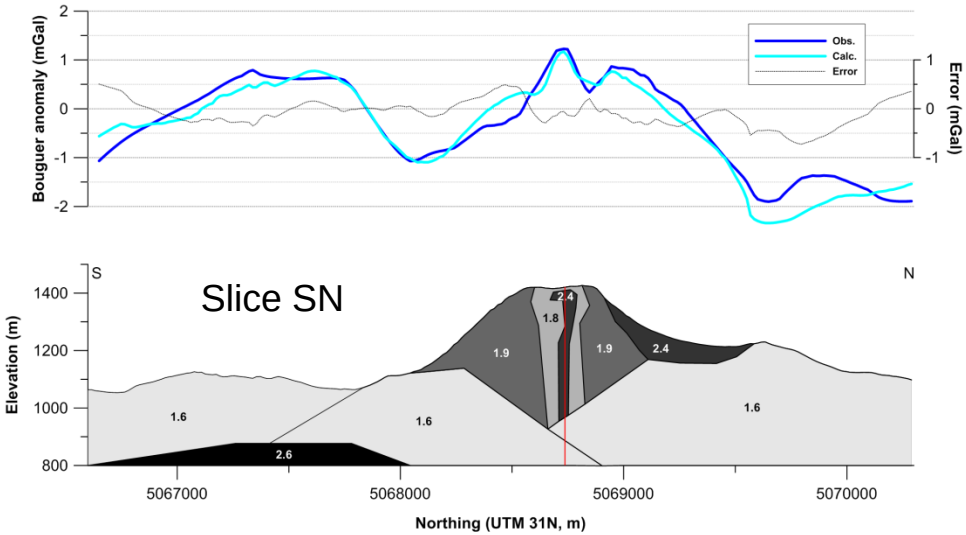
    ↳ Lava dome massive core ?
  - 2 high anomalies (>3000 nT) northward to the PdD

    ↳ Massive volcanic rocks (intrusion, filled crater ?)

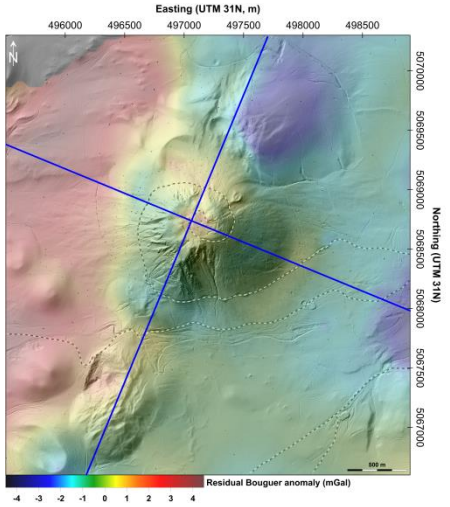


➢ 2D$^{1/2}$ model

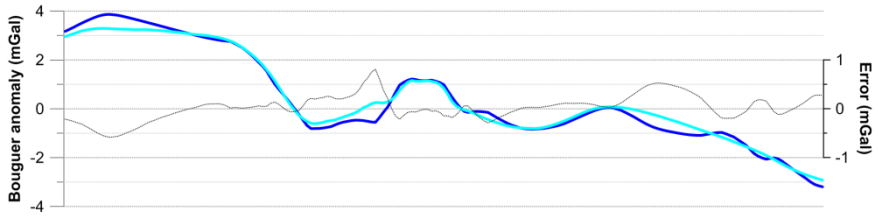


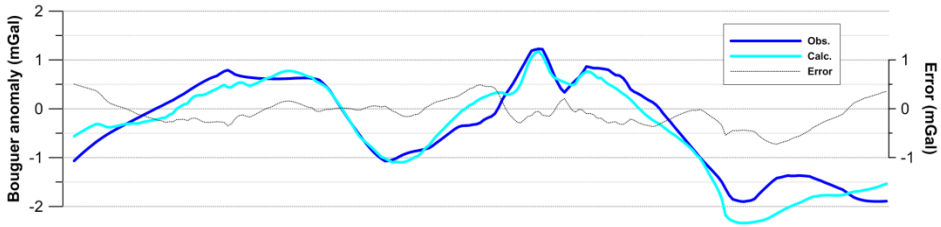


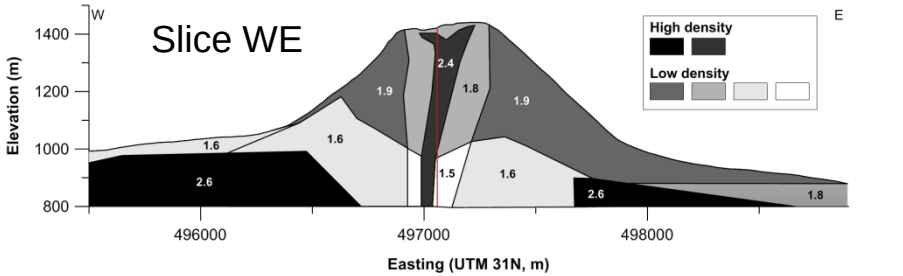
- Direct model of the Bouguer anomaly based on inferred geological structure
  - Low density basement (ρ<1.6)
  - High density structures at depth (ρ≈2.6)
  - Wide density range for the Puy de Dôme

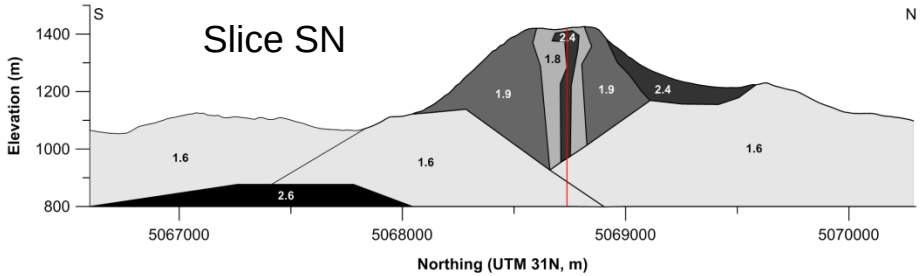


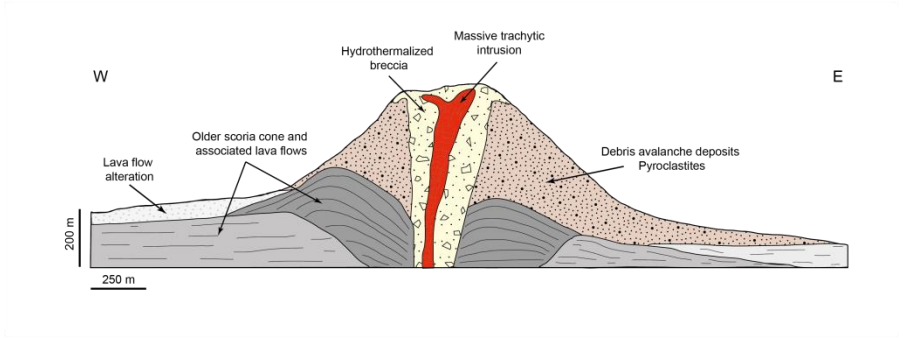
➢ Geological interpretation

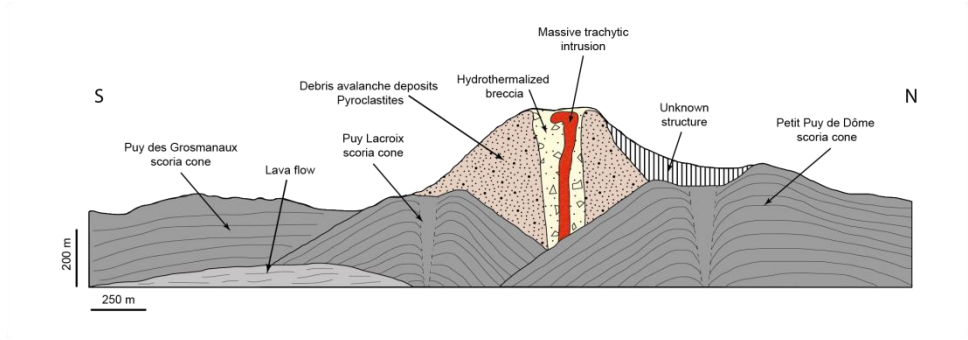




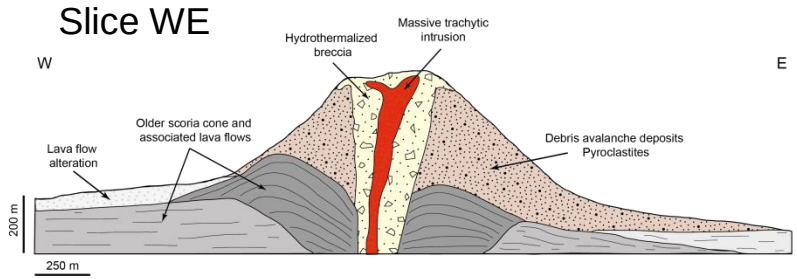


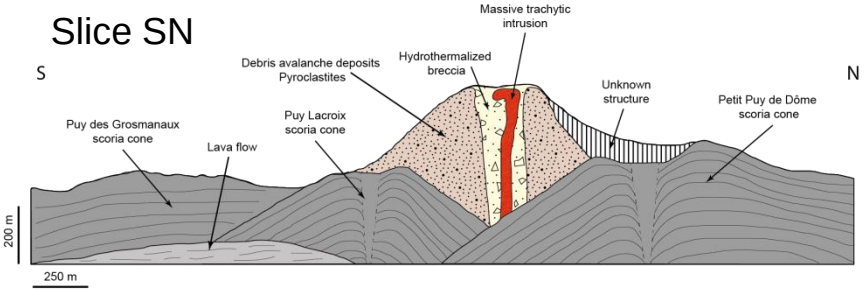






➢ Geological interpretation





- *Basement*
  - older scoria cones partially (e.g. Petit Puy de Dôme) or totaly covered (Puy Lacroix)
  - associated lava flows oriented toward East and West

- *Puy de Dôme*
  - central massive intrusion (dyke) with W-E extension
  - breccia ring around the intrusion, probably highly altered by hydrothermal fluids
  - edifice mainly composed of unconsolidated material (blocks, pyroclastites and breccias)

- Geological interpretation of the northern part of the volcanic system stays difficult

➢ Conclusion

- **Morpho-structural analysis** shows that the Puy de Dôme is a composite edifice

- New **gravity and magnetic anomalies maps**
  - highlight the well identified geological features
  - provide new information about the dome complexity

- **2D direct modeling** of the Bouguer anomaly better simulates complex geological structures whereas 3D approach provides more global information

- Comparison with complementary geophysical models (ERT, muography) give constraints about the geological structure of the dome *(see Portal et al., 2015, GMPV6.5 poster session)*

- Observations of recent domes growth suggest composite structure of dome after the end of the eruption

Confirmed by our study of the Puy de Dôme volcano !

Thank you for your attention !

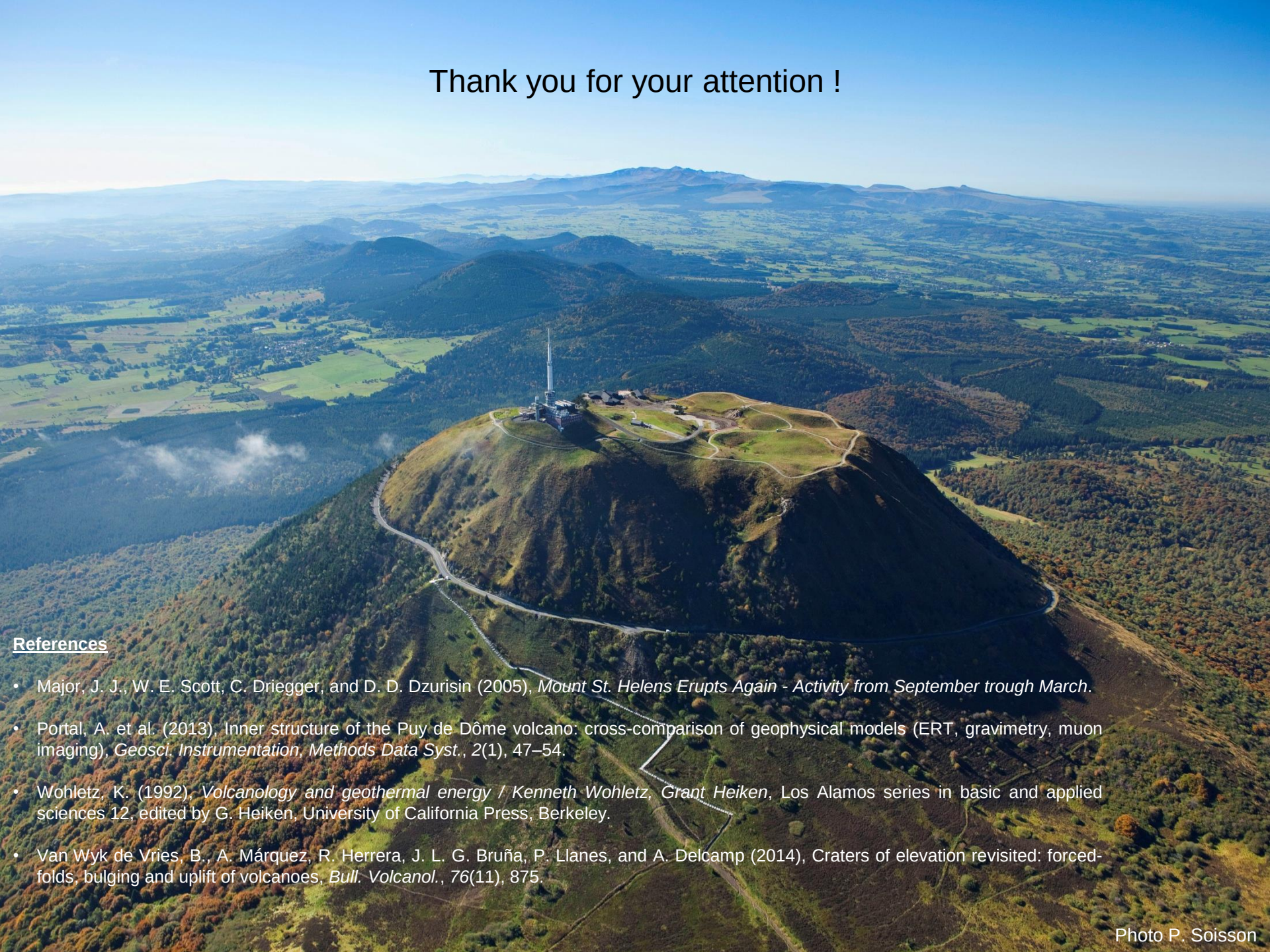


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Photo P. Soisson