Volcanic Unrest in Europe and Latin America: phenomenology, eruption precursors, hazard forecast, and risk mitigation

DOMINICA EXERCISE PLAN

14th – 15th May 2015

WP 9: Decision-making and unrest management

Task 9.6: Simulation of unrest and decision making

CONTENTS

1. GENERAL OVERVIEW

The island of Dominica is located within the Lesser Antilles Island Arc (Fig. 1A).The island has 9 volcanic centres, which are considered to have the potential to erupt in the future (Fig. 2). With the exception of raised limestone on the western side of the island, Dominica is comprised of volcanic rocks and their weathering products (Fig. 3; Lindsay et al. 2005). Volcanic activity on the island began in the Miocene and continues to the present day. The island has had frequent swarms of volcanic earthquakes during the historical period (post-1700s) but has only had two eruptions, both phreatic (1880 and 1997), from the Valley of Desolation in the south-east part of the island. The most recent magmatic eruption in Dominica occurred ~600 years ago from Morne Patates, a dome within the Plat Pays volcanic complex, in the southern part of the island.

This exercise is undertaken as part of the European project *"VUELCO – Volcanic Unrest in Europe and Latin America: Phenomenology, Eruption Precursors, Hazard Forecast and Risk Mitigation"* (see www.vuelco.net for full details), funded through the EU 7th Framework Program.

The exercise is designed totes the effectiveness of a number of tools and products derived from the VUELCO project, coming as it does as the final exercise for the project done in its final year. It will also test various aspects of the Dominica Volcanic Emergency Plan, which was updated in 2014 through funds provided by DIPECHO in a project administered by the French Red Cross (Watts, 2015). Finally, it will be used to test aspects of the CARICOM Regional Response Mechanism (RRM) and the SRC's emergency protocols for the management of volcanic emergencies.

The exercise will not involve the local population and its operations will be restricted to government and other agencies involved in responding to volcanic emergencies in Dominica and the Eastern Caribbean.

The exercise provides for the participation of the members of the VUELCO consortium team who will be integrated as members of the scientific group assembled to respond to the emergency or as observers evaluating the exercise. It will also involve the CDEMA Coordinating Unit (CDEMA-CU) in Barbados.

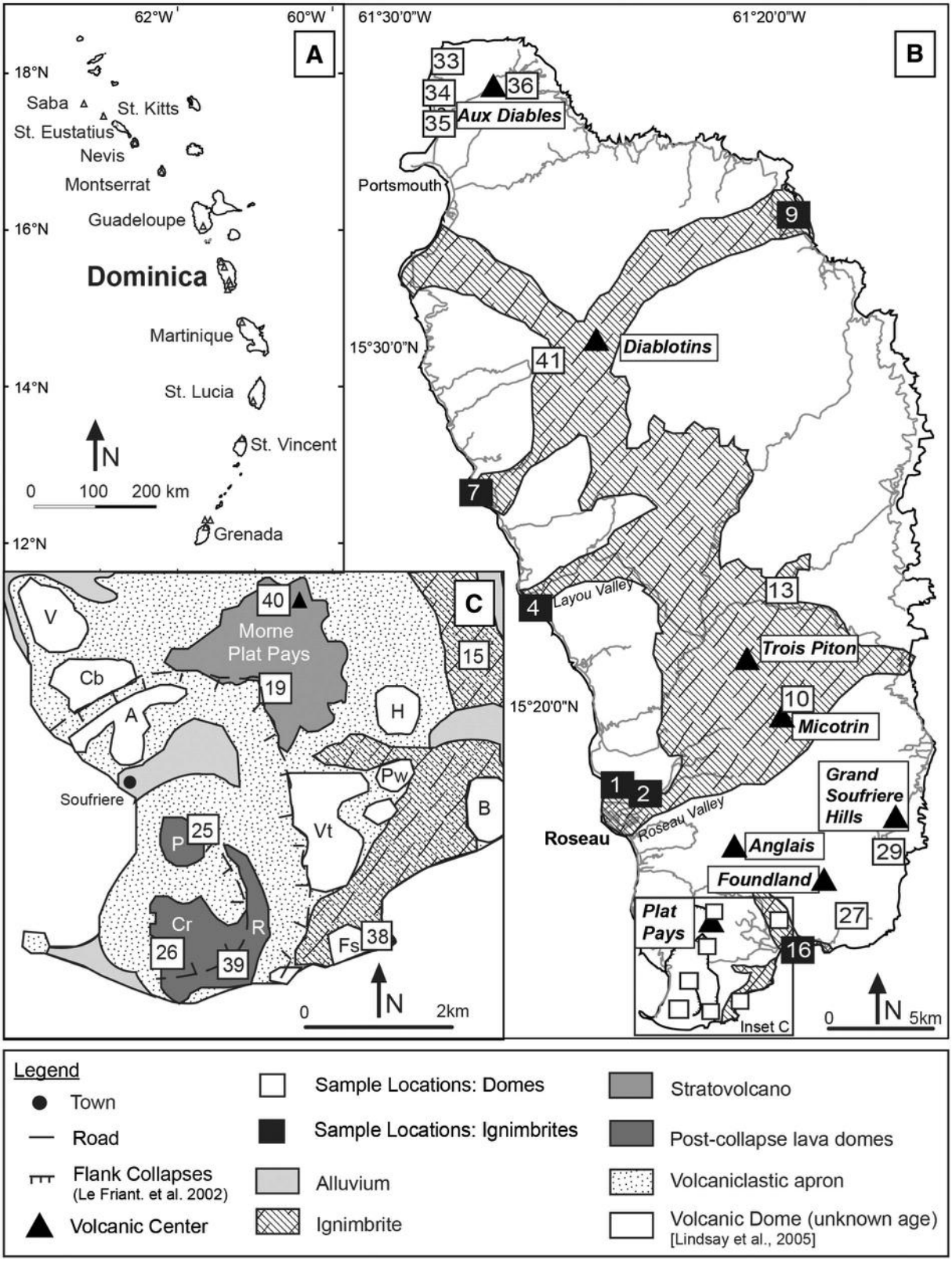

Figure 1: Map of (A) the Lesser Antilles volcanic arc; (B) Dominica showing the main volcanic centres and (C) Simplified geology map of the Plat Pays Volcanic Complex indicating major features taken from Howe et al (2015).

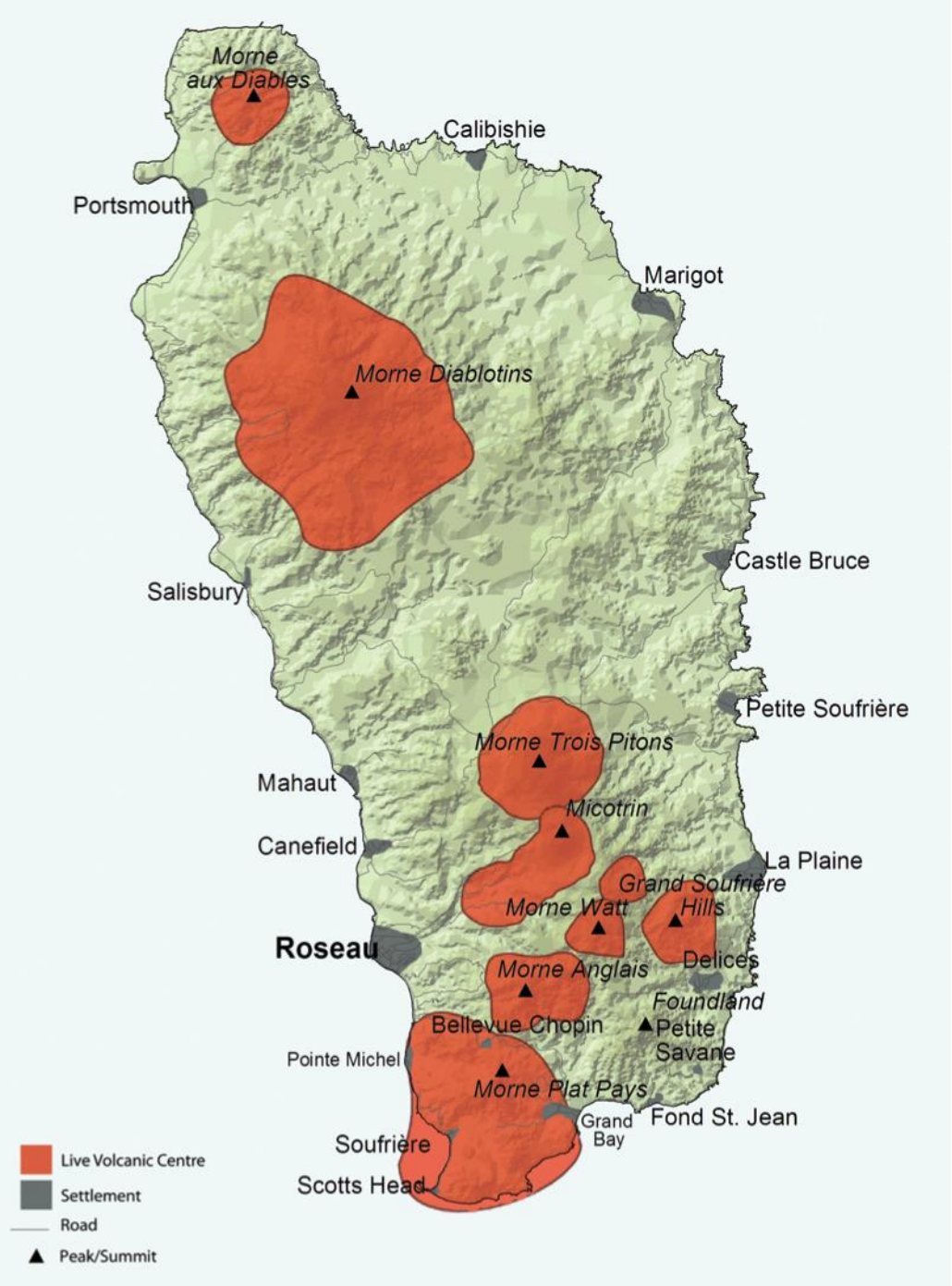

Figure 2: Potentially active volcanic centres on Dominica (from Lindsay et al. 2005).

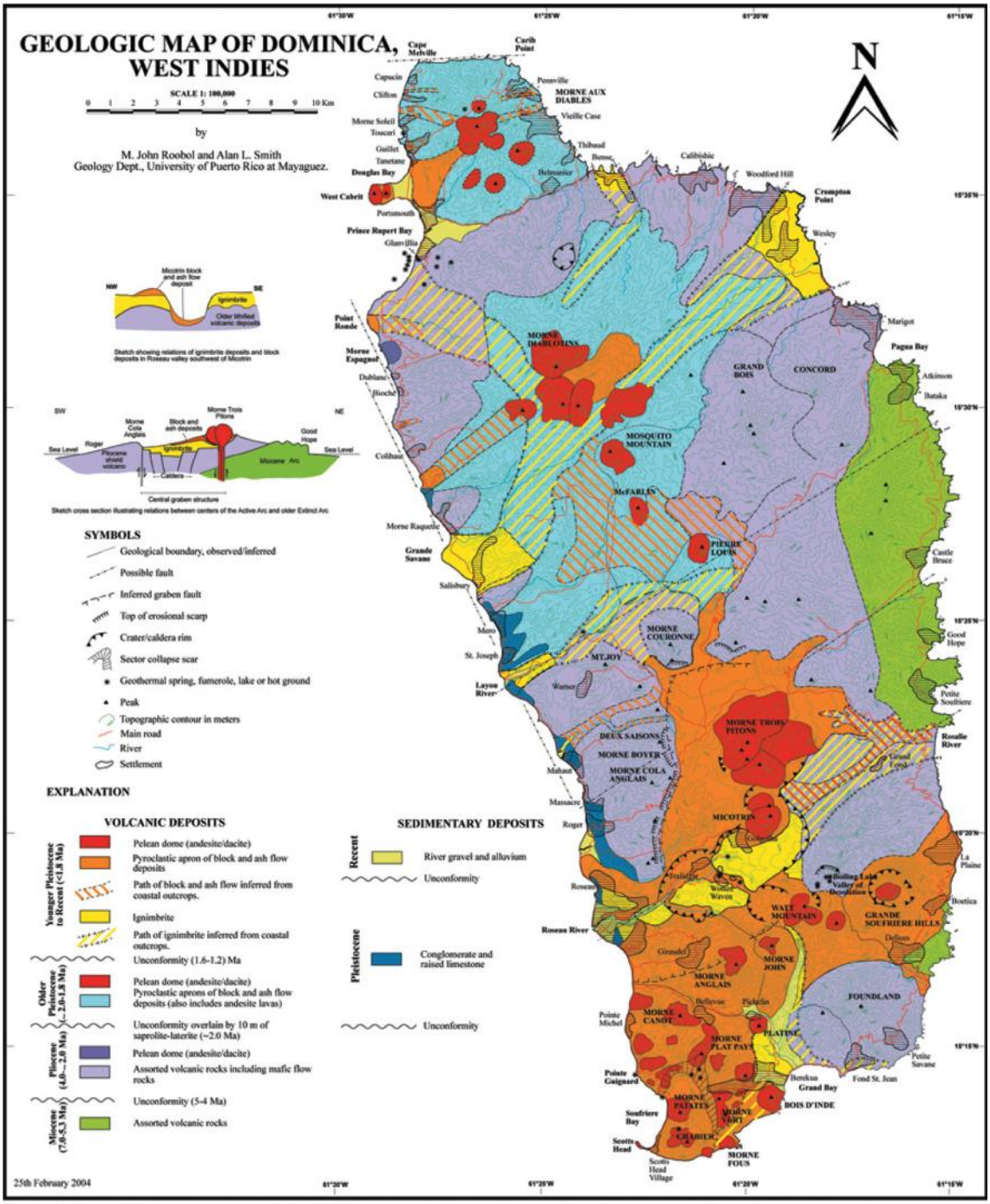

Figure 3: Geological map of Dominica (Lindsay et al. 2005).

2. VOLCANIC HAZARD AND RISK IN DOMINICA

Several scenarios for future activity covering the six most seismically and geothermally active volcanic centres have been presented in the Dominica chapter of the Volcanic Hazard Atlas of the Lesser Antilles (Table 1; Lindsay et al. 2005). **Participants in this exercise are asked to review this chapter prior to the exercise**. Copies of this and other relevant publications are available at this dropbox link: [https://www.dropbox.com/sh/yckt1egawr668nt/AACotz6By4hzBQJxTWSQXddia?oref=e&n=343668636]

Scenario	Volcanic centre	Description
1	Valley of Desolation	Phreatic eruption from either Valley of Desolation or the Boiling Lake
2	Plat Pays volcanic complex	Dome-forming eruption from within the complex, possibly from either Morne Canot or Morne Patates
3	Morne Anglais/John	Explosive eruption from Morne Anglais
4	Wotten Waven/ Micotrin	Dome-forming eruption from Micotrin
5	Wotten Waven/ Micotrin	Explosive plinian eruption from the Wotten Waven caldera
6	Morne aux Diables	Dome-forming eruption from central vent

Table 1: Most-likely scenarios for future volcanic activity in Dominica (Lindsay et al. 2005)

In order of decreasing probability of occurrence, the most likely type of eruptive activity on the island is a phreatic eruption from the explosion craters of the Valley of Desolation. Such an eruption is expected to be relatively small and to only affect the area directly surrounding the vent. The most likely scenario for a magmatic eruption is a dome-forming eruption from within the Plat Pays volcanic complex. Such an eruption will probably generate dome-collapse pyroclastic flows, pyroclastic surges and lapilli and ash falls. It is also expected that lahars would be generated at times of heavy rainfall during and after such an eruption. A dome-forming eruption may continue for many years and would affect large areas of southern Dominica. The least likely yet most devastating scenarios considered for Dominica is a Plinian eruption from the Wotten Waven. Pyroclastic surges resulting from the collapse of a Plinian column would affect most of the island except for the far north. Other possible scenarios for Dominica include explosive magmatic eruptions from Morne Anglais or Morne Plat Pays and dome-forming eruptions from Micotrin or Morne aux Diables. Hazard maps generated for the six most-likely scenarios involving major magmatic eruptions in Dominica have been combined to develop a map of integrated hazard zones for Dominica, indicating overall long-term hazard on the island(Fig. 4 and Table 2).

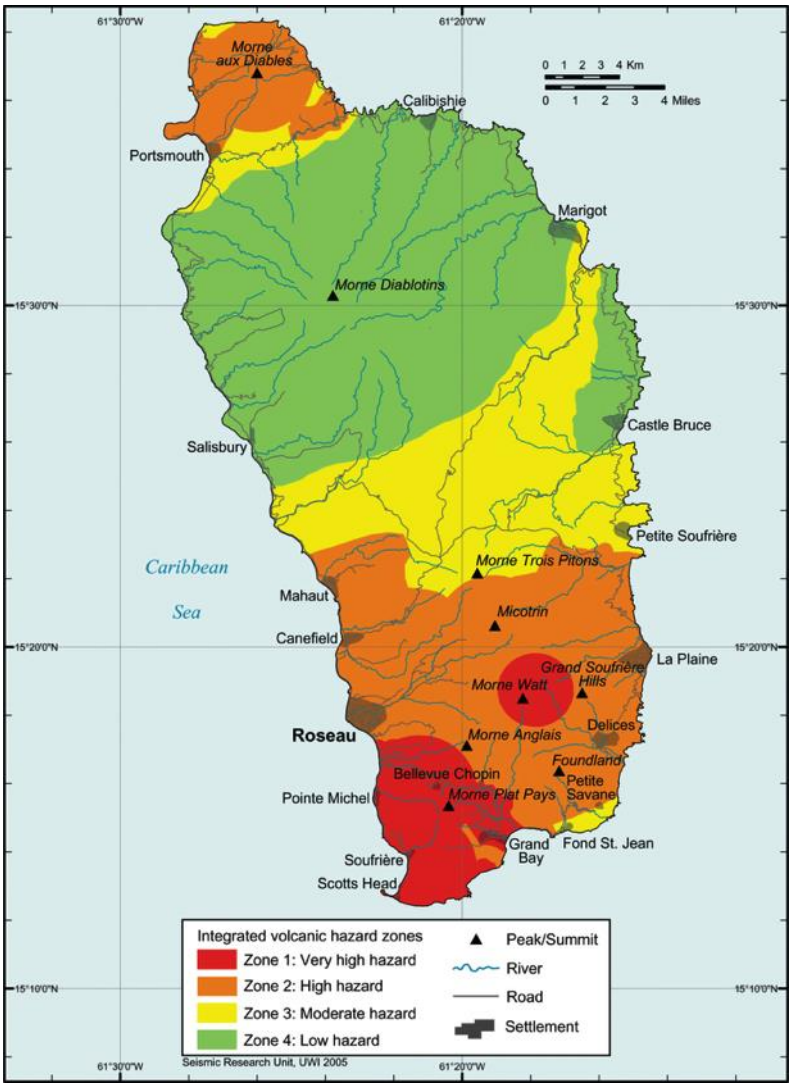

Figure 4: Overall Integrated volcanic hazard zones for Dominica based on a combination of the 6 most-likely scenarios

Description of Overall Integrated Volcanic Hazard Zones for Dominica
Zone 1 (red): Very high hazard
Property and structures in this zone have a significant (more likely than not) probability of destruction due to volcanic eruption within the next 100 years. This zone incorporates the predicted area of major impact associated with scenario 1 (phreatic eruption from Valley of Desolation) as well as the area of very high integrated hazard (i.e. zone 1; red area) associated with the two alternative vent areas from scenario two.
Zone 2 (orange): High hazard
Property and structures in this zone are more likely than not to be damaged, and they may be destroyed, within the next 100 years. This zone incorporates the area of high integrated hazard (i.e. zone 2; orange area) associated with the two vent areas from scenario 2 as well as the areas of very high integrated hazard (zone 1; red area) from scenarios 3, 4, 5 and 6.
Zone 3 (yellow): Moderate hazard
Property and structures may be damaged, but destruction is unlikely within the next 100 years. This zone incorporates the area of moderate integrated hazard (i.e. zone 3; yellow area) associated with the two vent areas of scenario 2 as well as the areas of high integrated hazard (i.e. zone 2; orange area) from scenarios 3, 4, 5 and 6.
Zone 4 (green): Low hazard
Property and structures in this zone are unlikely to be affected by volcanic eruption within the next 100 years. This zone incorporates the areas of moderate integrated hazard (i.e. zone 3; yellow area) from scenarios 3, 4, 5 and 6 as well as the rest of the island.

Table 2: Description of Overall Integrated Volcanic Hazard Zones for Dominica (Lindsay et al 2005).

3. SRC MONITORING NETWORKS AND EMERGENCY PROTOCOLS

The UWI Seismic Research Centre based in St. Augustine, Trinidad, monitors volcanic and seismic activity in Dominica. Continuous instrumental monitoring of earthquakes in Dominica began in 1953 when the first seismograph was installed in the Botanical Gardens. In 1974 a temporary network of 4 additional seismographs was installed to record and locate the earthquakes occurring in southern Dominica at that time. Four additional permanent stations were installed in response to a 1985-86 earthquake swarm. A major network upgrade was completed in 1998, just prior to the most intense volcano-seismic activity in Dominica since instrumental monitoring began. Two further stations were added in 2000 and 2003, and the network comprised 11 permanent stations. Ten of these stations transmit their data to two complete seismograph network base stations at Morne Daniel and Wesley (Fig. 5).

Between October 1998 and December 2004 a 22-station GPS network was established in southern Dominica, and in early 2004 a network of 8 stations was installed around Morne aux Diables in the north (Fig. 6). These networks are reoccupied at regular intervals to monitor for ground deformation. Gases and fluids from geothermal areas on the island are collected and analysed at annually to look for thermal or compositional variations that may reveal changes in the behaviour of the volcano (Fig 5).

It is anticipated the existing network will be strengthened in the near future through a World Bank funded capacity development project. This project provides funding to enable the purchase, installation and maintenance of monitoring equipment; the production of education materials and the execution of a public education campaign to vulnerable communities in Dominica. This project is expected to be executed in the coming year.

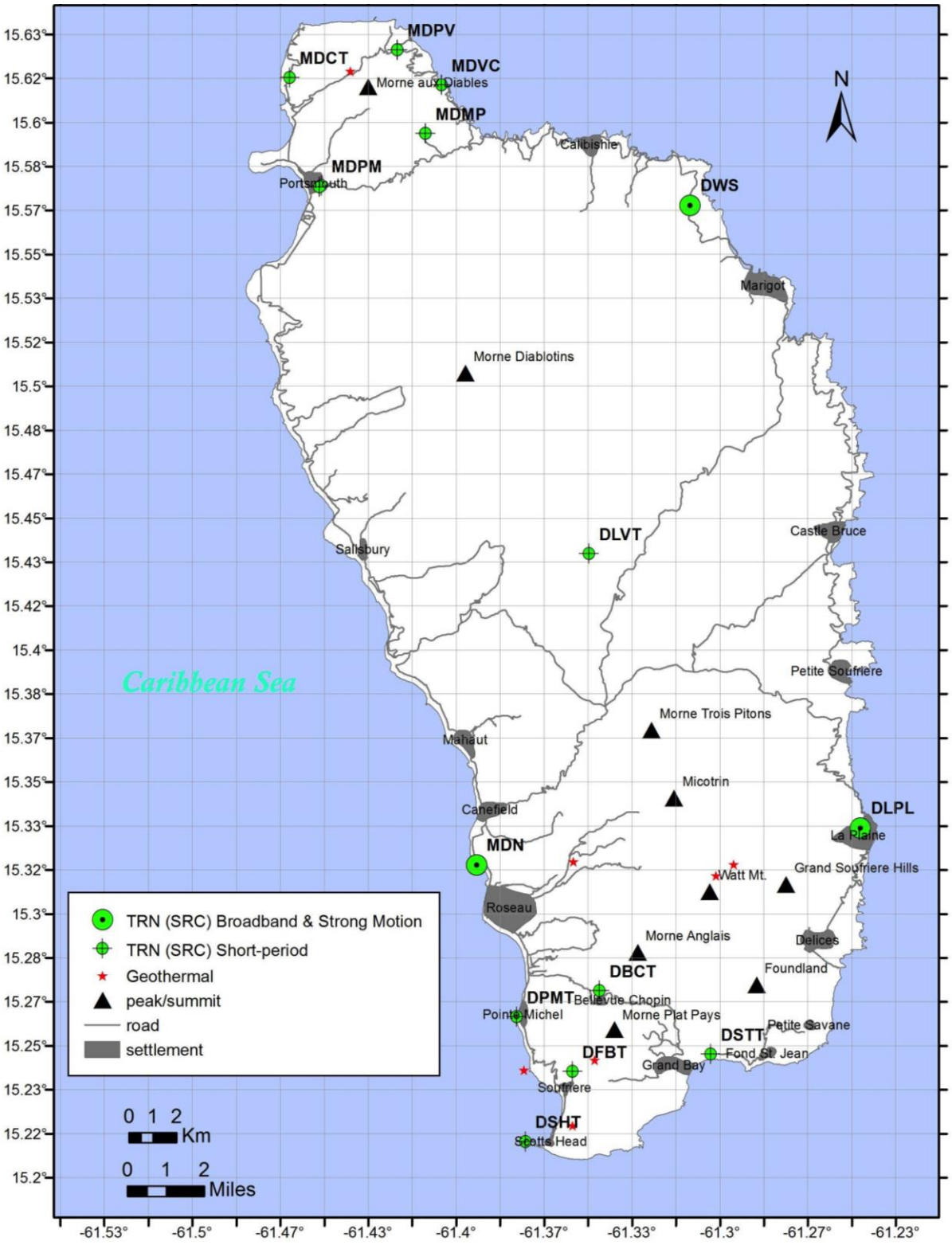

Figure 5: Map of seismic stations and hydro-volcanological monitoring sites in Dominica as at 2014. A new broadband station installed at Salisbury is not shown.

Figure 6: Map of GPS network in Dominica as at 2014.

4. DOMINICA VOLCANIC EMERGENCY PLAN

The Office of Disaster Management is the local agency with responsibility to coordinate and manage all hazards in the Commonwealth of Dominica. Emergency Management in Dominica is driven by: (a) the National Disaster Plan of 2009; (b) the draft CDM Disaster Legislation of 2010 and (c) the 2009-2012 Country Work Programme (CWP). The National Volcanic Contingency Plan guides action in the event of a volcanic emergency in Dominica. This plan is currently in draft form with the latest version dated April 2015 (Watts, 2015). Its stated objectives are to prevent loss of life, plan for the safe relocation of populations in danger, inform and direct the relevant agencies and educate the general public. It contains evacuation plans for each of the key geographical areas of Dominica.

5. REGIONAL RESPONSE MECHANISM

The Regional Response Mechanism is based on the collaboration and cooperation of the *Caribbean Disaster Emergency Management Agency* (CDEMA) and a number of key regional organisations. It rests on a collection of Agreements, Memoranda of Understanding and Protocols for the provision of assistance to CDEMA Participating States (CDEMA-PS) impacted by events.

It is executed by the CDEMA Coordinating Unit (CDEMA-CU) on behalf of CDEMA-PS and consists of:

- a number of Plans, Procedures & Guidelines;
- a group of Response Units, agencies and organizations.

The extent of CDEMA's involvement in disaster response operations in Participating States depends on the severity of the situation and the type of assistance required by the affected State. Three levels of regional response have been defined:

Level 1: This is a local incident where no external assistance is required. The affected participating State has adequate resources to manage the event. The Regional Response Mechanisms is not activated for a Level 1 event. The CDEMA Coordinating Unit (CDEMA-CU) will monitor and share information with partners and other CDEMA Participating States (CDEMA-PS).

Level 2: This is an event that does not overwhelm national capacity to response but some external assistance is required. The affected State may or may not declare a state of emergency. The CDEMA-CU provides technical assistance, specialized equipment, support personnel, information sharing.

Level 3: This is an event which overwhelms the capacity of an affected State(s) to respond. In such cases the Regional Response Mechanisms activated and regional operations are mounted in response. Other support from international agencies may be required.

6. THE UNREST EXERCISE

The exercise will run from Thursday 14th to Friday 15thMay 2015. It will take place in three sessions and will be preceded by a series of lectures as part of the VUELCO summer school.

The participants involved in the exercise will be divided into three groups respectively composed of monitoring scientists, local civil authorities and regional disaster management officials. In addition there will be a number of evaluators.

6.1 EXERCISE OBJECTIVES

The exercise is designed primarily to test the following:

1. The Communication of scientific information from the monitoring scientists to the Office of Disaster Management (ODM) of Dominica.
2. The ODM response mechanisms for volcanic emergencies.
3. The emergency protocols of the SRC (the regional monitoring entity) in dealing with volcanic emergencies.
4. The Regional Response Mechanism for volcanic emergencies.
5. The application of various tools (e.g. BET-UNREST, HASSET) developed by the VUELCO consortium in a volcanic emergency.

6.2 TEAMS

Volcano Team

This group consists of 3 scientists who will drive the exercise by providing scientific bulletins on the state of activity at the volcano. This information will consist of details of the state of the volcano through the provision of scientific data (seismic, deformation, geochemical, etc.) derived from the monitoring network. This data will be in an already processed format as text and tables of numbers, types and magnitude of measured phenomena. One or two members of this team will be present during the scientific analysis to clarify any information presented. The information will be provided in a written format by hardcopy and emailed to participants involved in the scenario.

Scientific Team

This group will consists of all scientists involved in the exercise including members of the VUELCO consortium, participants in the Summer School and regional scientists drawn mainly from the Seismic Research Centre. Dr Joan Latchman of the SRC will coordinate the Scientific Team and therefore act as the

Chief Scientist. One of the requirements of the co-ordinator will be to assign each member of the scientific team to several groups based on different disciplines each of which will have a team leader.

ODM Team:

This group will consists of local disaster management officials possibly supplemented by the disaster management officials from neighbouring islands. Mr Don Corriette, National Disaster Coordinator, will coordinate the ODM Team.

CDEMA Team:

This group will consist of members of the Regional Response Mechanism coordinated by CDEMA-CU.

Evaluators/Observers Team:

This group will consist of 3-4observers who will evaluate the exercise and provide a report to the participants after the exercise has ended. Dr Stefano Ciolli, from Italian Department of Civil Protection (DPC) will be coordinating this team.

6.3 ACTIVITIES

Monday 11th May to Thursday 14th May

Field Trips & Summer School

This period will consist of field trips to various locations in Dominica to familiarize members of the scientific team with the specific nature of the geology of the island in preparation for the exercise.

It will also consist of a number of lectures around the general theme of "unrest simulation" as part of the VUELCO summer school and also to present relevant results of research undertaken as part of the project.

Session 1: Afternoon of Thursday 14th May (4-5 hours in total)

The exercise will start immediately after lunch on Thursday. It will be triggered by a scientific bulletin released by the "volcano team" to the Scientific Team assembled for the exercise, which will contain scientific data obtained from the monitoring network. It is assumed that the Scientific Team, led by the SRC have been assembled in Dominica in response to the SRC request for support from various regional and international agencies.

The Scientific Team may be presented with additional injects from the Volcano Team during this period which would supplement the initial bulletin. The scientific team will review the information provided with a view toward the provision of advice to the ODM Team to guide any necessary mitigation action.

A general timeline for the first session would be:

1. *Organisation of the scientific group: the scientific team will organise itself into different groups based on disciplines (e.g. seismology, geodesy, geochemistry, probabilistic modelling) to analyze and discuss the scientific bulletin (1 hour allocated);*
2. *Discussion and analysis: the scientific team will discuss the scientific bulletin and prepare a written briefing for emergency managers (the ODM Team) based on these discussions including the results of estimates derived from probabilistic forecast models (1.5 hours allocated);*
3. *Briefing of ODM: A small, selected group from among the scientific team (led by the Chief Scientist) will present the briefing to emergency managers, including a statement about whether or not the alert level should be raised (30 minutes allocated);*
4. *Interaction and Decision-making: The ODM team will discuss the scientific briefing, seeking any needed clarification from the scientific team that delivers the briefing. Then ODM team will make its decision on possible mitigation measures to adopt. In the end, ODM and selected scientists prepare a statement for public dissemination, which will be delivered by way of a press conference involving both teams. This group will define beforehand the role(s) of each person involved in the press conference [e.g. emergency managers to address mitigation and scientists to discuss hazards](1 hour allocated);*
5. *Press conference: The National Disaster Coordinator (possibly accompanied by 1-2 other members of the ODM Team) and accompanied by the Chief Scientist (possibly with 1-2 other members of the Scientific Team) will provide an update to the general public on the state of volcanic activity including any decisions taken. They will also answer questions from selected participants who will play the role of the press (30 minutes allocated).*

This first period is expected to last 4-5 hours. Subsequent sessions could be somewhat shorter as there will not be the need for the initial organisational period. However their general format will be of a similar nature.

Session 2: Morning of 15th May.

Update given to the Scientific Team by the Volcano Team and organisation of activities along the same trend as outlined in session 1 with less time allocated to item 1 and more given to item 2.

Session 3: Afternoon of 15th May

Update given to the Scientific Team by the Volcano Team and organisation of activities along the same trend as outlined in session 1 with less time allocated to item 1 and more given to item 2.

Session 4: Debriefing: Evening of 15th May

The debriefing amongst all the participants present on Dominica (i.e. the Scientific Team and the ODM Team) will be coordinated by the DPC and arranged amongst various working groups. Feedbacks and comments will be requested on the following aspects: (1) general organization of the exercise; (2) scientific Process; (3) interaction between scientists and decision makers and (4) civil protection aspects and public communication (press conference). Strong and weak points are expected to be highlighted for each theme.

6.4 ORGANISATIONS EXPECTED TO BE INVOLVED

Caribbean organizations

- *The UWI Seismic Research Centre*
- *The Office of Disaster Management, Commonwealth of Dominica*
- *The Montserrat Volcano Observatory*
- *French Volcano Observatories in Martinique & Guadeloupe*
- *Caribbean Disaster Emergency Management Agency*

VUELCO project partners

- *University of Bristol, United Kingdom (UNIVBRIS)*
- *University of Leeds, United Kingdom (UNIVLEEDS)*
- *Agencia Estatal Consejo Superior de Investigaciones Cientificas, Spain (CSIC)*
- *Istituto Nazionale di Geofisica e Vulcanologia, Italy (INGV)*
- *Dipartimento della Protezione Civile, Italy (DPC)*
- *Ludwig-Maximillian University of Munich, Germany (LMU)*
- *Centre National de la Recherche Scientifique, France (CNRS)*
- *Instituto Geofisico Escuela Politecnica Nacional, Ecuador (IGEPN)*

Other possible (unconfirmed) groups

- *Dominica Red Cross*
- *Disaster Management Coordination Agency of Montserrat*
- *National Emergency Management Organisation of St. Vincent*

6.5 EXERCISE RULES

The exercise will be triggered by a scientific advisory from the SRC to the ODM, which will outline the state of the volcano. The evolution of the volcano as a system will then be directed by information provided by the "Volcano Team" who will be the only group that will know the final outcome of the system.

The exercise will be played out in three sessions that will represent different periods in the evolution of the system. These sessions will be spaced at various periods.

At the beginning of each session the "Volcano Team" will provide data to the "Scientific Team" upon which they will determine the current state of the volcano and from which they will arrive at a consensus decision (also taking advantage of probabilistic models developed by the VUELCO consortium) of its immediate future activity. This information will be provided to the "ODM Team" in the form of a written prognosis including probabilistic evaluations, which will also include implications for hazards and upon which they will take action.

For each of the sessions of the exercise, the following cycle of activity will be repeated:

1. *The Volcano Team will notify the Scientific Team of the monitoring data (seismicity, ground deformation, gas output, etc.), determined over the period from the volcano-monitoring network. This information will include data derived from remote methods as well as direct observations. All relevant data derived for the period under review will be given to the Scientific Team. This information will be provided in the form of electronic and written reports that will be provided by the Leader of the Volcano Team.*
2. *The Scientific Team will review and discuss the data, running any models (including probabilistic ones) and using any tools available to derive a prognosis on the state of the volcano. This prognosis will be used to assess the volcano hazards and to advice the ODM Team in the form of a written scientific advisory both in terms of the state of the volcano, its activity in the immediate (near) future (including probabilistic evaluations) and possible*

mitigation action which may be appropriate. The Chief Scientist will deliver this advisory.

3. *The ODM Team will discuss the report provided by the Scientific Team, seeking clarifications as needed from the Chief Scientist and decide on actions needed to minimize the hazard impact on the local population. The ODM Team will also liaise with the CDEMA Team as needed.*
4. *Information to be transmitted to the general public will be done through a press conference (that will occur at the end of each of the three sessions). The key people (e.g. the Chief Scientist and National Disaster Coordinator) will be interviewed in all three press conferences. Other members of the scientific and emergency management team will participate in at least one of the conferences to provide support and also answer relevant questions upon request of the Chief Scientist. The "media" would be represented by a number of specific people tasked to function as the press. They would be provided with some pre-arranged questions and also briefed generally on the kinds of issues to raise; otherwise the press conference will be spontaneous. No actual members of the press are expected to be involved in the exercise.*

7. SELECTED BIBLIOGRAPHY

Bignami, Christian et al. "Handbook for volcanic risk management: Prevention, crisis management and resilience." Handbook for volcanic risk management: Prevention, crisis management and resilience. MiaVita. Bureau de Recherches Géologiques et Minières, 2012. http://miavita.brgm.fr/default.aspx

Daniel Andrade; Stefano Ciolli; Chiara Cristiani; Mario Calixto Ruiz (2015), "VUELCO-Cotopaxi Volcano Exercise - Debriefing Report," https://vhub.org/resources/3796.

Di Napoli, Rossella, Alessandro Aiuppa, and Patrick Allard. "First multi-gas based characterisation of the Boiling Lake volcanic gas (Dominica, Lesser Antilles)." Annals of Geophysics 56.5 (2014): S0559.

Fournier, N., Witham, F., Moreau-Fournier, M., & Bardou, L. (2009). "Boiling Lake of Dominica, West Indies: High-temperature volcanic crater lake dynamics". Journal of Geophysical Research: Solid Earth (1978–2012), 114(B2).

Howe, T. M., Lindsay, J. M., & Shane, P. (2015). "Evolution of young andesitic–dacitic magmatic systems beneath Dominica, Lesser Antilles". Journal of Volcanology and Geothermal Research, 297, 69-88.

Howe, T. M., Schmitt, A. K., Lindsay, J. M., Shane, P., & Stockli, D. F. (2015). "Time scales of intra oceanic arc magmatism from combined U-Th and (U-Th)/He zircon geochronology of Dominica, Lesser Antilles. Geochemistry, Geophysics, Geosystems".

Howe, T. M., Lindsay, J. M., Shane, P., Schmitt, A. K., & Stockli, D. F. (2014). "Re-evaluation of the Roseau Tuff eruptive sequence and other ignimbrites in Dominica, Lesser Antilles". Journal of Quaternary Science, 29(6), 531-546.

Joseph, E. P., Fournier, N., Lindsay, J. M., & Fischer, T. P. (2011). "Gas and water geochemistry of geothermal systems in Dominica, Lesser Antilles island arc." Journal of Volcanology and Geothermal Research, 206(1), 1-14, doi:10.1016/j.jvolgeores.2011.06.007.

Le Friant, A., Boudon, G., Komorowski, J.C., Deplus, C., 2002. "L'île de la Dominique, àl'origine des avalanches de débris les plus volumineuses de l'arc des Petites Antilles The Island of Dominica, site for the generation of the most voluminous debris avalanches in the Lesser Antilles Arc". C. R. Geosci. 334 (4), 235–243.

Lindsay, J. M., Stasiuk, M. V., & Shepherd, J. B. (2003). “Geological history and potential hazards of the late-Pleistocene to Recent Plat Pays volcanic complex, Dominica, Lesser Antilles”. Bulletin of volcanology, 65(2-3), 201-220.

Lindsay, J.M., Robertson R.E.A., Shepherd, J.B. & Ali, S. (Eds) 2005. “Volcanic Hazard Atlas of the Lesser Antilles”. Seismic Research Unit, The University of the West Indies, Trinidad and Tobago, W.I., 279p. ISBN: 9769514209 9789769514201.

McCarthy, Kevin T., Thomas Pichler, and Roy E. Price. "Geochemistry of Champagne Hot Springs shallow hydrothermal vent field and associated sediments, Dominica, Lesser Antilles." Chemical Geology 224.1 (2005): 55-68.

Stefano Ciolli; Servando De la Cruz-Reyna (2013), "Colima Volcano Exercise Plan," https://vhub.org/resources/2475.

Stefano Ciolli; Servando De la Cruz-Reyna (2013), "Colima Volcano Exercise Debriefing Report" https://vhub.org/resources/2477.

Stefano Ciolli; Chiara Cristiani; Giuseppe Amorosi Golisciani (2014), "VUELCO- Campi Flegrei Caldera Unrest Scientific Simulation - Simulation Plan," https://vhub.org/resources/3635.

Stefano Ciolli; Chiara Cristiani; Giuseppe Amorosi Golisciani (2014), "VUELCO- Campi Flegrei Caldera Unrest Scientific Simulation - Debriefing Report," https://vhub.org/resources/3640.

Watts, Robert B. (2015),“Draft National Volcanic Contingency Plan for Dominica, West Indies”. 48p.

8. CONTACTS

At SRC-UWI:
Richard Robertson richie_robertson@uwiseismic.com

At Italian Department of Civil Protection (DPC):
Stefano Ciolli stefano.ciolli@protezionecivile.it
Chiara Cristiani chiara.cristiani@protezionecivile.it