The link between magma degassing and the dynamics of explosive eruptions of compositionally monotonous andesite-dacite volcanoes (Ciomadul, Eastern Carpathians)

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Introduction

This report presents the results of the post-doc research project entitled" The link between magma degassing and the dynamics of explosive eruptions of compositionally monotonous andesite-dacite volcanoes (Ciomadul, Eastern Carpathians)" supported by the NKFI fund PD-16. The host institute was changed after the first year and the project was continued at the Eötvös Loránd University under a new project number. This final report contains the results of the whole project independently from the project number.
Understanding the processes responsible for the eruption styles of volcanoes are crucial due to the social and environmental impact of volcanic eruptions. The present research study aims to deepen our knowledge about the control of conduit processes on the changing eruptive styles of the volcanoes which are fed monotonously by dacite (andesite) magmas. Ciomadul volcano is a unique natural laboratory for such studies due to several reasons:

- the most important point is the geochemistry of the erupted magmas because the Ciomadul dacite belongs to the high-K Calc-alkaline series which composition is rarely studied. The alkaline content influences the viscosity and crystallization conditions of the silicate melts, both is strongly affect conduit processes.
- almost all knowledge of volcanic conduits is based on volcanoes from subduction zones but Ciomadul was grown in a post-collisional geodynamic setting.
- Ciomadul has an extremely small erupted volume ~8 km^3 and it is characterized by low-frequency and very low average output rate but long lifetime ~1 million year.
- the available data suggest that Ciomadul produced lava domes for most of its lifetime except the last eruption period during which pumiceous layers were also produced.
- the pre-eruptive magma chamber conditions can influence the eruption style but in the case of Ciomadul this effect can be neglected. Thus, the eruption style of the volcano can be directly linked to the conduit processes.

All of these indicates that studying of Ciomadul can provide new aspects for monotonous dacite(andesite) volcanoes.

It shall be noted that this study is a pioneer in our region because it is the first example (according to my knowledge) for such a complex study of conduit processes including the analyses of textural, geochemical and physical properties of pyroclasts to understand the eruption styles of volcanoes. So this project establish the basis of this perspective of volcanology and petrology in our country also.

Ciomadul volcano

Ciomadul is intensively studied in the last 5 years and several new results were published. These

were focusing on the volcanology, stratigraphy, geochronology and on the temporal, spatial evolution of the volcano. The results are controversial especially in the case of the young pumiceous layers, while every one agree in the possible rejuvenation of the volcanic activity at the area. Although the lack of any active monitoring system on the volcano hampers any prediction for the rejuvenation theoretically the chance is very low. Regardless of this lot of data is still necessary to understand the past activity of the volcano.
Although recently there are some debate especially about the stratigraphy and temporal evolution of the volcano, there are some important common results. All study found that Ciomadul has a ~1 million year long lifetime during which very low amount of magma erupted. The erupted composition is high-K dacite dominantly. It is also commonly found that the eruption rate increased dramatically ~200-150 kyrs ago. One of the most interesting common point is the change of the explosivity of the volcano as all study concluded that high-intensity explosive eruptions occurred only during the most recent active period in the last ~60kyrs.

Results

List of outcrops involved into the field work and the observed units from bottom to top (Detailed descriptions are not presented here):

- Bolondos-hegy(Bl) layered pumiceous sequence
    - Unit A: pumice rich lapilli stone
    - Unit B: layered tuff and pumiceous lapilli stone sequence
    - Unit C: lapilli stone, occasionally with bread crusted lapillus
- Románpuszta(Rp) layered pumiceous sequence
    - Accretionary lapilli tuff exposing close to the pumice sequence but it's connection to the pumiceous layers is unclear.
    - Unit A: Pumice rich lapilli stone
    - Unit B: layered tuff and pumiceous lapilli stone sequence
- Sepsibükszád(Bx) layered volcanoclastic sequence
    - Unit A: cross stratified epiclastic sediment
    - Unit B: coarse grained dacite breccia
    - Unit C: white lapilli tuff deposited in a valley
- Mohos(Moh) layered pumiceous sequence
    - Unit A: layered lapilli stone
    - Unit B: layered tuff and pumiceous lapilli stone sequence
    - Unit C: gray lapilli tuff
    - Unit D: white lapilli stone with bread crusted bocks
- Döngő(Dg) layered volcanoclastic sequence
    - Unit A: layered, pumiceous, brown lapilli tuff sequence
    - Unit B: white lapilli stone with bread crusted blocks
    - Unit C: reworked volcanoclasit sediment
- Tusnádfürdő(Tf) layered volcanoclastic sequence
    - Unit A: layered pumiceous lapilli stone
    - Unit B: brown tuff layer
    - Unit C: reworked volcanoclastic sediment
    - Unit D: pumiceous lapilli tuff

This satellite image shows the Ciomadul and the studied pumiceous outcrops(LP: layered Pumice Sequence, LV: Layered Volcanoclastic Sequence).

I was focusing on the primary pumiceous units and layers.
They can be classified as:

- (Sub)Plinian fall out deposits (stable eruption column):
  - Tf Unit A
  - Moh Unit A
  - Rp Unit A
  - Bl unit A
- Subplinian PDC deposits (collapsing eruption column):
  - Tf Unit D
  - Dg Unit B
  - Moh Unit B
  - Rp Unit B
  - Bl Unit B
- Vulcanian fall/flow deposits
  - Dg Unit C
  - Moh Unit D
  - Bx Unit C
  - Bl Unit C
  - Moh Unit C

Vulcanian flow deposit. Bx Unit C

Subplinian PDC deposits (collapsing eruption column). Moh Unit B

(Sub)Plinian fall out deposits (stable eruption column). Bl Unit A

Vulcanian bread crusted bomb with vesicular interior and glassy rind. (loose material).

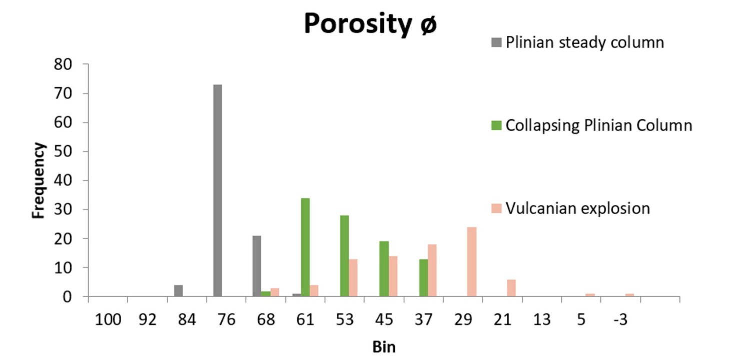
The vesicularity of the juvenile clasts which represents the bulk porosity was determined based on density measurements of 1800 clasts from 18 layer from the Moh and Tf outcrop to cover all of the above mentioned eruption style. The density and porosity values show large range in case of the whole data set and based on the porosity value the juvenile clasts were classified as:

- Extremely porous: 95 - 80%
- Highly porous: 80-60 %
- Moderately porous: 60-40%
- Poorly porous: 40-20%

- Non porous: <5%

The eruption styles can be distinguished based on the porosity mean value and interquartile range.

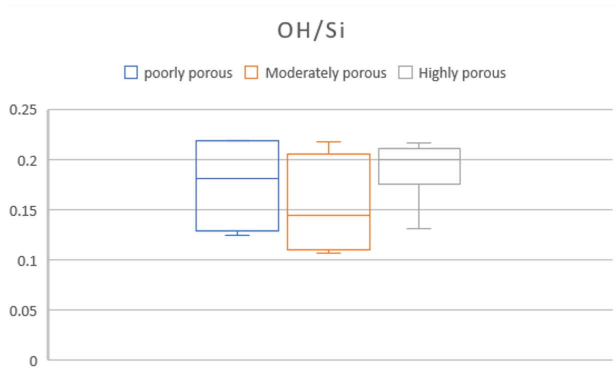
- (Sub)Plinian fall out with steady column:
  - high porosity, narrow range
- Subplinian PDC deposits (collapsing eruption column)
  - moderate porosity, moderate range
- Vulcanian explosion
  - Moderate and poor porosity, wide range



Examples for porosity distribution of different eruption styles.

The matrix glass volatile content was studied with Raman spectroscopy in 12 layer from the Moh and Tf units including the above mentioned eruption styles, units and density groups. Asymmetric peeks in the ~3000-3800 cm^{-1} vibration region indicates H_2O dissolved in the glass. The alumino-silicate domain was also recoded for internal calibration. The recorded water band area was normalized to the area of the bands of the alumino-silicate region in case of every measurement. Peaks of crystalline phases were often recognized in the glass, especially in the denser, less porous clasts. These are interpreted as microlites. The calculated OH/Si ratio fall within the range of 0.1-0.2 independently of the porosity of the studied clast. This indicates, that denser, less porous clasts represents efficiently degassed, densified magma portion.

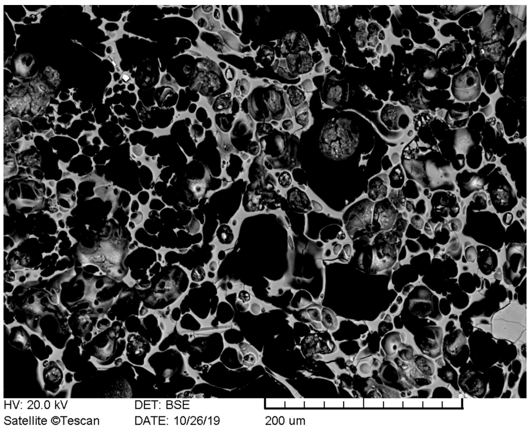
Based on the calibration curve defined for this study this OH-Si range is equal to ~0.6 - 1.3 wt% H_2O.



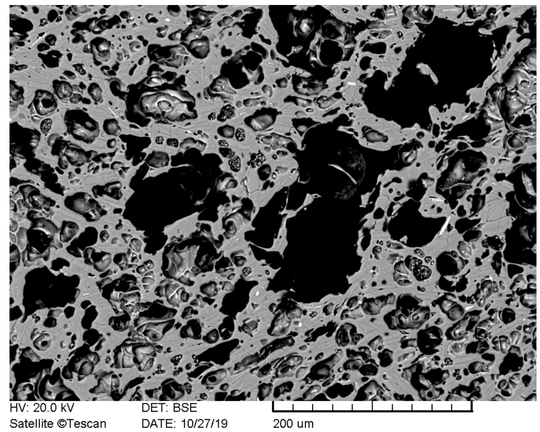
OH/Si ratio of the matrix glass.

The micro texture of representative clasts from the different porosity groups from 10 layer of the Moh and Tf units involving the different eruption styles were studied by BSE and neutron tomography to characterize the vesicle and microlite shape and size. One sample from the Kövesponk lava flow was also studied as an effusive example. This effusive eruption is the only

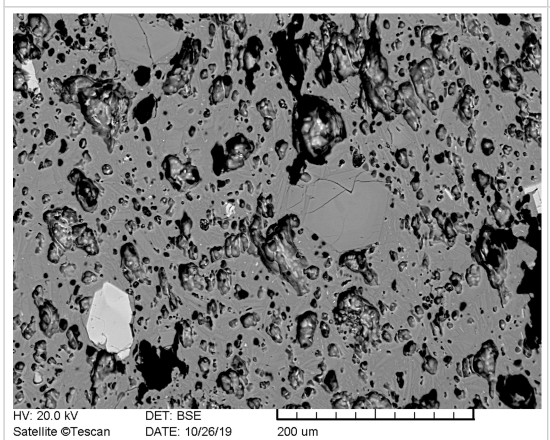
known effusive example which was coeval with the explosions.
The textural characteristics are in close connection with the density of the clasts. Only low density, highly porous clasts (ø ≥ 80%) are really foamy with no or minor microlite content, thin and rounded vesicle walls and coalescing bubbles. Sheared clasts with higher microlite content are also occur in the high porosity group. The clasts from higher density and lower porosity groups show larger microlite content with evolved crystal shape and vesicles with irregular surface and deformed vesicles. The studied lava sample show variable matrix texture with squeezed vesicles or totally dense parts. Vesiculation at phenocryst's side were often observed but bubble nucleation was mainly homogenous based on the foamy low density clasts.



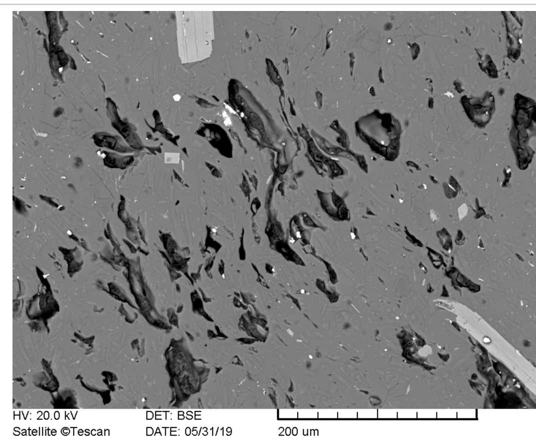
Highly porous foamy clast rounded vesicles.



Moderately porous clast with deformed vesicles.

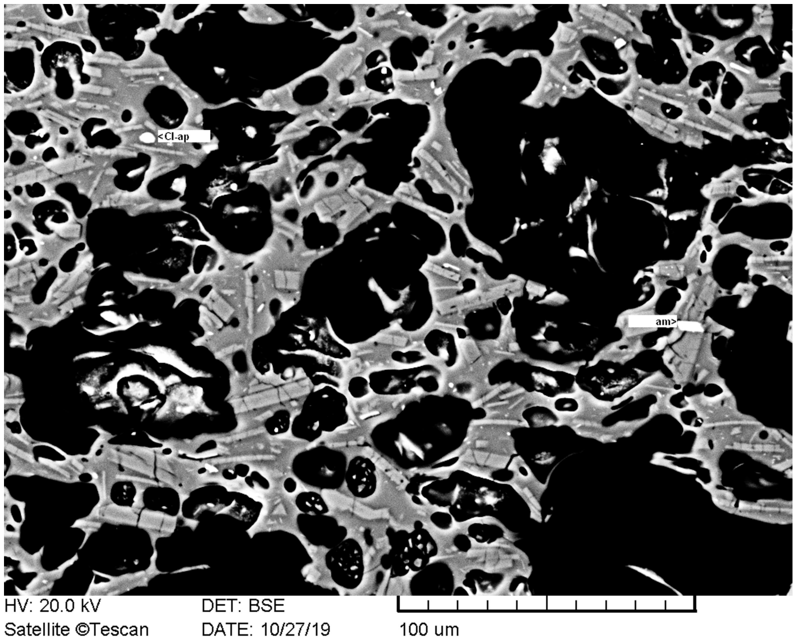


Poorly porous clast with deformed vesicles.



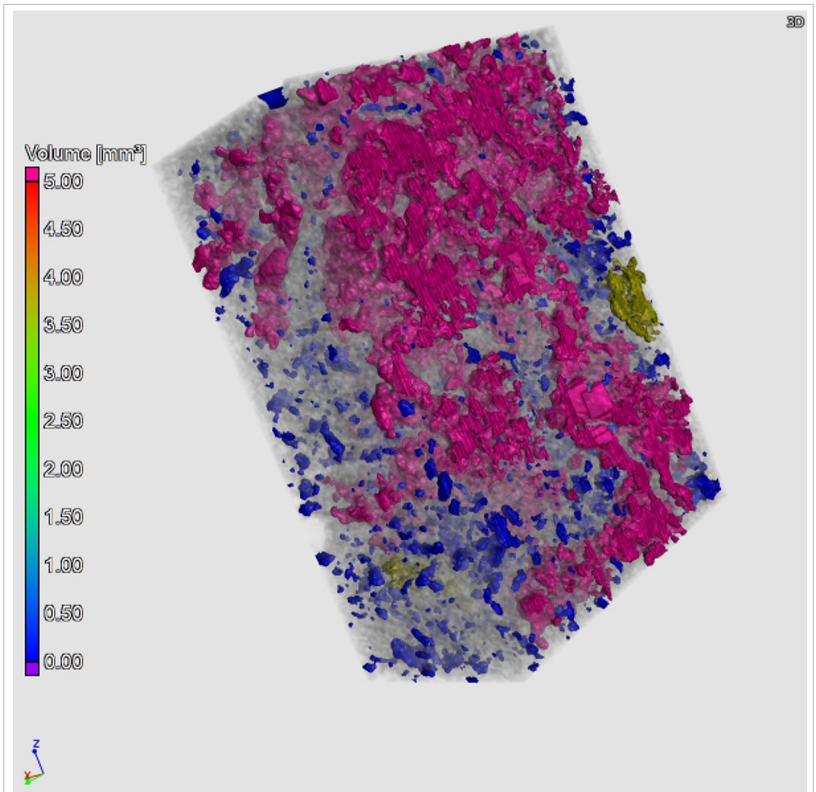
Lava sample with squeezed vesicles.

Microlites are dominantly plagioclase but surprisingly amphibole, biotite and Cl-apatite were also observed which is unexpected in conduit conditions. The late crystallization of minerals containing OH, Cl indicate that the upward moving melt volatile budget was controlled by the combination of degassing due to decompression and crystallization.



Example for Cl-apatite, amphibole (red) and abundant plagioclase (grey needles and laths) microlite.

The resolution of the neutron tomography was ~200 µm and it is used to characterize larger sized vesicle population which can not be well studied in thin section. The NT study revealed that 1/5-1/6 of the porosity can be observed above this resolution threshold indicating a fine grained vesicle size in the Ciomadul dacite. Large interconnected vesicle network can be found in some clasts which probably represent high permeability conduit portions.



Example for large interconnected vesicle network.

Publication

The results of this study are being presented in the VMSG2020 conference.
Two manuscript is also under preparation which will discuss the above mentioned results.
Some of the results were already presented in two publication but in these papers the focus was not on the conduit processes.