

# EUROVOLC

## European Network of Observatories and Research Infrastructure for Volcanology

### Deliverable Report

#### D16.1 Report on the WP16 TA activities during the project

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## Summary

The WP16 was designed to provide access to the Azores Volcano Observatory offering a unique opportunity for users from different contexts (volcanological stakeholders – research institutions, academics, students, industries, etc.) to perform research experiments on some Azorean volcanoes, in this case in the ones existing in S. Miguel Island. This offer intended to contribute to the strengthening of the volcanological community through a closer contact with the challenges provided by active volcanoes either by the singular fieldwork environments and/or by the high demanding volcano observatory interdisciplinary work experience, which ultimately will conduct to cutting-edge research and to technological innovations. To accomplish this, CIVISA offered access to its facilities and to fieldwork to carry out different types of experiments.

Two calls for transnational access were opened by EUROVOLC, in the months of August 2018 and 2019. For the first call no proposal to the Azores Volcano Observatory was received but four proposals were received in the second call, of which three were accepted. In total, one application request access only for fieldwork and the two other requested access for both AZVO facilities and fieldwork.

Due to the global COVID-19 pandemic none of the approved proposals foreseen for summertime of 2020 could be executed, and all of them were postponed to the summer of 2021, following the 10-month extension of the EUROVOLC project.

## Introduction

The Azores Volcano Observatory infrastructure (AZVO) is operated within the Centre for Information and Seismovolcanic Surveillance of the Azores (CIVISA), located at one of the buildings of the University of the Azores in Ponta Delgada, S. Miguel Island. Having the University of the Azores as an associated entity, CIVISA benefits from the scientific support of all members and collaborators from IVAR (Institute for Volcanology and Risk Assessment). CIVISA is responsible for the natural hazards monitoring, operating multiparametric monitoring networks from S. Miguel Island. Regarding volcanic hazard it comprehends the monitoring of all active volcanoes in the Azores islands. The infrastructure includes instruments and multidisciplinary laboratories to support research and monitoring activities. Two installations/facilities were offered, keeping the access to the existing, permanent monitoring infrastructure and databases:

1. AZVO facilities consisted of the AZVO Building - Access to CIVISA's office spaces including access to computers, internet, office support and multidisciplinary data bases relevant to the activity.
2. Fieldwork consisting of:
  - Fieldwork - Logistic support for field experiments providing vehicles, equipment, including the assistance of one scientist and one technician,
  - Seismic equipment: 3 portable seismic sensors, of which 2 are broadband and 1 are short period stations for field experiments,
  - GPS equipment: 3 GPS instruments, which can be accessed for campaign measurement when not in use.

- Gas equipment: 1 portable station to measure soil gases (CO<sub>2</sub>, CH<sub>4</sub>, H<sub>2</sub>S), 1 portable CO<sub>2</sub> flux station; 1 portable radon station and thermometers.
- additional support equipment needed for powering instruments.

## First call for research proposals

The WP16 participated in all the steps conducting to the definition of the access to the AZVO were established in the agenda of EUROVOLC Project. Indeed, WP16 achieved:

- TA survey - preparation for the launch of the first TA call;
- Definition by CIVISA of the services offered for the first TA call and other supportive information.

The call was opened from August to 10<sup>th</sup> October 2018. No proposals were submitted for the access to AZVO, so CIVISA was not involved in the pre-evaluation of proposals of the first call due to the lack of applicants.

## Second call for research proposals

Overview of second call

The second TA call was open between August and 14<sup>th</sup> October 2019. For this call CIVISA was able to offer the total number of accesses that were foreseen in the project (4), since no application for access to Azores Volcano Observatory was received in the first call, and so no budget was spent. CIVISA was also involved in the dissemination of the advertisements of the second call, both through the input to WP3 and by CIVISA web page.

### Installation and facilities offered for the 2nd call:

- AZVO facilities – Maximum number of Projects: 2
- Fieldwork – Maximum number of Projects: 2

The four proposals that were submitted to access AZVO infrastructure were the following:

- **EV-C2\_016:** 3D mapping of water-dissolved carbon dioxide in lake and sea waters (Azores, Portugal) – 3DCO2 Azores; submitted by Giancarlo Tamburello from INGV (sezione di Bologna), ITALY;
- **EV-C2\_023:** Pyroclastic proxies: Correlating patches of explosive eruption deposits by geochemical and textural characteristics – PYROPRO; submitted by Ulrich Kueppers from LMU Munich, GERMANY.
- **EV-C2\_037:** Constraining magmatic signature of CO<sub>2</sub> at S. Miguel Island (AzoRES) – CORE; submitted by Andrea Luca Rizzo from INGV (sezione di Palermo), ITALY;
- **EV-C2\_042:** Understanding Volcano Unrest: Comparison of volcano unrest at Fogo, Azores and unrest preceding the 2010 Eyjafjallajokull eruptions, Iceland – UNREST; submitted by Freysteinn Sigmundsson from, Institute of Earth Sciences, University of Iceland, ICELAND

**EV-C2\_016:** The proposed time for **3DCO2 Azores** was from 2020-07-20 to 2020-08-07 requesting 36 access (18 days \* 2 persons) to the Fieldwork installation. The aim of the project was to perform 3D mapping of the dissolved CO<sub>2</sub> in offshore sites and in freshwater lake basins, by measuring the partial pressure of CO<sub>2</sub> gas dissolved in liquids using a portable submersible probe for dissolved-CO<sub>2</sub>. Also, the robustness of this new approach would be tested by comparing the results obtained with previous data at the same sites and with simultaneous measurements in water samples.

**EV-C2\_023:** The proposed time for **PYROPRO** was from 2020-08-31 to 2020-09-12, requesting a not clear number of access 24 access for (12 days \* 2 persons) to the AZVO facilities and Fieldwork installations. The aim of the project was to find independent links that would allow for correlating the deposits of the last Sete Cidades volcano eruption (P17 stratigraphic unit) to the supposed vent (Caldeira Seca) inside the caldera, to constrain eruption style and history more precisely and test their genetic correlation via defining geochemical and textural fingerprints. Also, a plan for involving MSc students during field work and laboratory investigations was pointed.

**EV-C2\_037:** The proposed time for **CORE** was from 2020-07-06 to 2020-07-15, requesting 20 access (10 days \* 2 persons), distributed as 5 accesses to the Fieldwork installation and 5 accesses to AZVO facilities. The aim of the project was to compare  $\delta^{13}\text{C}$  from fumaroles with the same measures in CO<sub>2</sub> trapped in fluid inclusions of CO<sub>2</sub>-rich olivines and pyroxenes from already available erupted products, for better understanding the observed variability in relation to gas-water-rock interaction processes and constraining the magmatic signature. This novel approach will allow constraining CO<sub>2</sub> magmatic signature and identifying potential sites suitable for geochemical monitoring,

**EV-C2\_042:** The proposed time for **UNREST** was from 2020-09-14 to 2020-09-24, requesting 20 access (10 days \* 2 persons), distributed as 10 accesses to the Fieldwork installation and 10 accesses to AZVO facilities. The aim of the project was to increase the understanding of the behaviour of the Fogo volcano (Água de Pau) with updating time series of GPS in the area at critical points, and compare the volcano behaviour with that of Eyjafjallajökull volcano in Iceland with numerical models.

## Results of second call

The evaluation process involved two stages regarding CIVISA participation: A two phase evaluation for the technical and logistic evaluation (October-November 2019) and a last phase for the revision/confirmation of the number of projects that could be supported (February). Regarding the two-phase evaluation, CIVISA made the technical and logistic evaluation of the four (4) proposals received, regarding its feasibility, according with the criteria and classification established, in preparation for the subsequent evaluation by the International Scientific Review Panel (ISRP).

In result of the evaluation of the 4 proposals received, and according with the ISRP ranking of the proposals and with the conditions assumed by the Steering Board, regarding the number of projects that could be supported in the 2nd call, three proposals were approved. **EV-C2\_023** PYROPRO was considered as being outside of the scope of the access offered, and so did not pass the technical and logistic pre-evaluation and was rejected.

## Execution of funded projects

Due to the global COVID-19 pandemic crisis and subsequent travelling restrictions, and the imposed limited access to CIVISA installations at the University of the Azores, none of the approved proposals could be carried out during the foreseen summertime period of 2020, and were forced to be postponed to the summer of 2021, implying a 10-month extension of the EUROVOLC project.

The PIs and their teams were questioned twice to define an alternative plan (Plan B) to carry out their projects remotely with the local support of CIVISA teams, complemented by IVAR members. The first TA survey took place before the summer of 2020 and after the identification of all the constraints to the execution of the proposed work. All PIs agreed that it was very difficult to propose a Plan B to replace the original Plan A. Just the PI of CORE project considered that a different solution could be applied in case of no other option would be available. A second TA survey was done from March to May 2021. This time it was possible to establish a Plan B for each one of the 3 projects. For **3DCO2 Azores** the equipment for sampling would be shipped and CIVISA/IVAR team would carry out the needed fieldwork; samples would be shipped to the PI for lab analysis at INGV labs. For **CORE** the equipment for fieldwork would be shipped by the and CIVISA team would carry out the sample preparation and fieldwork sample collection; sample analysis would be performed both at CIVISA and PI INGV labs after their shipment to the PI. For **UNREST** CIVISA/IVAR team would carry out the fieldwork and data would be analysed by the PI in collaboration with CIVISA/IVAR researchers. It was decided with the PI that all projects (either Plan A or Plan B) would occur only in September 2021, and all possible needed budgets adjustments were identified for each kind of plan considering the imposed COVID-19 restrictions existing at that time.

From May to August 2021, WP16 prepared with the projects PI's all the logistic for the TA activities providing administrative guidelines for the project management by the PI's. Short summaries of the work achieved can be completed with scientific reports. All accesses were planned to be implemented according with what was defined in Plan A with the exception of project **UNREST** which needed to change to Plan B close to the planned starting date and it was performed by CIVISA team. The execution of the accesses was performed according with the dates indicated in Table 1. **3DCO2 Azores** had its time of access reduced relatively with what was previously proposed. Changes were introduced in **CORE** relatively to the initial field work plan regarding the target study areas, being extended to two other islands, S. Jorge and Graciosa. **UNREST** was carried out remotely using and the access number of days for field-work.

Table 1: Planned durations for the 3 TA projects:

Projects	2020		2021	
	Starting date:	Ending date:	Starting date:	Ending date:
EV-C2_016 – 3DCO2 Azores	20/07/2020	07/08/2020	29/08/2021	04/09/2021
EV-C2_037 – CORE	06/07/2020	15/07/2020	26/09/2021	05/10/2021
EV-C2_042 – UNREST	14/09/2020	24/09/2020	26/08/2021	10/09/2021

## EV-C2\_016: 3DCO2 Azores

The **3DCO2 Azores** TA project was carried out from 29<sup>th</sup> of August to 4 of September 2021. The team was composed by Giancarlo Tamburello (PI) and Dmitri Rouwet (both from INGV, Bologna), César Andrade (local host, CIVISA), Fátima Viveiros, and José Virgílio Cruz (both from IVAR/UAc), and CIVISA technical support tea. From the 36 fieldwork accesses previously requested (18\*2p) only 16 (8\*2p) were used.

The 3DCO2 Azores work had as scientific objectives the following points:

- Measure the dissolved CO<sub>2</sub> and physicochemical properties of the waters of Furnas lake;
- Perform the measurements at different sampling sites and at fixed depths;
- Analyse the dataset in order to interpolate the dissolved CO<sub>2</sub> values (pCO<sub>2</sub>) at different depths and around the lake area;
- Find the lateral extension of the deep CO<sub>2</sub> accumulation
- Integrate the interpolated pCO<sub>2</sub> value to obtain the total mass of CO<sub>2</sub> dissolved in the lake.

The field work required 5 days (from 30<sup>th</sup> August to 3<sup>rd</sup> September) to produce a 3D mapping of the dissolved CO<sub>2</sub> at Furnas Lake. Sampling points were selected across the major known degassing anomalies and across the non-degassing areas, in a total of 19 points offshore, 15 points inshore around the lake coast having as reference the previous work of Andrade et al. (2016). Two transects at a higher sampling density across the two main fumarolic bubbling areas were also performed. Two probes for measuring the physicochemical properties of Furnas lake were used (Fig. 1 b,c): a mini-CO<sub>2</sub> probe for measuring the partial pressure of CO<sub>2</sub> gas dissolved in liquids and a multiparametric probe to measure pH, ORP, conductivity, dissolved O<sub>2</sub>, and temperature.



Figure 1: Map of Furnas lake (a) showing the sampling points from boat and by walk along the coast. Fieldwork photos with the Mini-CO<sub>2</sub> (a) and the multi-parameter (b) dropped from boat.

The mini-CO<sub>2</sub> probe from Pro Oceanus is an infrared detector hosted in a cylindrical (length 28 cm, diameter 5.3 cm) acetal plastic body that measures the partial pressure of CO<sub>2</sub> gas dissolved in liquids (pCO<sub>2</sub> range 0-5% vol, accuracy  $\pm$  2% of max range, resolution 0.1% of max range). The measurement requires a certain amount of time ( $t_{63} \sim 3$  minutes) for the equilibration between the CO<sub>2</sub> inside the probe and the dissolved CO<sub>2</sub> separated by a hydrophobic membrane. The mini-CO<sub>2</sub> can reach 600 meters of depth. A rope is required to drop the probe at different depths. The HI9829 multiparametric probe hosts an integrated GPS system and an autonomous sensor for measuring pH, conductivity, redox potential, dissolved oxygen and temperature on a 20m cable. A small boat was used to reach each point of measurement (Fig. 1b,c). A rope was required to drop the probe at different depths. The HI9829 probe was stationed at a constant depth every 2 meters for a few minutes. The mini-CO<sub>2</sub> was stationed at three different depths (1 meter, midpoint, bottom) depending on the max depth of the measurement point.

The measured pCO<sub>2</sub> values will be integrated to obtain a total mass of dissolved CO<sub>2</sub> in the lake. Direct quantification of the total dissolved CO<sub>2</sub> in a volcanic lake is expected to be obtained and the reported methodology opens new perspectives for volcanic lake monitoring and risk assessment.

### **EV-C2\_037 – CORE**

The **CORE** TA project was carried out from 26<sup>th</sup> September to 5<sup>th</sup> October 2021. The team was composed by Andrea Luca Rizzo (PI, INGV-Palermo), Catarina Silva (local host, CIVISA); Vittorio Zanon and Fátima Viveiros (both from IVAR/UAc); and CIVISA technical support team. All the accesses previously requested 10 (10\*1p), fieldwork/AZVO facilities, were used. Changes were introduced to the initial project regarding the target study areas, being extended to two other islands, S. Jorge and Graciosa, upon permission requested to the EUROVOLC project coordination. In the days 28<sup>th</sup> and 29<sup>th</sup> of September fieldwork took place at Graciosa and S. Jorge Islands, respectively. The remaining access days were used in S. Miguel Island.





Figure 2: Study areas where fieldwork was carried out in S. Miguel and Graciosa islands.

The CORE project had as scientific objectives the following points:

- integrate the already available knowledge on carbon isotopic ratios ( $\delta^{13}\text{C} - \text{CO}_2$ ) in the Azores with new measurements in the western part of the S. Miguel Island and the Graciosa Furna do Enxofre.
- Compare the  $\delta^{13}\text{C}$  signature of new and existent data of gases with the same measures in  $\text{CO}_2$  trapped in fluid inclusions of  $\text{CO}_2$ -rich olivines and pyroxenes from already available data of erupted products. This novel approach will allow constraining  $\text{CO}_2$  magmatic signature and identifying potential sites suitable for geochemical monitoring.
- make new  $3\text{He}/4\text{He}$  ratios measurements in a poorly studied spring of S. Jorge (Fajã dos Vimes), whereas on this island no visible degassing is present and the He isotopic signature is not constrained at all.
- improve the existent understanding of the carbon and helium isotopic variability along the Azores, for constraining the local magmatic signatures.

The activities of CORE project comprised three main steps:

- 1) field work and sampling campaign at the Azores;
- 2) first laboratory measurement and preliminary data elaboration at CIVISA;
- 3) following laboratory measurements at INGV-Palermo and more detailed data elaboration

At Graciosa Island, inside Furna do Enxofre lava cave, gases were sampled from a mud pool at boiling temperature and from a soil fumarole, both sampled in previously CIVISA campaigns. At the mud pool and in the soil fumarole (T as high as 92° C) dry gases were collected, using different sampling methodologies, and stored in two glass bottles and in one stainless-steel bottle, and in one Giggenbach bottle filled with about 40% of alkaline solution (4M NH<sub>4</sub>OH, Giggenbach, 1975). On the island of S. Jorge, the water emitted from the Fajã dos Vimes spring was sampled, that had showed before a conductivity of about 200 µS/cm and an alkalinity of 50 mg/L in previous studies carried out by CIVISA. Despite the several difficulties related with the sampling point, to avoid air contamination a silicone tube was inserted in the spring and directly connected to a copper tube equipped with two clamps at its ends. On the island of S. Miguel, a soil CO<sub>2</sub> flux prospection was carried out in the areas of Ferraria and Mosteiros, located at the base of the Sete Cidades volcano, in the western part of the island. The prospection was made in a selected grid of points by using a portable soil CO<sub>2</sub> flux station that performed measurements based on the accumulation chamber method, and the sampling was done in the highest degassing areas where two dry gas samples per point were collected for investigating the  $\delta^{13}\text{C}$  of CO<sub>2</sub>.

Dry gases collected at Graciosa, S. Jorge and S. Miguel Islands were analysed at the laboratories of INGV, Palermo, namely the noble gas laboratory and the stable isotope laboratory. One bottle from Graciosa mud pool was analysed at the Gas Geochemistry laboratory of CIVISA (Azores).

The results that will be obtained on the carbon and helium isotopic signature of Graciosa, S. Jorge and S. Miguel islands are expected to increase the study of the isotopic signature of volatiles and the definition of their spatial variability along the Azores, aiming filling this gap of knowledge.

## **EV-C2\_042 – UNREST**

The **UNREST** TA project was carried out remotely from 26<sup>th</sup> August to 10<sup>th</sup> September 2021 following what was established for its Plan B. The team was composed by Freysteinn Sigmundsson (PI, University of Iceland), Chiara Lanzi (UI), Rita Silva (CIVISA), João Araújo (IVAR/UAc), Teresa Ferreira (IVAR/UAc) and CIVISA technical support team. Due to COVID-19 related issues, the PI of UNREST and its UI collaborator could not travel to the Azores. Fieldwork was assisted by Rita Silva (CIVISA) and João Araújo (IVAR/UAc).

The team worked with colleagues in the Azores to define measurements strategy for GPS stations during fieldwork, from 26 August to 10 September 2021, and to evaluate the ground deformation data available, from unrest periods at Fogo volcano (Água de Pau), with main activity occurring 2003–2006 and 2011–2012. Regular videoconference meetings were kept during the month of October 2021. An important observation is that subsidence follows inflation periods, that may relate to processes that are open not fully modelled, such as: geothermal activity, viscoelastic relaxation, and magma flow back into deeper levels of volcanoes. Models are being evaluated and two papers in preparation on Fogo volcano unrests. Furthermore, EUROVOLC is acknowledged in an associated publication submitted to Journal of Geophysical Research: Solid Earth, by D'Araújo, J., Sigmundsson, F., Ferreira,

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T., Okada, J., Lorenzo, M., & Silva, R. (2022). Plate boundary deformation and volcano unrest at the Azores triple junction determined from continuous GPS measurements, 2002–2017.

## Conclusions

WP16 had no project submitted in the first call and was able to accept 4 projects in the second call. 3 projects fulfilled the scientific evaluation and were accepted for funding. They were all carried out successfully. Almost all users were able to travel to the Azores and benefit from the access to the AZVO Research Infrastructure and interact with the teams from CIVISA/IVAR. The interaction between the users and the local researchers has promoted a quick exchange of knowledge on the scientific themes of the projects and created new experiences regarding the use of field instruments in different working conditions, that revealed to be very fruitful for both sides.

The fact that the users and VO staff share similar or complementary needs and scientific interests that were put in connection through the TA activities, has already revealed its high potential in promoting further scientific collaborations beyond EUROVOLC lifetime, that will contribute for sure for the building of a less fragmented and isolated, and a stronger volcanological community.

From the point of view of the WP16 TA activities carried out by the AZVO, despite the reduced number of projects approved and all the challenges and limitations imposed by COVID-19 pandemic, have revealed to be a highly enriching experience allowing to achieve in a faster way more and better results that otherwise would take longer time and more effort to both sides (VO and users).