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EUROVOLC

European Network of Observatories and Research Infrastructure for Volcanology

Deliverable Report

D4.1 Tephra_DB
Tephra database implementation for facilitated access and use to partners

Work Package:	*Networking atmospheric observations and connecting the volcanological community with Volcanic Ash Advisory Centres (VAACs)*	
Work Package number:	*WP4*	
Work Package leader:	*Lucia Gurioli*	
Task (Activity) name:	*Tephra database implementation and instruments practice definition*	
Task number:	*4.1.1*	
Responsible Activity leader:	*Simona Scollo*	
Lead beneficiary:	*INGV*	
Authors:	*Lucia Gurioli and Simona Scollo*	
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Dissemination level:	*Public X* *Prog. Participants [ ]*	*Restricted Designated Group [ ]* *Confidential (consortium) [ ]*

Programme: H2020
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CONTENTS

Summary

The object of the D4.1 deliverable (Tephra_DB) was the implementation of a Tephra database to facilitate access and use of tephra parameters and instruments to EUROVOLC partners. Because several databases already exist between the different Volcanic Research Institutes (VRIs) and Volcanological Observatories (VOs), we decided to build up an informative data table to list all the studied volcanoes and the main parametrized explosions/eruptions activities or periods of activities. Twelve VOs and RIs (INGV-RM[1]; INGV-OE[2]; INGV-CNT[3]; INGV-NA[4]; IMO[5]; UI[6]; UNIRM[7]; LMV-OPGP-UCA[8]; UNIFI[9]; UNIGE[10]; CIVISA-IVAR[11]; CSIC-IGN[12]) filled in the tables, for a total of 22 volcanoes (Bárðarbunga, Batu Tara, Campi Flegrei, Copahue, Cordon Caulle; Etna, Eyjafjallajökull, Fogo, Fuego, Grímsvötn, Hekla, Laacher See, Montserrat, Nyaragongo, Piton De La Fournaise, Sakurajima, Sete Cidades, Stromboli, Teide, Tungurahua, Vesuvius and Yasur). Ten main parameters: (i) plume height, (ii) mass eruption rate, (iii) volcanic particle content, (iv) temperature, (v) weather data, (vi) particle properties, (vii) volcanic gas composition (viii) vertical distribution of gas and particles in the cloud (ix) velocity, (x) total grain size distribution have been measured or derived through ground, airborne and space-based tools. Unprocessed data have also been listed. Other 5 main parameters related to the deposit features have been listed as well: (i) deposit thickness and dispersion, (ii) density of the deposit, (iii) deposit grain size distribution, (iv) particle componentry, (v) particle shape (vi) particle density, connectivity and permeability. All the information has been organized in an open google site:
https://drive.google.com/drive/folders/1UE0S6m7giqO2sqqNJO3hh6QaWY4xlRWv?usp=sharing

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Footnotes

1. INGV-RM: Istituto Nazionale di Geofisica e Vulcanologia, Roma
2. INGV-OE: Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy
3. INGV-CNT: Istituto Nazionale di Geofisica e Vulcanologia- Centro Nazionale Terremoti
4. INGV-NA: Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano
5. IMO: Icelandic Meteorological Office
6. UI: University of Iceland
7. UNIRM1: University of Roma 1
8. LMV-OPGP-UCA: Laboratoire Magmas et Volcans-Observatoire de Physique du Globe de Clermont-Ferrand-Université Clermont Auvergne
9. UNIFI: University of Florence
10. UNIGE: University of Geneva
11. CIVISA-IVAR: Centro de Informação e Vigilância Sismovulcânica dos Açores, Portugal- Instituto de investigação em Vulcanologia e Avaliação de Riscos
12. CSIC-IGN: Consejo Superior de Investigaciones Cientificas-Instituto Geografico Nacional

1. Introduction

Volcanic ash plumes (Fig. 1) are commonly observed phenomena during explosive events and result from the fragmentation of erupting magma and accidental rocks into fragments referred to as tephra (particles of juvenile or not juvenile material that ranges in dimension from meters to nano-micron in diameter). The mass flux of ash (particles less than 2 mm in diameter, Heiken and Wohletz 1985) injected in the rising plume and laterally transported in the atmosphere can be important especially for small-scale explosive eruptions that every month inject more than a million cubic meters of ash into the Earth’s atmosphere (Simkin and Siebert 2000).

Figure 1 *From plinian (Cordon Caulle 2011 eruption in Chile), to subplinian (Etna, Italy) and strombolian volcanic plumes (Piton de La Fournaise, La Réunion, September 2016).*

Because these ash particles are easily transported by the wind and have a high surface-to-volume ratio, their generation and dispersion are of great societal concern, as witnessed during the 2010 eruption of Eyjafjallajökull (Dellino et al. 2012; Horwell et al. 2013) and recent Etna eruptions (Barsotti et al. 2010; Scollo et al. 2013). Furthermore, many developing countries are located in areas where 94% of the global historic volcanic activity occurs (e.g. Central and South America, Asia-Pacific region, Simkin and Siebert 2000).

Volcanic ash plume impacts are highly varied in terms of type, spatial scale and duration of impact. On a regional scale, Volcanic ash plumes from short, high-intensity eruptions can contaminate water supplies, affect the health of humans and livestock, damage agricultural land, enhance soil erosion, and severely impact critical infrastructure (Blong 1984; Fig. 2). Long term effects such as volcanic ash storms from wind-remobilized ash still plague regions in Chile as the result of a large eruption in 1991 of Cerro Hudson volcano, and are causing severe visibility problems in Iceland down-wind of ash deposits from both the 2010 Eyjafjallajökull and the 2011 Grímsvötn eruptions (Liu et al. 2014). Extremely fine ash (<0.063 mm) produced by Plinian events can impact global climate as demonstrated by the 1991 Pinatubo eruption that reduced global temperature by 0.5 °C (McCormick et al. 1995). Volcanic ash also forms the soils of many parts of the world (Ping 1999), exposure to which may occur in dust storms (Hefflin et al. 1994) and in agriculture, construction work and quarrying (Damby et al. 2013).

Figure 2 *a) and b) Impact of volcanic ash on infrastructures, c) health of humans and d) livestock, e) damage of agricultural land, and f) impact on critical infrastructure.*

Therefore, the characterization of tephra fallout represents a major source of information for the understanding of explosive volcanism as well as for the parametrization of ash dispersion models used for operational forecast of the ash dispersion in the atmosphere (Cashman and Rust 2016 and Fig. 3).

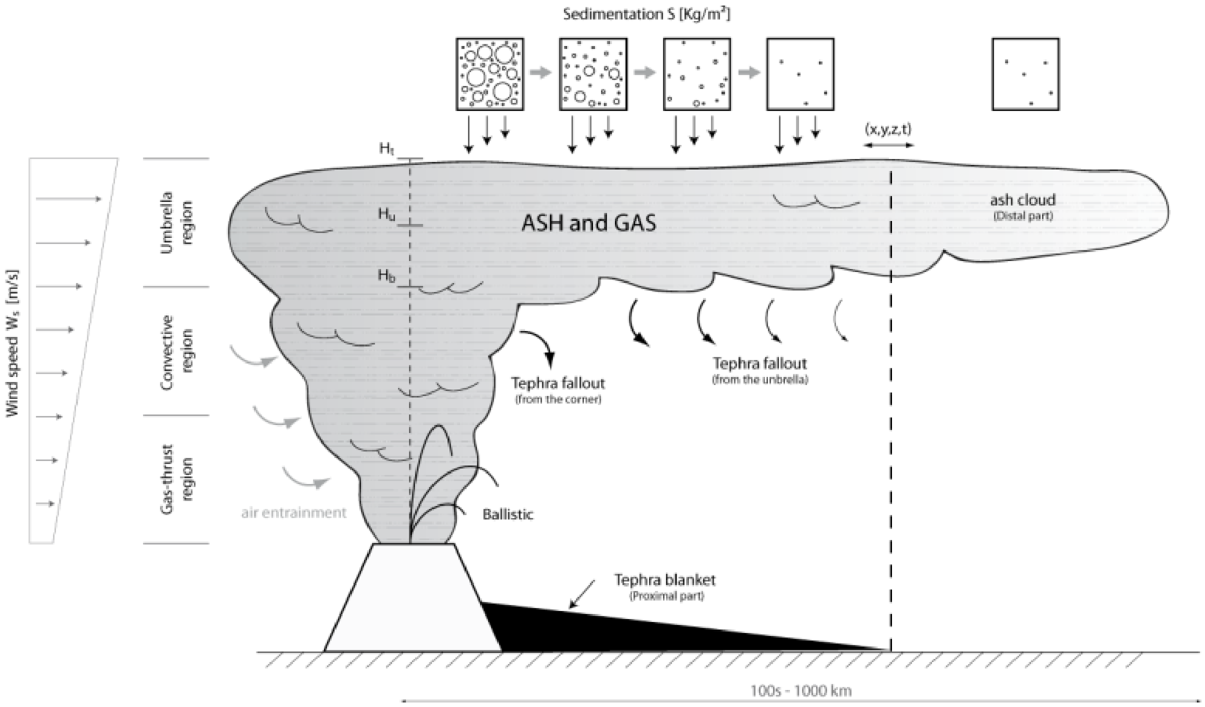


Figure 3 *Schematic diagram of a volcanic plume. On the left: wind profile variation from the base (weak) to the top (strong), followed by the names of the different regions of the plume. At the top the tephra grain size variation from coarse (proximal to the eruptive vent) to fine (distal to the eruptive vent) is represented. In black, the geometrical schematization of the tephra fall deposit, decreasing in thickness with distance from the eruptive vent, is reported.*

2. Objective of WP4.1.1

Many observations are being made from VOs, VRIs and Operational Institutes (such as VAACs - Volcanic Ash Advisory Centers - or Civil Protection). Because we realize that each VO, VRI and OI has different catalogues and different databases, which can have different features, and which are often unknown to the scientific community, it was decided to formulate a **Tephra Metadata Informative table** to be filled in by the participants of WP8 and WP4. In the table we asked each VRI to list all the ground, airborne and space-based tools used to measure and/or derive the eruption source parameters from an on-going or past eruption and or the methodology and/or instruments or sampling strategy used to measure or derive those parameters from the tephra deposits.

In doing that we tried to:

- ✓ gather information about data from various eruptions to produce an informative tephra database (grain-size, total grain-size distribution, componentry, thickness/load, total volume/mass, density of the deposit, particle shape and density);
- ✓ gather information about access to the data through repository materials and/or databases;
- ✓ facilitate the knowledge and access to spatial and ground-based databases;
- ✓ gather information about the best practice in sampling, measuring and compiling the data;
- ✓ list existing instruments and allow researchers to gain know-how on existing techniques and their use.

Therefore, this Metadata table was thought to fill the expectation of tasks 4.1.1 and 4.1.2, but at the same time would be the first STEP for WP8 to select the best case-study eruptions and then enable them to perform their second STEP in collecting the data listed in the Metadata table for the chosen eruptions. Task 4.1.3 on the other hand would use this information to integrate the data collections from the European volcanoes and their representative eruptions. This latter effort was already started within WP11 with the creation of the European Catalogue of Volcanoes and Volcanic Areas.

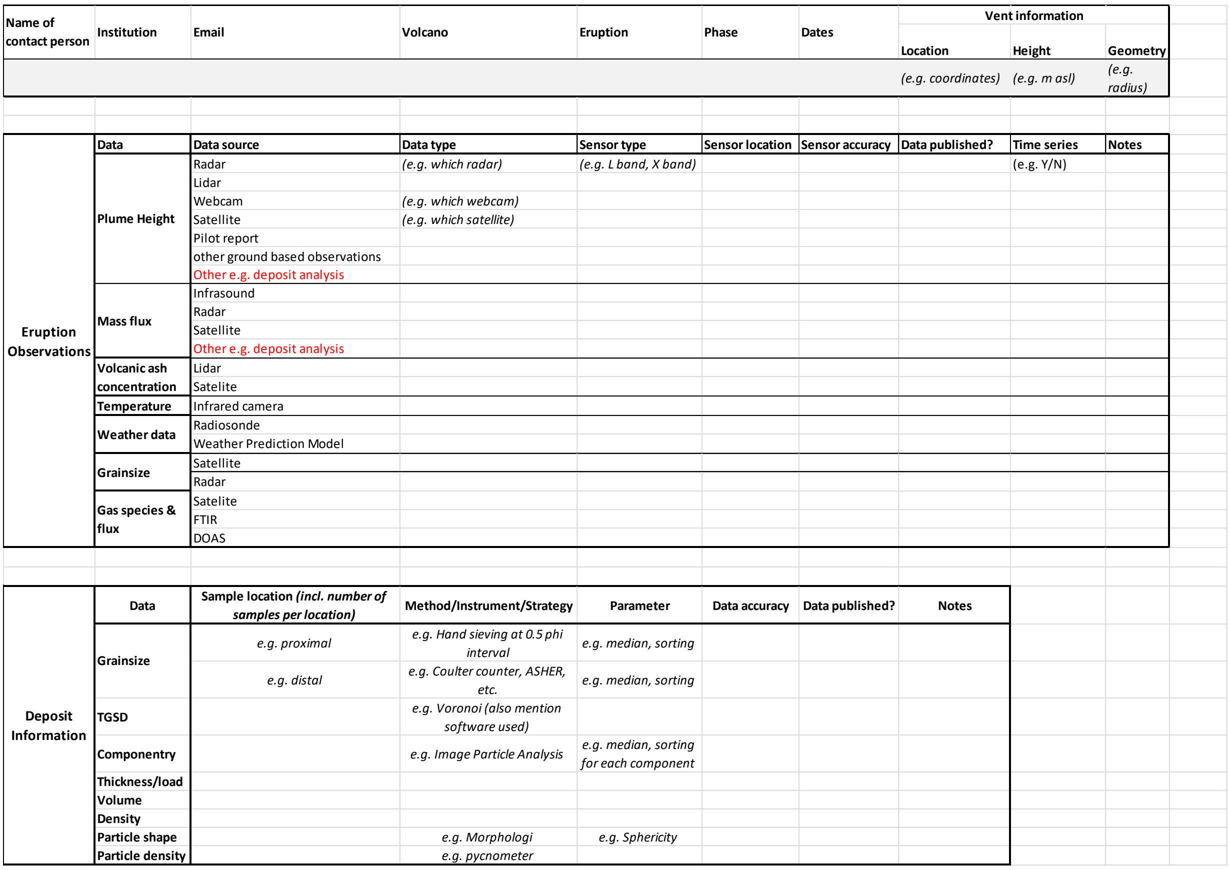
3. STEPS taken to reach the objective with references to activity meetings

Discussions between several WP4 participants started at the *EUROVOLC kick-off meeting* in Iceland. We presented the two main Networking activities: (NA2.1/Task4.1) Networking atmospheric gas and aerosol observations and (NA2.3/Task4.2) Connecting the Volcanological Community with Volcanic Ash Advisory Centres (VAACs). Within NA2.1, the “WP4.1.1 Tephra database implementation and instruments practice definition” activity was defined. It was decided to develop a questionnaire and send to the EUROVOLC WP4 and WP8 partners to identify: (i) Tephra databases, (ii) whether they were open access, (iii) completeness and list of data/ parameters and metadata, (iv) what the databases were good for and (v) what was missing.

After the kick-off meeting, several *Skype* and *email discussions* went on between the WP4 leaders and some components of WP8 to discuss, revise and correct the data collection list.

At the 11-16 April *EGU 2018 meeting in Vienna*, a common milestone between WP4 and WP8 was defined about the compilation of a Metadata table to be filled in by the participants of WP8 and WP4.

21/05/2018: A first WP4-WP8 spreadsheet representing this Metadata table was uploaded in a google drive document (Fig. 4):
https://drive.google.com/file/d/1bhZ7KtRl5HS_rDnKWu_266a4BfSm-isQ/view?usp=sharing



Name of contact person	Institution	Email	Volcano	Eruption	Phase	Dates	Vent information		
							Location	Height	Geometry
							(e.g. coordinates)	(e.g. m asl)	(e.g. radius)

	Data	Data source	Data type	Sensor type	Sensor location	Sensor accuracy	Data published?	Time series	Notes
Eruption Observations	Plume Height	Radar	(e.g. which radar)	(e.g. L band, X band)				(e.g. Y/N)	
		Lidar							
		Webcam	(e.g. which webcam)						
		Satellite	(e.g. which satellite)						
		Pilot report							
		other ground based observations							
		Other e.g. deposit analysis							
	Mass flux	Infrasound							
		Radar							
		Satellite							
		Other e.g. deposit analysis							
	Volcanic ash concentration	Lidar							
		Satelite							
	Temperature	Infrared camera							
	Weather data	Radiosonde							
		Weather Prediction Model							
	Grainsize	Satellite							
		Radar							
	Gas species & flux	Satelite							
		FTIR							
		DOAS							

	Data	Sample location *(incl. number of samples per location)*	Method/Instrument/Strategy	Parameter	Data accuracy	Data published?	Notes
Deposit Information	Grainsize	*e.g. proximal*	*e.g. Hand sieving at 0.5 phi interval*	*e.g. median, sorting*			
		e.g. distal	*e.g. Coulter counter, ASHER, etc.*	*e.g. median, sorting*			
	TGSD		*e.g. Voronoi (also mention software used)*				
	Componentry		*e.g. Image Particle Analysis*	*e.g. median, sorting for each component*			
	Thickness/load						
	Volume						
	Density						
	Particle shape		*e.g. Morphologi*	*e.g. Sphericity*			
	Particle density		*e.g. pycnometer*				

Figure 4 *First WP4-WP8 spreadsheet uploaded in Google Drive on the 21 of May 2018.*

During the 2-6 September *COV 2018 meeting in Naples*: a small WP4 + WP8 meeting was held to discuss the compilation of the different tables listed in WP4 deliverables. During the meeting it was clear that there was some overlap and misunderstanding about the different tables. It was clarified that (i) the table jointly designed by WP4 & WP8 was aimed to look into the "availability" of a variety of data for different eruptions; (ii) the WP4.1.3 table, describing volcanic eruptions (definition of metadata and the data themselves, originally designed within the FUTUREVOLC project), was designed to provide detailed information on individual eruptions as a support to those volcanoes that will be accessible through the European Catalogue of Volcanoes and Volcanic Areas provided by WP11; (iii) the tephra data table for Icelandic volcanoes presented by Bergrún Óladóttir (UI) at the COV10 meeting (funded through a national and independent project), is a real database to be referred to within the WP4-WP8 informative table.

3-7 December 2018 *UCA-OPGC-LMV hosted the WP4.1.1 leader* allowing rich discussions between the WP4 leaders to work out new strategies for the Data table, to prepare the 9-month interim report and discuss all the deliverables.

Unfortunately we realized that the idea to make an electronic version of the table discouraged people and no-one at that point had filled in the table.

18/12/2018 a second WP4-WP8 Metadata_Collection table was sent again to the WP4 and WP8 participants. This time the spreadsheet sent consisted of 4 sections:

- Name and contact details of the Contact person(s) (top left)
- Eruption details (e.g. volcano name, location, etc.) (top right)
- Eruption Observations (e.g. MER, plume height) (centre)
- Deposit Information (e.g. TGSD, componentry, thickness) (bottom)

Only a few VRIs sent us the filled tables.

At the 18-25 February 2019 *EUROVOLC 1st Annual Meeting in Ponta Delgada* (Azores Islands), during the WP4-WP8 discussion some partners complained about the format of the table, which they thought did not allow the possibility of including raw data (e.g. infrasound signals). At the end of the meeting a whole day was dedicated to the correction and reorganization of the WP4-WP8 informative table. We had then agreed to make it more detailed and include this option. Also, we noted that the deposit table could have been homogenized and merged with the ground-, airborne- and space-based tools table, since the headers were really similar but just structured in a different way. Finally we were more explicit and detailed concerning the ESPs (Eruptive Source Parameters), also to make use of a WP8 NERC survey.

02/04/2019 the final **WP4-WP8_data_availability_survey table** was sent to both the whole WP4 and WP8 participants and personally to specific VOs and RIs.

Since April 2019 we have been working to merge all the WP4_WP8_data_availability_survey tables that we finally received from almost all the VOs and RIs

All this work has been done in collaboration with WP8 (Costanza Bonadonna, Samantha Engwell; Fabio Dioguardi, Matteo Cerminara). All the tables are available in the open access google drive:
https://drive.google.com/drive/folders/1UE0S6m7giqO2sqqNJO3hh6QaWY4xlRWv?usp=sharing

4. The Tephra_DB: explanation of the WP4-WP8_data_availability_survey table

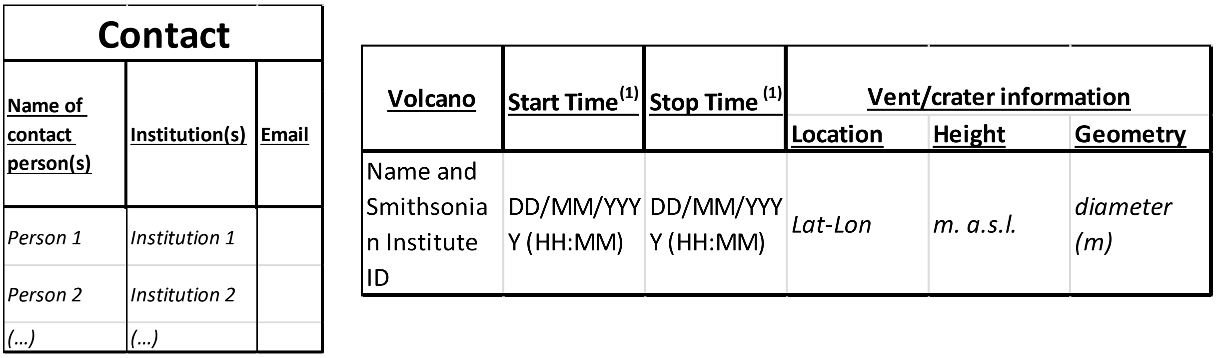
The final WP4-WP8_data_availability_survey table included a first page of explanation and a second page for the survey table itself, divided into two fields:

- Volcanic column/cloud information at the vent/atmosphere source, referring to the syn- and/or post-eruptive (from deposits) measurements of the phenomenon
- Deposit characterizations, referring to the post-eruptive measurements of the deposits

Below are the guidelines for filling in the Tephra table.

1) Contact (Fig. 5left): we asked for the contact information of the person responsible and/or in charge of the informative data, the relative institute and email. This information is crucial to allow the users to contact the source providing the information/data.

2) Volcano, activity and vent information (Fig. 5 right): for each volcano the responders were asked to provide the name and the corresponding identification number as reported by the Smithsonian Institute. Start time can refer either to the start of an eruptive activity, to the beginning of the data acquisition, or to the beginning of a single phase or explosive event. Stop time refers to the end of the explosion/eruption or studied eruptive period, specifying the day (DD) month (MM) and year (YYYY) and the time in hours (HH) and minutes (MM) in UT, when possible.

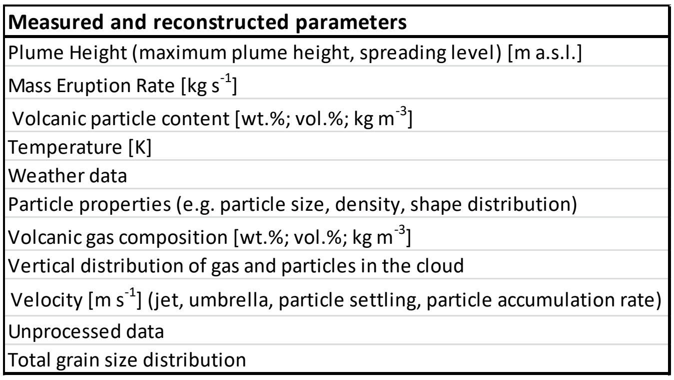


Contact		
Name of contact person(s)	**Institution(s)**	**Email**
Person 1	*Institution 1*	
Person 2	*Institution 2*	
(...)	*(...)*	

Volcano	**Start Time[(1)]**	**Stop Time [(1)]**	**Vent/crater information**		
			Location	**Height**	**Geometry**
Name and Smithsonian Institute ID	DD/MM/YYYY (HH:MM)	DD/MM/YYYY (HH:MM)	*Lat-Lon*	*m. a.s.l.*	*diameter (m)*

Figure 5 *WP4-WP8_data_availability_survey table: with contact information and Volcano, activity and vent information.*

3) Several main measured and reconstructed parameters (10 in total plus the unprocessed data) related to volcanic plume were listed (Fig. 6).



Measured and reconstructed parameters
Plume Height (maximum plume height, spreading level) [m a.s.l.]
Mass Eruption Rate [kg s^{-1}]
Volcanic particle content [wt.%; vol.%; kg m^{-3}]
Temperature [K]
Weather data
Particle properties (e.g. particle size, density, shape distribution)
Volcanic gas composition [wt.%; vol.%; kg m^{-3}]
Vertical distribution of gas and particles in the cloud
Velocity [m s^{-1}] (jet, umbrella, particle settling, particle accumulation rate)
Unprocessed data
Total grain size distribution

Figure 6 *WP4-WP8_data_availability_survey table: list of measured and reconstructed parameters related to the volcanic plume.*

3a) Plume Height (maximum plume height, spreading level, Fig. 7) [m a.s.l.], as the height of the center of the mass of the umbrella cloud (Degruyter and Bonadonna 2013)

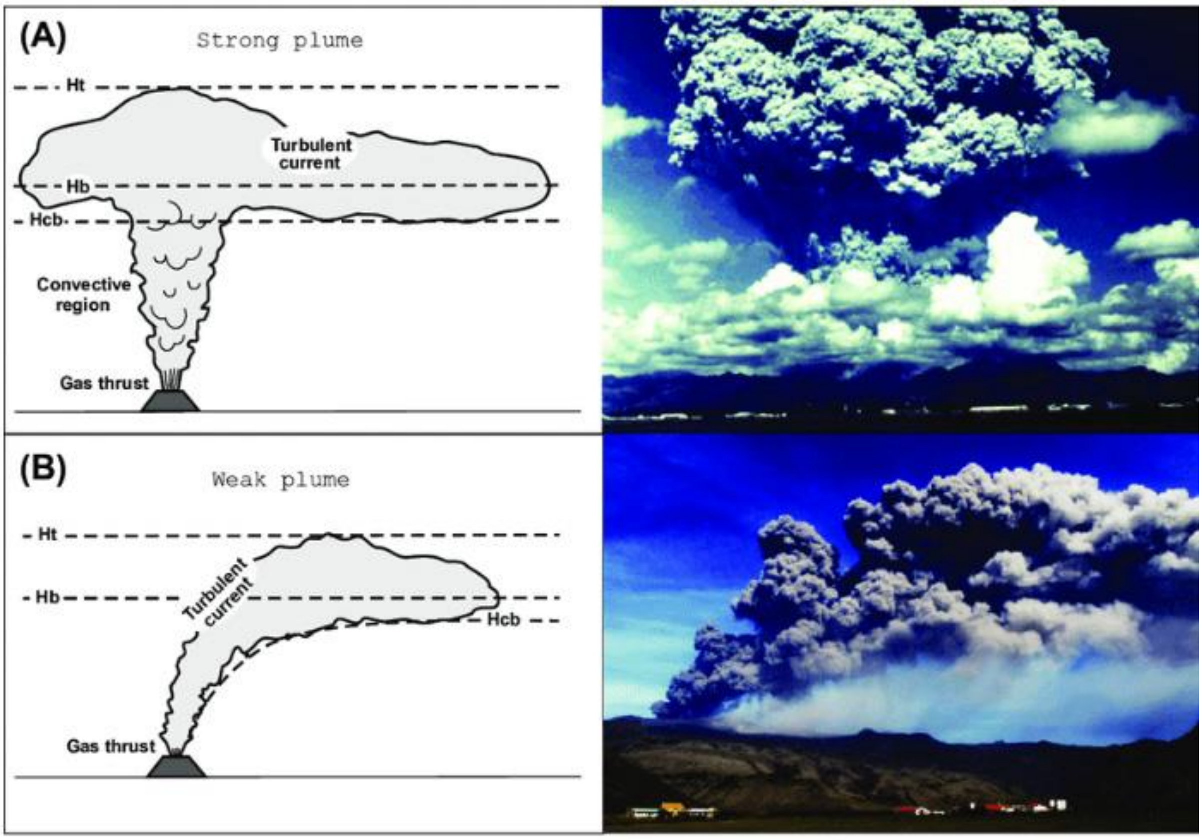


Figure 7 *Sketch showing the main characteristics of (A) a strong volcanic plume and (B) a weak volcanic plume (in Degruyter and Bonadonna 2013). Examples are also shown of a strong plume (18 km-high volcanic plume from one of a series of explosive eruptions of Mount Pinatubo beginning on June 12, 1991; photograph by David H. Harlow, USGS) and a weak plume (Eyjafjallajökull plume spreading toward the southeast of Iceland on May 4, 2010). Ht, Hb, and Hcb indicate maximum plume height, height of Neutral Buoyancy Layer (NBL), and height of based current, respectively.*

3b) Mass Eruption Rate [kg s^{-1}]: amount of volcanic material (i.e., tephra and gas) pushed into the atmosphere per unit time, (e.g., Sparks 1986; Sparks et al. 1997; Mastin et al. 2009; Kaminski et al. 2011). This parameter can be provided either as an average value during the eruptive duration or as a time series.

3c) Volcanic particle content [wt.%; vol.%; kg m^{-3}] (Fig. 8) given as either mass fraction concentration or as density.

3d) Temperature [K] (Fig. 8) Temperature of the volcanic mixture or of the single phases. It can also be obtained with petrological studies depending of the magma properties.

3e) Weather data (wind speed gradient, humidity, etc.). To be fill in when there are weather data available from local stations and/or model (not open-access), or the open-access source that has been used is specified.

3f) Particle properties (e.g. particle size, density, shape and the distribution of these parameters laterally and vertically in the plume, e.g. Bombrun et al. 2015).

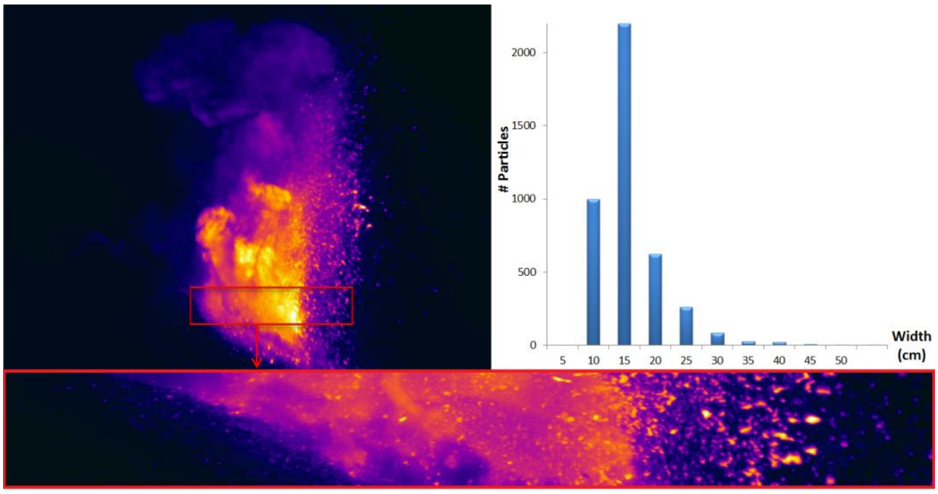


Figure 8 *Strombolian plume and related total grain size distribution of the particles (larger than 5 cm in diameter) at the vent exit (see red inset) derived with a thermal camera (modified from Bombrun et al. 2015). Data cited in table Stromboli from UCA-OPGC-LMV.*

3g) Volcanic gas composition [wt.%; vol.%; kg m^{-3}], as the relative mass fraction of the single components of the exsolved gas phase. It can also be obtained with petrological studies depending on the magma properties.

3h) Vertical distribution of gas and particles in the cloud.

3i) Velocity [m s^{-1}] (velocity of the jet, the umbrella, particle settling, particle accumulation rate).

3k) Total grain size distribution, as the whole eruptive mixture ejected during an explosive eruption (Pioli et al. 2019).

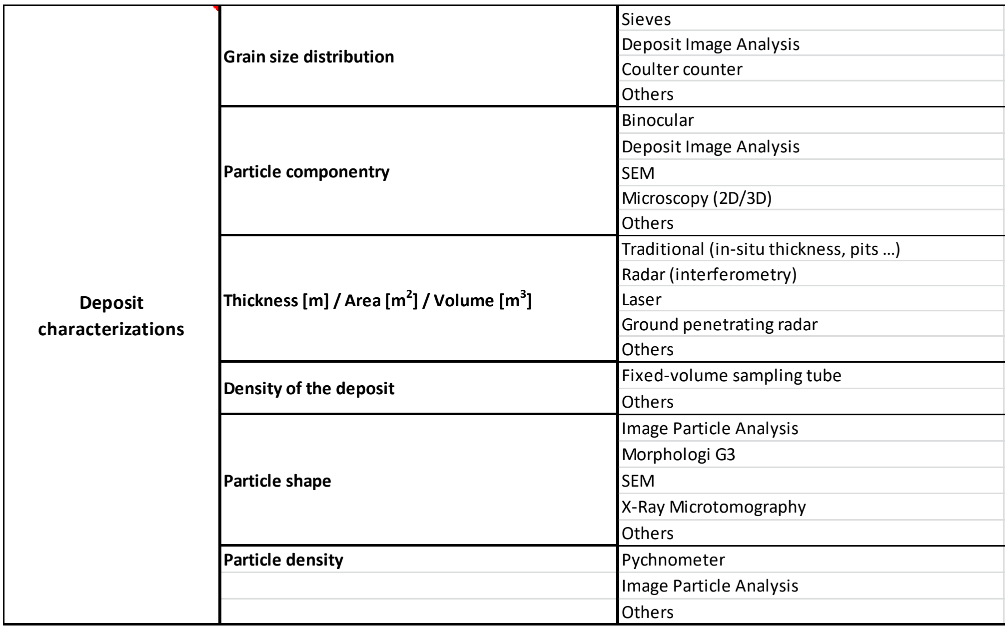
3j) Unprocessed data. If no measured and reconstructed parameters have been processed, then the “unprocessed data” field should be used to provide instrument information.

We also specified that units of the parameters were just for a clearer definition of the measured and reconstructed parameters. For each parameter the author was free to add additional data sources, when available, in the row “others”. Also, when a single field is unknown or not well defined for the instrument, then it should be left blank.

4) For the deposit characterization 6 main parameters were listed (Fig. 9):

4a) Grain size distribution of the deposit is the size and distribution of the particles that are classically sorted according to a logarithmic scale expressed by phi, where phi = $-\log_2 d$, and d is the grain diameter in mm (Walker 1971).

4b) Particle componentry is the grouping of the particles in juvenile or non-juvenile clasts (White and Houghton 2006). Juvenile clasts are all the particles that are derived from the erupted magma, such as pumice, scoria more or less vesiculated and free crystals. The non-juvenile particles are the particles that pre-date the eruption, such as xenoliths, deep seated rocks forming the magma chamber, wall fragments from the conduit erosion, and altered rocks from a geothermal reservoir at the fragmentation level depth or eroded from the substratum.



Deposit characterizations	**Grain size distribution**	Sieves
		Deposit Image Analysis
		Coulter counter
		Others
	Particle componentry	Binocular
		Deposit Image Analysis
		SEM
		Microscopy (2D/3D)
		Others
	Thickness [m] / Area [m^2] / Volume [m^3]	Traditional (in-situ thickness, pits ...)
		Radar (interferometry)
		Laser
		Ground penetrating radar
		Others
	Density of the deposit	Fixed-volume sampling tube
		Others
	Particle shape	Image Particle Analysis
		Morphologi G3
		SEM
		X-Ray Microtomography
		Others
	Particle density	Pychnometer
		Image Particle Analysis
		Others

Figure 9 *List of the main five parameters reported in the WP4-WP8_data_availability_survey table from the deposits measurements.*

<u>4c) Geometry of the deposit</u> in terms of thickness (and its variation in space), area (dispersion) and volume (see for example Prival et al. 2020)

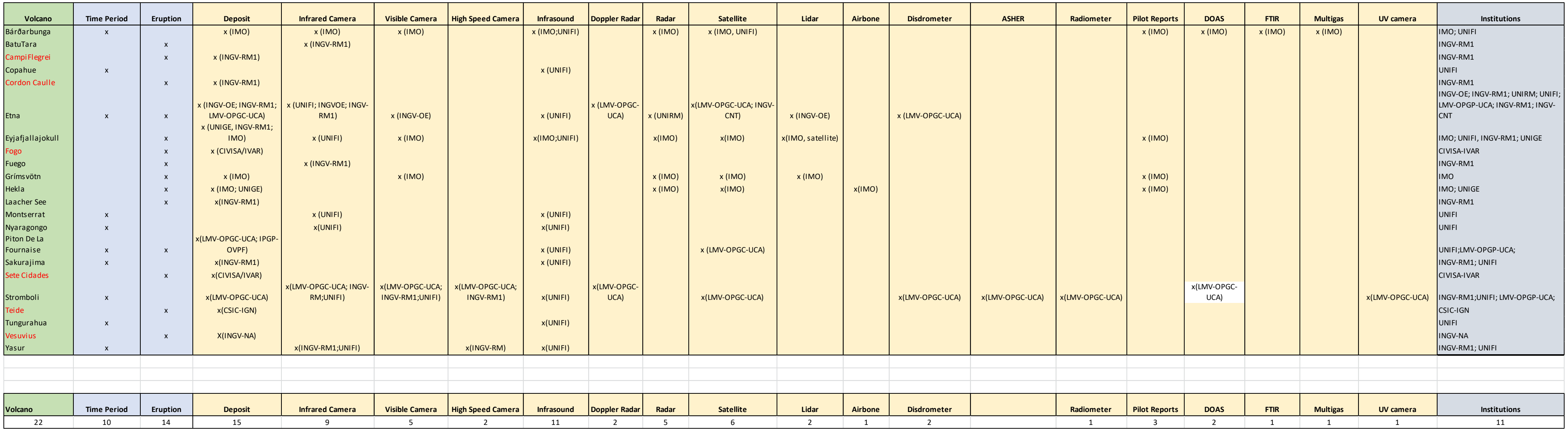
<u>4d) Density of the deposit</u> as the dry density of a slightly compacted, dry deposit (Prival et al. 2020)

<u>4e) Particle shape measurements</u> as the particle's three main axes (a, b, c), the perimeter and the area of the particle and all the derived parameters (Thivet et al. 2020)

<u>4f) Particle density, vesicularity connectivity and permeability</u>: the bulk properties of a particle in terms of its density, the derived vesicularity, the grade of connectivity of vesicles and the permeability of the particle (e.g. Colombier et al. 2017a, 2017b; Gurioli et al. 2018).

5. The Tephra_DB: some results of the WP4-WP8_data_availability_survey table

Twelve VOs and VRIs (INGV-RM; INGV-OE; INGV-CNT; INGV-NA; IMO; UI; UNIRM; LMV-OPGP-UCA; UNIFI; UNIGE; CIVISA-IVAR; CSIC-IGN) filled in the tables, for a total of 22 volcanoes (Bárðarbunga, Batu Tara, Campi Flegrei, Copahue, Cordon Caulle; Etna, Eyjafjallajökull, Fogo, Fuego, Grímsvötn, Hekla, Laacher See, Montserrat, Nyaragongo, Piton De La Fournaise, Sakurajima, Sete Cidades, Stromboli, Teide, Tungurahua, Vesuvius and Yasur, Fig. 10).



Volcano	Time Period	Eruption	Deposit	Infrared Camera	Visible Camera	High Speed Camera	Infrasound	Doppler Radar	Radar	Satellite	Lidar	Airbone	Disdrometer	ASHER	Radiometer	Pilot Reports	DOAS	FTIR	Multigas	UV camera	Institutions
Bárðarbunga	x		x (IMO)	x (IMO)	x (IMO)		x (IMO;UNIFI)		x (IMO)	x (IMO, UNIFI)						x (IMO)	x (IMO)	x (IMO)	x (IMO)		IMO; UNIFI
BatuTara		x		x (INGV-RM1)																	INGV-RM1
CampiFlegrei		x	x (INGV-RM1)																		INGV-RM1
Copahue	x						x (UNIFI)														UNIFI
Cordon Caulle		x	x (INGV-RM1)																		INGV-RM1
Etna	x	x	x (INGV-OE; INGV-RM1; LMV-OPGC-UCA)	x (UNIFI; INGVOE; INGV-RM1)	x (INGV-OE)		x (UNIFI)	x (LMV-OPGC-UCA)	x (UNIRM)	x(LMV-OPGC-UCA; INGV-CNT)	x (INGV-OE)		x (LMV-OPGC-UCA)								INGV-OE; INGV-RM1; UNIRM; UNIFI; LMV-OPGP-UCA; INGV-RM1; INGV-CNT
Eyjafjallajokull		x	x (UNIGE, INGV-RM1; IMO)	x (UNIFI)	x (IMO)		x(IMO;UNIFI)		x(IMO)	x(IMO)	x(IMO, satellite)					x (IMO)					IMO; UNIFI, INGV-RM1; UNIGE
Fogo		x	x (CIVISA/IVAR)																		CIVISA-IVAR
Fuego		x		x (INGV-RM1)																	INGV-RM1
Grímsvötn		x	x (IMO)		x (IMO)				x (IMO)	x (IMO)	x (IMO)					x (IMO)					IMO
Hekla		x	x (IMO; UNIGE)						x (IMO)	x(IMO)		x(IMO)				x (IMO)					IMO; UNIGE
Laacher See		x	x(INGV-RM1)																		INGV-RM1
Montserrat	x			x (UNIFI)			x (UNIFI)														UNIFI
Nyaragongo	x			x(UNIFI)			x(UNIFI)														UNIFI
Piton De La Fournaise	x	x	x(LMV-OPGC-UCA; IPGP-OVPF)				x (UNIFI)			x (LMV-OPGC-UCA)											UNIFI;LMV-OPGP-UCA;
Sakurajima	x		x(INGV-RM1)				x (UNIFI)														INGV-RM1; UNIFI
Sete Cidades		x	x(CIVISA/IVAR)																		CIVISA-IVAR
Stromboli	x		x(LMV-OPGC-UCA)	x(LMV-OPGC-UCA; INGV-RM;UNIFI)	x(LMV-OPGC-UCA; INGV-RM1;UNIFI)	x(LMV-OPGC-UCA; INGV-RM1)	x(UNIFI)	x(LMV-OPGC-UCA)		x(LMV-OPGC-UCA)			x(LMV-OPGC-UCA)	x(LMV-OPGC-UCA)	x(LMV-OPGC-UCA)		x(LMV-OPGC-UCA)			x(LMV-OPGC-UCA)	INGV-RM1;UNIFI; LMV-OPGP-UCA;
Teide		x	x(CSIC-IGN)																		CSIC-IGN
Tungurahua	x						x(UNIFI)														UNIFI
Vesuvius		x	X(INGV-NA)																		INGV-NA
Yasur	x			x(INGV-RM1;UNIFI)		x(INGV-RM)	x(UNIFI)														INGV-RM1; UNIFI

Volcano	Time Period	Eruption	Deposit	Infrared Camera	Visible Camera	High Speed Camera	Infrasound	Doppler Radar	Radar	Satellite	Lidar	Airbone	Disdrometer		Radiometer	Pilot Reports	DOAS	FTIR	Multigas	UV camera	Institutions
22	10	14	15	9	5	2	11	2	5	6	2	1	2		1	3	2	1	1	1	11

Figure 10 *Summary table of the WP4-WP8_data_availability_survey table in* *https://drive.google.com/drive/folders/1UE0S6m7giqO2sqqNJO3hh6QaWY4xlRWv?usp=sharing*

The tables are grouped by the different volcanoes and divided according to the measurements performed, either as time series or as single eruptions. For each volcano the tables have also been divided according to the tools/methods used for the quantitation of the parameters.
Because the filled-in tables were received quite late, and a few are still coming, organization of their parameters has not yet been completed. However, due the fact that a few groups have sent unprocessed measurements without specifying the parameters, we found that this organization is the best that we can provide at the moment.
For now, we therefore report two summary tables, one related to the volcanoes, the instruments used for each volcano and the institutes involved, the other just showing a list of all the ground, airborne and spatial tools.

6. Other deliverables

In collaboration with WP8, one paper is in progress, based on past multi-parametric field work on Etna in 2011, where scoria fountaining deposits were collected in parallel with Doppler radar measurements, volcanic tremor and thermal videos (data reported in WP4-WP8_data_availability_survey table). The physical and textural characterizations of the pyroclasts collected at that time will be used as validation to retrieve some important parameters measured by the Doppler Radar. In these papers we will present some best practice case-studies (including full methodological detail).

We have also recently published a paper discussing the difficulty to accurately estimate eruptive parameters and assess volcanic hazard on oceanic islands, taking Sete Cidades as a key example. The paper is part of a special volume on Ocean Island Volcanoes:

- Kueppers U, **Pimentel A**, Ellis B, Forni F, Neukampf J, Pacheco J, Perugini D, Queiroz G (2019) Biased volcanic hazard assessment due to incomplete eruption records on ocean islands: an example of Sete Cidades Volcano, Azores. Front. Earth Sci. 7:122. doi: 10.3389/feart.2019.00122.
  at https://www.frontiersin.org/articles/10.3389/feart.2019.00122/full).

Finally, a paper published in G-cubed related to the characterization of a weak ash plume at Piton de La Fournaise and the parametrization of the source parameters, with acknowledgement to EUROVOLC. All the data are available at:

http://opgc.fr/vobs/so_interface.php?so=dynvolc (DynVolc 2017)

- **Thivet S**, **Gurioli L, Di Muro A,** Derrien A, Ferrazzini V, **Gouhier M**, Coppola D, Galle B, Arellano S (2020) Evidences of plug pressurization triggering secondary fragmentation during the September 2016 basaltic eruption at Piton de la Fournaise (La Réunion Island, France) G-Cubed DOI: 10.1029/2019GC008611.

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