



**European Network of
Observatories and Research Infrastructure for Volcanology**

Deliverable Report

D19.1 Report on the WP19 TA activities during the project

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Summary

Within WP19 - *Physical access to on-site modelling resources including hazard assessment tools* the provider CSIC offers Transnational Access (TA) to 2 installations (On-site modelling resources and hazard assessment tools). CSIC infrastructure is the largest public multidisciplinary research organization in Spain. The Geosciences Barcelona (GEO3BCN - CSIC), former Institute of Earth Sciences Jaume Almera (ICTJA), is one of the main CSIC centres dedicated to Earth Sciences. The Group of Volcanology of Barcelona (GVB)(<https://gvbcsic.wordpress.com/>), offering the TA to both installations, has vast experience in numerical and experimental modelling of volcanic and related processes oriented to the quantitative assessment of the parameters controlling volcanic phenomena in active areas, as well as in the development of hazard assessment and risk management e-tools and methodologies to be applied in active volcanic regions. Moreover, under the framework of the European project VeTools (EC ECHO Grant SI2.695524), the GVB has created a multiplatform method (VOLCANBOX, <http://www.volcanbox.eu>) for assessing hazards and risks. For both EUROVOLC Transnational Access calls, access has been organized in two phases: (1) physical on-site access to the modelling resources and hazard assessment tools (2 weeks); (2) guaranteed remote assistance during research development (2 weeks). In each EUROVOLC Transnational Access call, GEO3BCN-CSIC has offered access to 3 projects for each TA. GEO3BCN-CSIC has provided to each successful project on-site and remote scientific assistance by highly trained staff on aspects related to: (i) the selection and preparation of the required input data, (ii) potential problems when setting-up and running of the tools, and (iii) doubts that raised once obtained the results and while interpreting them. Besides, the GEO3BCN-CSIC has offered technical (incl. computational capacities), logistic and administrative support. During the duration of the project the main actions carried out within WP19 have included:

- * Description of the infrastructures to be offered in the 1st and 2nd EUROVOLC Transnational Access calls.
- * Maintenance, update and fine-tuning of the infrastructures to be offered in the 1st and 2nd EUROVOLC Transnational Access calls.
- * Technical evaluation of the project applications received during the 1st and 2nd EUROVOLC Transnational Access calls.
- * TA access and management of the users' logistics and provision of administrative support prior to the access of the project applications received during the 1st (M6) and 2nd (M18) EUROVOLC Transnational Access calls.
- * Participation in the design of the EUROVOLC Transnational Access database and the register of the CSIC infrastructures into the database. The services offered by CSIC within WP19 are: (i) Physical access to on-site modelling resources, and (ii) Physical access to on-site hazard assessment tools.

Overall in the two calls, WP19 received a total of 5 (4 in the 1st call and 1 in the 2nd call) proposals of which 3 (2 in the 1st call and 1 in the 2nd call) were positively evaluated for funding. It is noteworthy that besides the mere provision of access and the logistic support offered, all TA

activities have also promoted scientific collaborations that are still continuing, thus contributing to the networking and community building aims of EUROVOLC.

Introduction

Provider and installations offered during the 1st and 2nd EUROVOLC Transnational Access calls

The installations offered for Transnational Access (TA) within WP19 are provided by CSIC, the largest public multidisciplinary research organization in Spain. The Geosciences Barcelona (GEO3BCN - CSIC), former Institute of Earth Sciences Jaume Almera (ICTJA), is one of the main CSIC centres dedicated to Earth Sciences. The Group of Volcanology of Barcelona (GVB)(<https://gvbcsic.wordpress.com/>), offering the TA to both installations has vast experience in numerical and experimental modelling of volcanic and related processes oriented to the quantitative assessment of the parameters controlling volcanic phenomena in active areas, as well as in the development of hazard assessment and risk management e-tools and methodologies to be applied in active volcanic regions. The GVB has expertise in simulating numerically pre-eruptive processes occurring in a volcanic system with the Finite Element Method and has access to some of the most sophisticated computational resources worldwide. Moreover, under the framework of the European project VeTools (EC ECHO Grant SI2.695524), the GVB has created a multiplatform method (VOLCANBOX, <http://www.volcanbox.eu>) for assessing hazards and risks. It is a novel resource to improve volcanic hazard and risk assessment and management capacities in active volcanic regions.

In both EUROVOLC Transnational Access calls, the GEO3BCN-CSIC has offered access to two installations:

Physical access to on-site modelling resources (Task 19.1) (including initial training, guidelines and technical assistance) to simulate with the FEM modelling software COMSOL Multiphysics (<https://www.comsol.com/>): (i) thermo-fluid dynamic processes occurring during the pre- and syn-eruptive phases of magma injection, accumulation and cooling; and (ii) local and regional stress field of a volcanic area. Figure 1 shows an example of simulations produced by COMSOL Multiphysics.

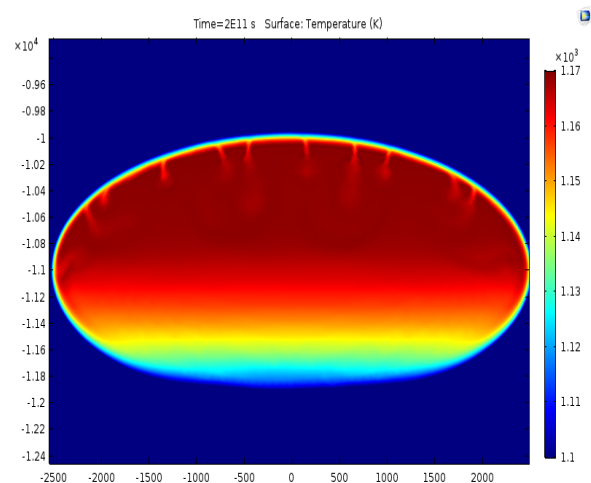


Figure 1: Example of simulations of magma chambers with COMSOL Multiphysics.

Physical access to on-site hazard assessment tools (Task 19.2) (including initial training, guidelines and technical assistance) to use VOLCANBOX. VOLCANBOX (see interface on figure 2). is an e-tool that integrates, in a systematic and sequential way, a series of well-tested tools addressing various aspects of the volcanic hazard processes and risk assessment by providing an integrated set of e-tools and methodologies to conduct long- and short-term hazard assessment. VOLCANBOX looks at how to make scientific information understandable for decision makers and community planners who manage risk in volcanic areas. Through step-by-step instructions, scientists using VOLCANBOX show community planners how to identify the most probable eruptive scenarios and their potential effects, which helps officials triage emergency responses in the event of an eruption.

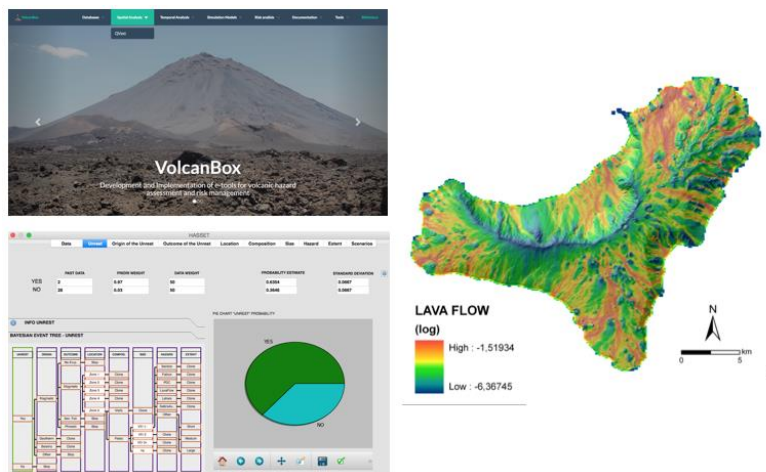


Figure 2: Screenshots of the VOLCANBOX tool and example of potential results.

In each EUROVOLC Transnational Access call, GEO3BCN-CSIC has offered access to 3 projects for each TA (Tasks 19.1 and 19.2). This access has been organized in two phases:

- 1) physical on-site access to the modelling resources and hazard assessment tools (2 weeks);
- 2) guaranteed remote assistance during research development (2 weeks).

GEO3BCN-CSIC has provided to each successful project on-site and remote scientific assistance by highly trained staff on aspects related to:

- i) the selection and preparation of the required input data,
- ii) potential problems when setting-up and running of the tools, and
- iii) doubts that raised once obtained the results and while interpreting them.

Besides, the GEO3BCN-CSIC has offered technical (incl. computational capacities), logistical and administrative support to the TA users.

Preparation activities prior to the access provision offered during the 1st and 2nd TA calls

Previous to the provision of access to the CSIC infrastructures considered in Tasks 19.1 and 19.2, WP19 had to carry out the following activities:

- Provide detailed description of both infrastructures (ICTJA.1 and ICTJA.2) offered during the 1st- and 2nd EUROVOLC Transnational Access calls to be included in the webpage of the TA calls. A full copy of the description of the infrastructures ICTJA.1 and ICTJA.2 presented in the EUROVOLC Transnational Access calls is included in Annex 1.
- Perform maintenance tasks on the offered infrastructures in order for these to be updated, fine-tuned and ready for those projects accepted for funding in the 1st and 2nd EUROVOLC Transnational Access calls.
- Attract potential users for the offered infrastructures using the general dissemination tools and strategies applied in the project. Specific users were also contacted at international and national scientific conferences, workshops and meetings.
- During the second half of October 2018, carry out the technical evaluation of those projects requesting access to the infrastructures ICTJA.1 and ICTJA.2 during the 1st EUROVOLC Transnational Access call. The technical evaluation aimed at assessing the logistic, technical, and financial feasibility of the proposals, based on the characteristics and description of each infrastructures defined and reported in the TA webpage of the project website. In the 1st call, WP19 received 4 proposals of which 2, one per offered infrastructure, were positively evaluated for funding. These were:
 - *“Flowing and cooling of subsurface magma within a growing magma reservoir - MAGMAGROW”* led by Dr. Erika Rochin (Sapienza University of Rome, Italy) (access to ICTJA.1).
 - *“E-tools for short-term volcanic hazard assessment -E-THA”* led by Dr. Diana Jimenez (Universidad Gerardo Barrios, El Salvador) (access to ICTJA.2).
- During January 2019, carry out the technical evaluation of those projects requesting access to the infrastructures ICTJA.1 and ICTJA.2 during the 2nd EUROVOLC Transnational Access call. In the 2nd call, WP19 received 1 proposals that was positively evaluated for funding:
 - *“Dynamic mass transfer at restless volcanoes-DynaVolc”* led by Dr. James Hickey and with Mr. Rami Alshembari as part of the research team (University of Exeter, UK) (access to ICTJA.1).
- Agree with the project PIs funded during the 1st and 2nd EUROVOLC Transnational Access calls the best periods to carry out their project activities and accesses to ICTJA.1 (Task 19.1) and ICTJA.2 (Task 19.2)
- Provide administrative support and facilitate logistics to the TNA users prior to the access of the project applications funded during the 1st and 2nd EUROVOLC Transnational Access calls.

Access provision offered during the 1st EUROVOLC Transnational Access call per Task

Task 19.1 Physical access to on-site modelling resources (ICTJA.1)

1st EUROVOLC Transnational Access call

Following the scientific evaluation process, 1 project proposal requesting physical access to on-site modelling resources (ICTJA.1) was accepted for funding (MAGMAGROW). The access of the project user and the related activities were carried out in two one-week visits during September and October 2019. The splitting of the access for MAGMAGROW project into two visits allowed the optimization of the support offered by the TNA Access. This strategy was convenient for overcoming some issues that required time-consuming tests and bibliographic research that were addressed in the period between the two visits with remote assistance. A short summary of the MAGMAGROW project is provided here and an overview of the results obtained is available in the Main results chapter below.

MAGMAGROW: The MAGMAGROW (*Flowing and cooling of subsurface magma within a growing magma reservoir*) project, led by Dr. Erika Ronchin (Sapienza University of Rome, Italy), aimed at improving the understanding of how magma flows and cools while intruding into a growing reservoir. The goal was to generate Finite Element Method models (FEMs) able to simulate the interaction of processes that in nature interplay during the life of a magma reservoir, but that are still treated separately in model literature: magma flowing, cooling, and deformation of the reservoir. Results about how magma flows, sinks, and accumulates while cooling during the formation of shallow intrusions can help in investigating dynamics, extent, and causes of reservoir instabilities, contributing to the understanding of volcanic activity and associated hazards. Improvement in the understanding of magma migration in shallow magma reservoirs and the evolution of heat transfer in a cooling reservoir have implications in the interpretation of volcanic activity and in the production of geothermal energy.

2nd EUROVOLC Transnational Access call

Following the scientific evaluation process, 1 project proposal requesting physical access to on-site modelling resources (ICTJA.1) was accepted for funding (DynaVolc). The access of the project user and the related activities were planned for Spring 2020 but were postponed due to the COVID19 pandemic, first to Autumn 2020 but were finally rescheduled to take place on Fall 2021. Due to this delay on the access, Dr. James Hickey, PI of the DynaVolc project, was not able to carry out the activity and Mr. Rami Alshembari, member of the research team, was the final user of the infrastructure. Due to visa expedition problems and the proximity to the end of EUROVOLC project, Mr. Alshembari could only visit the infrastructure for five days instead of 2 weeks as previously expected. Considering this, on-line meetings have been carried out to offer the complementary technical support to finish the project. A brief overview of the DynaVolc project goals is provided here and an overview of the results obtained is available in the Main results chapter below.

DynaVolc: DynaVolc (*Dynamic mass transfer at restless volcano*) project, led by Dr. James Hickey (University of Exeter, UK) and with the participation of Mr. Rami Alshembari, had the objective to investigate the influence of poroelastic mechanical behaviour on reservoir pressure evolution and the

resultant spatio-temporal surface deformation. Identifying the underlying physical properties of magma reservoirs and their mechanical behaviour is of great importance for enhancing geophysical models that aim to understand the subvolcanic system's evolution and help inform hazard monitoring and mitigation. Widespread evidence suggests that large melt-dominated magma bodies are difficult to sustain for a significant time-periods, and that melts instead mostly reside within crystalline reservoirs, consisting of variably packed frameworks of crystals and interstitial melt. Current volcano deformation models assume static magmatic sources and thus provide little insight into dynamic internal reservoir processes; they ignore the presence of crystals, melt and other fluids, and therefore the likely poroelastic mechanical response to melt intrusion or withdrawal.

Task 19.2 Physical access to hazard assessment tools (ICTJA.2)

1st EUROVOLC Transnational Access call

In the frame of the 1st EUROVOLC Transnational Access call, 1 project proposal requesting physical access to hazard assessment tools (ICTJA.2) was accepted for funding (E-THA). The access of the project user and the related activities were carried out during September 2019. A short summary of the E-THA project is provided here and an overview of the results obtained is given in Main results chapter below.

E-THA: The main objective of the E-THA (*e-Tools for short-term volcanic Hazard Assessment*) project led by Dr. Diana Jimenez (Universidad Gerardo Barrios, El Salvador) was conducting a short-term temporal analysis for San Miguel volcano, to compare the evolution of variables and calculate the probability of scenarios characterized by those indicators. San Miguel volcano has had several apparently similar unrest periods, from which only a few ended in eruption. Therefore, it is important to try to fully understand its behavior to successfully face volcanic crisis. The main aim of project was to conduct a short-term temporal analysis for San Miguel volcano, to compare the evolution of variables, identify the increase or decrease of the volcanic activity and make exercises to estimate probability of the occurrence of eruptive scenarios combining monitoring and past data. The development of this study represented a step forward to assess volcanic hazard in El Salvador and contributed to considered to add other methodologies as other tool for scientist at the National Observatory of Ministerio de Medio Ambiente y Recursos Naturales (OA-MARN) and for Civil Protection agency to face future volcanic crises in the country.

Main results

Task 19.1 Physical access to on-site modelling resources (ICTJA.1)

A brief overview of the main preliminary results obtained during the projects funded during the 1st and 2nd EUROVOLC Transnational Access calls is presented here. Thanks to the provision of access, all TA activities have also promoted scientific collaborations that are still continuing, thus contributing to the networking and community building aims of EUROVOLC.

1st EUROVOLC Transnational Access call

MAGMAGROW: Models generated during the MAGMAGROW project were able to simulate the flowing, cooling, and accumulation of magma, together with the deformation of the rock hosting this magma (Fig. 3). These new models combined several interacting aspects: (1) the simulation of flow patterns, in space and time, of a magma with properties (e.g., viscosity and density) that strongly change during cooling, thus affecting the flow, and (2) the coupling of the migration of this magma with the expansion of the reservoir. The model simulated the intrusion of magma into a shallow reservoir that can expand by deforming the surrounding host rock. It simulated the evolution of magma flow and magma properties (velocity, viscosity, temperature, and solidity) over time in a semi-open magmatic system that exchanges heat with the host rock through the wall rocks (blue line in Fig. 1c) and accepted the influx of new magma from the inlet of the conduit. This results in a problem of heat transfer in forced-convection, non-isothermal laminar flow that moves through an inflating magma reservoir. This is an example of a coupled fluid-structure system in which large structural deformation occurs. The two-way coupling between deformation of the solid host-rock and the flow in the fluid is implemented using the Fluid-Structure Interaction (FSI) module of COMSOL Multiphysics Software.

The models have the ability of simulating some flow structures that are commonly observed in the field (Fig. 4). Although the models built are applied to study shallow magma reservoirs, the same approach and coupling of physics can be applied to different geometries (i.e., bigger and deeper reservoirs), expanding the possibilities of systems and processes to be investigated.

This access opened up new collaborations, between the Access Provider and Dr. Ronchin. Moreover, during her stay at the research infrastructure, Dr. Ronchin had the opportunity, through the Access Provider, to meet other researchers that work in complementary fields and to discuss with them possible future research together.

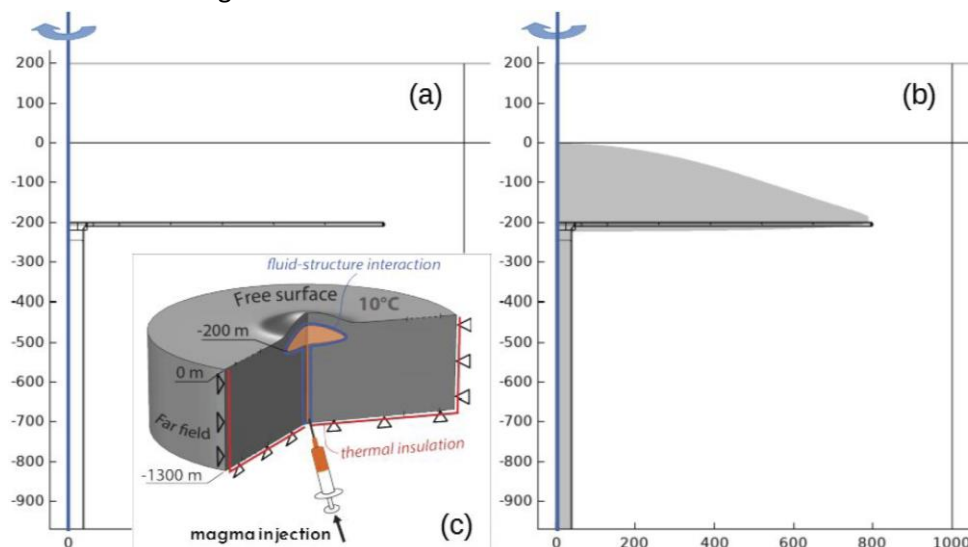


Figure 3: Details of the axis-symmetric model and reservoir geometry. (a) Initial geometry (sill). The layer between 0 and 200 m is used to simulate the lithostatic pressure at 200 m depth; (b) final shape (laccolith) after magma replenishment, (c) scheme (not to scale of boundary conditions). The initial thermal condition is a specified geothermal gradient of 30°C/km across the host rock domain (crust), with uniform lateral temperature profile.

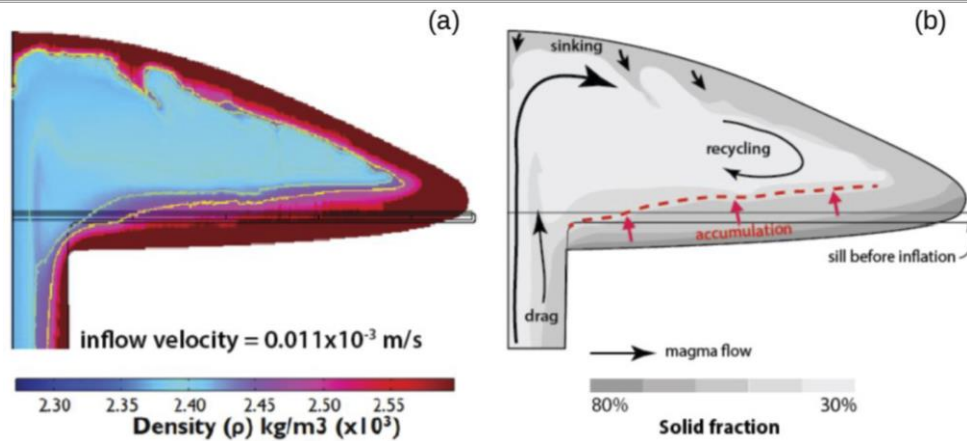


Figure 4: Example of some results computed by the model at a specific time. (a) Density distribution and (b) solid fraction distribution within the growing reservoir during the phase of forced-convection. Identified mechanisms of magma flow and magma accumulation within the reservoir.

2nd EUROVOLC Transnational Access call

DynaVolc: In the models generated in the framework of the DynaVolc project, the magma reservoir is considered to be crystalline, with melt distributed between solid crystals. Hence, the magma reservoir is simulated as porous, and to behave poroelastically (Fig. 5). The aim is to investigate how crystal-rich reservoirs react mechanically and dynamically to melt intrusion or withdrawal events, and the associated surface deformation. More specifically, the project seeks examining by using dynamic poroelastic magma reservoir models: (i) the role of magma and reservoir properties (e.g., viscosity, compressibility) on spatial and temporal surface deformation pattern on spatial and temporal surface deformation patterns; and (ii) examine how spatial and temporal deformation evolve in space and time following an injection and a withdrawal of melt from a poroelastic magma reservoir. Preliminary results obtained indicate that during the injection period, the fluid pressure within the reservoir increases linearly and drives the diffusion of melt content from the injection point toward the top of the reservoir and generates the syn-injection deformation. The magnitude of the syn-injection deformation depends primarily on the diffusion rate. Hence, surface inflation is greater for high-porosity reservoirs and decreases with low porosity (less permeable) reservoirs where the diffusion rate is lower (Fig. 6). The speed of this process is constrained by the finite diffusivity, which is a function of the mush and melt characteristics. For a low porosity mush (low permeability), the diffusion rate is slow, leading to a low rate of post-injection surface deformation, and vice versa for a high porosity mush (high permeability) (Fig. 6; j, k, l). In addition, with a decrease in permeability, the reservoir deformation becomes increasingly localized due to fluid accumulation around the injection source (e.g., Fig. 6h).

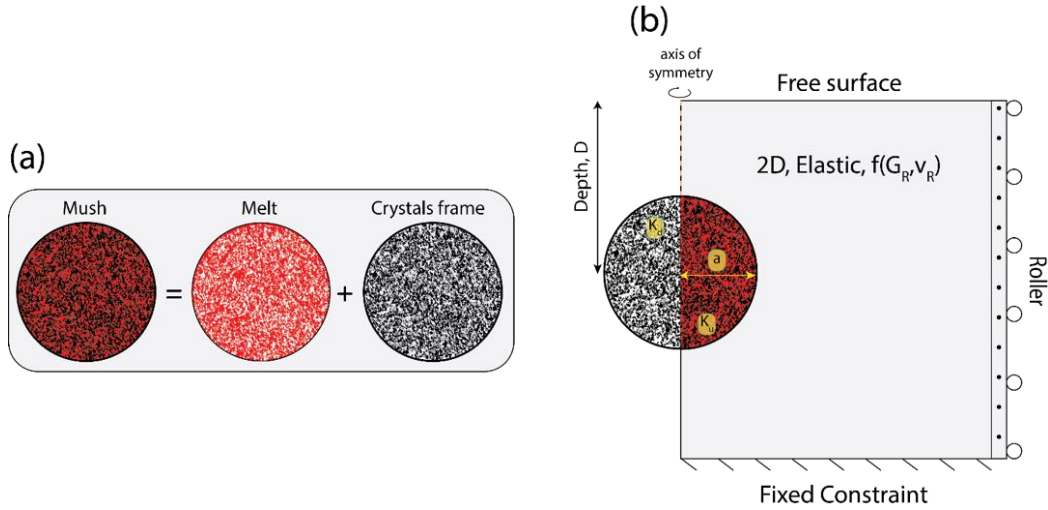


Figure 5: DynaVolc project model setup. (a) Representation of the mush definitions; the mush consists of both the crystal skeleton and the interstitial melt in the pores. (b) Illustration of the model in a 2D axisymmetric geometry. A shallow, spherical crystalline (poroelastic) magma reservoir of radius a at a depth D , surrounded by an elastic host rock of Shear Modulus G_R and Poisson's Ratio ν_R .

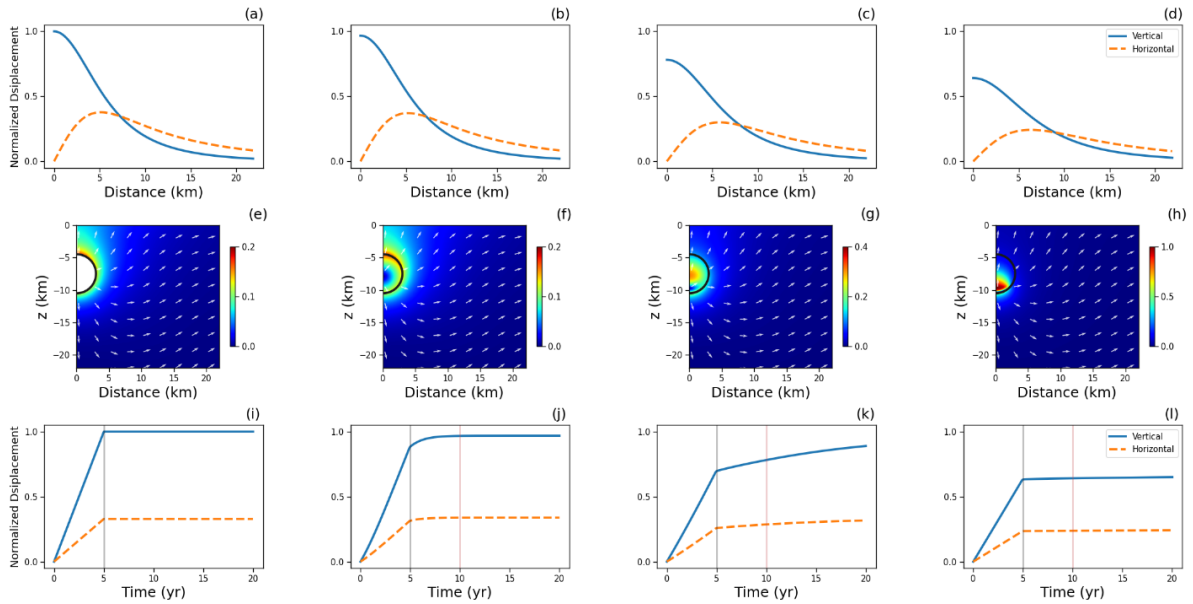


Figure 6: The normalized surface deformation with distance and time due to a uniform rate of melt injection into a spherical reservoir at depth $D = 7.5$ km, (a) Vertical and horizontal deformation for a melt dominated reservoir. (b)-(d) Three cases of reservoir porosities ($\phi=0.5, 0.3$ and 0.1 , respectively) at time $t=10$ years. (e)-(h) Subsurface normalized displacement (combined vertical and horizontal) distributions. (i)-(l) Normalized temporal evolution of the vertical deformation at $r = 0$ and the horizontal deformation with time at $r = D$.

Task 19.2 Physical access to hazard assessment tools (ICTJA.2)

1st EUROVOLC Transnational Access call

E-THA: San Miguel is one of the most active volcanoes of El Salvador with at least 28 eruptions in the last 430 years. The volcano is surrounded by several villages and cantons, which could be seriously affected in case of a new eruption. San Miguel's historical data show different episodes of unrest that need to be analyzed in order to fully understand the periods of increased activity and their possible relation with monitoring parameters. Within the framework of the E-THA Dr. Diana Jimenez used the HASSET short term e-tool to estimate the probability of occurrence of a particular eruptive scenario combining monitoring data with information on past eruptions and unrest episodes. For this study, monitoring data from 2002 to 2019 and the long-term hazard assessment for San Miguel were considered. Input information included: (i) 144 volcanic reports for San Miguel volcano; (ii) monitoring information (seismicity, Real-time Seismic-Amplitude Measurement (RSAM), SO₂ and superficial temperature) including data from 16 unrest episodes in the last 16 years and one eruption VEI 2 on December 29, 2013. The same scenario (i.e. total seismicity, RSAM, shallow seismicity, and VT) is compared within each unrest period. Preliminary results obtained indicate that the estimated probability of an imminent eruption considering this scenario is more consistent with the behavior in the next bulletin. For instance, in 2009 there were 2 unrest that ended in no eruption, in Figure 5 we can see the probability estimated is less than 1%; unlike to take others as RSAM that in most of the cases overestimate probabilities (Fig. 7). Results obtained in the framework of this access have been also of use for WP12 activities (Task 12.1) and are reported in detailed in Deliverable report D12.2.

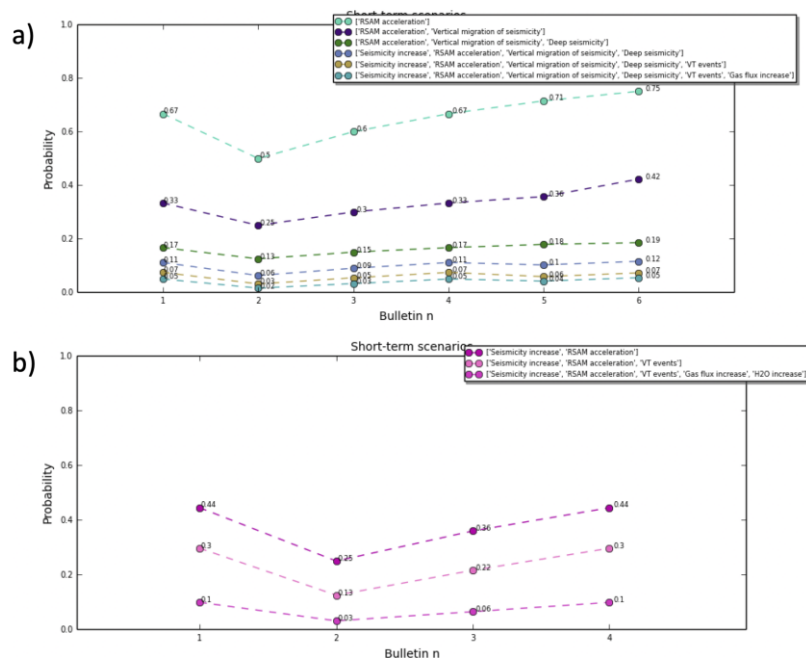


Figure 7: ST-HASSET the evolution of the unrest indicators for unrest in January 2014. Considering different scenarios (a), and RSAM scenarios and VT (b).

Concrete results

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