THE UNIVERSITY
OF THE
WEST INDIES

Biennial Report 2011-13

The UWI Seismic Research Centre is the official source of information for earthquakes and volcanoes in the English-speaking Eastern Caribbean.

SEISMIC RESEARCH CENTRE

St. Vincent's volcano

La Soufrière

Cover Image:

The youngest volcanic centre on the island, La Soufrière Volcano (1,178 m), occupies the northernmost third of the island. A classic strato-volcano with a crater 1.6km across and 300-600m in depth, La Soufrière is considered to be the only volcano that is likely to erupt in St. Vincent in the future.

Panoramic view of crater at La Soufrière Volcano, St. Vincent (photo courtesy R. Arculus)

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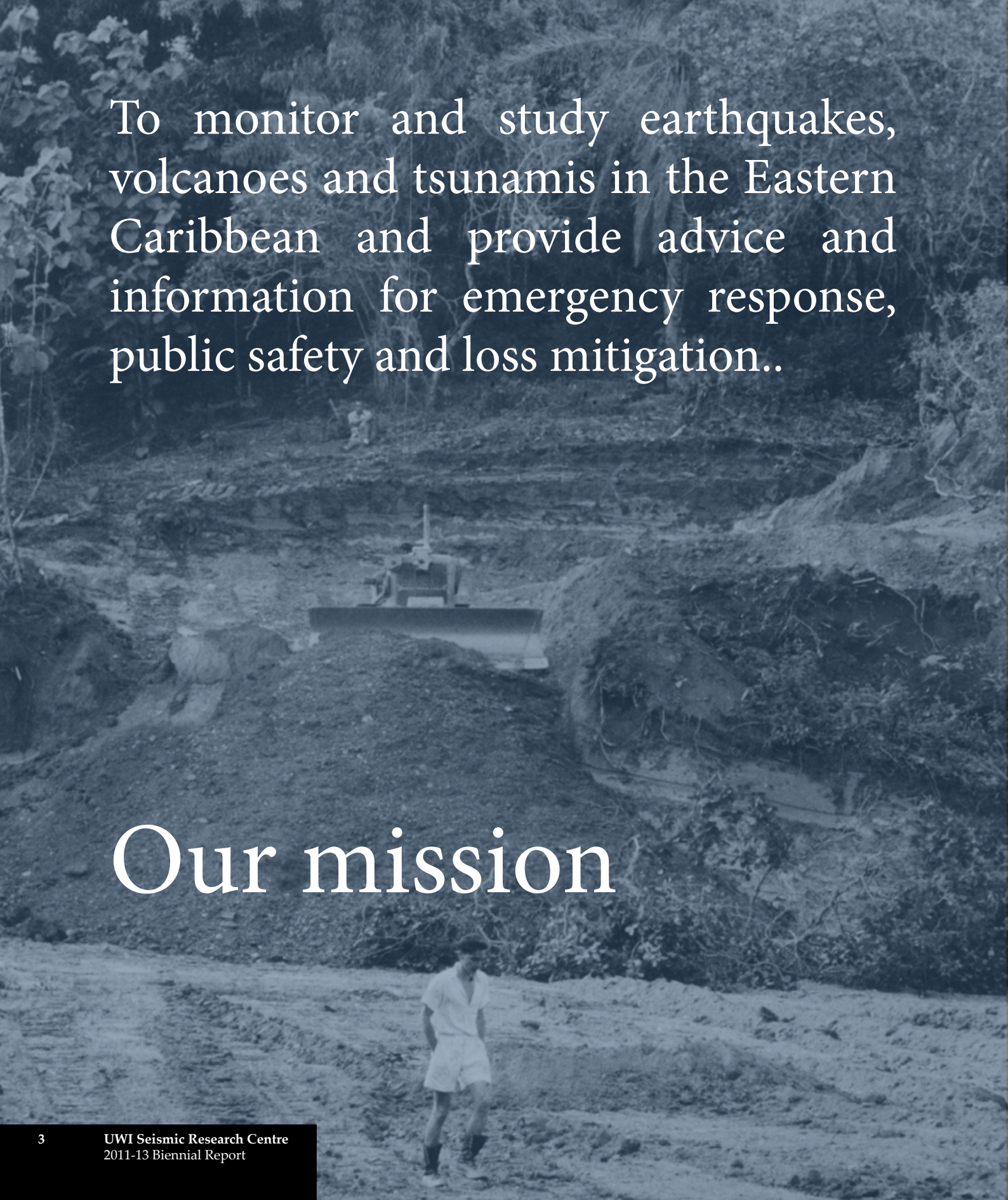


To monitor and study earthquakes, volcanoes and tsunamis in the Eastern Caribbean and provide advice and information for emergency response, public safety and loss mitigation..

Our mission

Pro Vice Chancellor and UWI St. Augustine Campus Principal, Professor Clement Sankat and SRC Director (Ag.) Dr. Joan Latchman shake hands at the end to the formal launching of SRC's 60th Anniversary.

Recipients of The UWI Vice Chancellor's 2013 Award for Excellence

Executive Summary

The period has been one of continued elevated activity at all levels of our work: the number of earthquakes recorded continues to increase; this is due both to increased recording capacity and a real increase in the number of events that are occurring. Through projects and collaborations, we have been densifying our various networks and our Education and Outreach efforts were increased to promote the need for awareness and preparedness for the next major-great earthquake and the demands of marking our 60th Anniversary in 2013. It was a period of a change in administration. Dr. Richard Robertson, who was appointed Head/Director of the agency, upon the retirement of the previous Head, in 2004, chose to step down, effective September 2011. Seismologist Dr Joan Latchman was appointed to the position from that time, in an acting capacity, for a year in the first instance and then another, pending a decision on a more long-term arrangement.

It was also a period of challenges occasioned by industrial unrest, on the St. Augustine Campus, in response to delays in the negotiation of new Collective Agreements. The work of the SRC

is not constrained by the semester system, neither do earthquake and volcanic systems respect holiday periods. Industrial action negatively impacts the day to day operations of the SRC and team health. Various activities were undertaken focussed on promoting a more positive working environment. In addition, during the period, we were advised that extended delays in payments from some contributing territories would result in cuts in our budget. While implementing measures to try to address this, we continued to seek to fulfil our mandate. During the period, therefore, a scientist to develop our automatic, earthquake location system was identified and recruited. The system allows for near real time release of earthquake parameters for events of general interest and is currently being developed.

For the last four decades, the SRC has been advising of the need for all territories in our area of responsibility, from Trinidad in the south to St. Kitts in the north, to be prepared, not just getting ready, for the next great earthquake, i.e. one near magnitude 8, since such an event appears over due and identifying the actual location is beyond the science, at this time; it should be noted that the impact of such an earthquake would not be limited to the immediate vicinity of its location, but would extend outwards, possibly hundreds of kilometres. Education and Outreach efforts play a major role in building awareness and projects to investigate the most effective strategies are currently in train and requests for such programmes have been increasing.

High level felt events near Trinidad spurred a request, from the Speaker of the House, for a presentation to be made to both Houses of Parliament, which was done in May 2013. With each passing day, the need for preparedness becomes more urgent and it is at that level it must be recognised to allow earthquake resistance and land use planning, as a region, to be included in all our development efforts. The Trinidad and Tobago Microzonation Project, being funded by the Government of Trinidad and Tobago, is a big step in the right direction for that country.

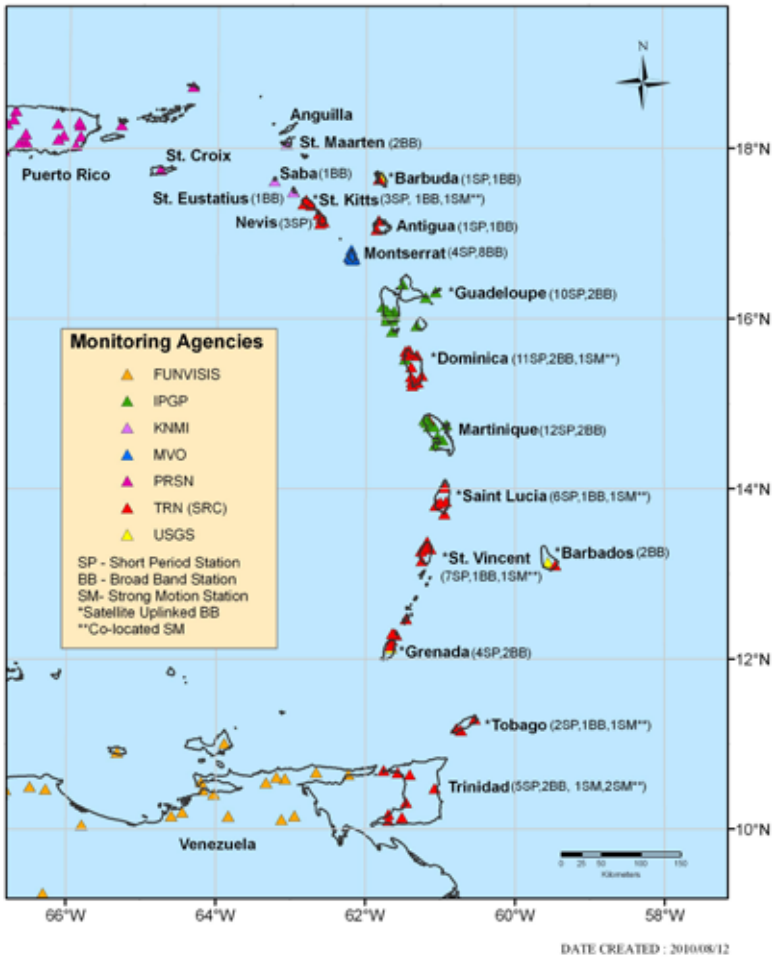
In this vein, concern over the siting of the Couva Children's Hospital close to the Central Range Fault, Trinidad, aroused national discussion in mid-2013 that culminated in a seminar, organised by the Association of Professional Engineers of Trinidad and Tobago to allow all stakeholders an opportunity to ventilate concerns and receive assurances. The SRC played an active role in these discussions, which helped to arouse general interest in earthquake resistant buildings and the current status of the existing building stock. The hazards monitored by the SRC have the potential to not only arrest development, but set it back decades. There are measures that have been employed in other more seismically vulnerable regions to reduce the impact when the largest magnitude events occur. The SRC will continue to promote the adoption of such measures in our region in an effort to guard our investment in our development. It is our hope that we heed the lessons of Haiti 2010 and not wait for their experience to be ours before moving to be genuinely prepared.

The period ended on a very positive note with the near completion of new accommodation for our operations and the SRC receiving The UWI Vice Chancellor's Award for Excellence – Research Accomplishments and Public Service (2013).

UWI-SRC Staff following the Vice Chancellor's Award ceremony.

Some of the drum recorders that are still on display at the SRC Office.

Operations



Seismograph Network

Seismic networks generally serve three broad purposes: general or specific earthquake monitoring, seismic alarm, and research on the earth's interior. In the Eastern Caribbean general earthquake monitoring aids in resolving regional seismotectonics and informs a broad range of activities that are aimed at mitigating seismic risk in the long-term. A fundamental and foremost goal of general monitoring is the timely and accurate determination of earthquake locations. In the Eastern Caribbean, the network is also specifically used to monitor volcanic activity.

The Eastern Caribbean Seismograph Network (ECSN) operated by the SRC consists of over 52 instruments (Figure 1) that comprise a mixture of three-component broadband stations, Kinemetric K2 accelerographs, three-component short-period seismometers and single vertical component stations. Data is transmitted in real or near real-time to the Centre headquarters in Trinidad but can be processed locally in real time if needed.

Figure 1: Eastern Caribbean seismic monitoring network.

..GPS monitoring of ground deformation is an excellent medium to near real-time monitoring tool.

Ground Deformation Network

The seven continuous GPS (cGPS) stations operated in Dominica, Grenada, St. Vincent, Antigua, St. Kitts, St. Vincent and Tobago were fully operational throughout the period under review. These stations along with three other stations from international institutes have continued to help in determining the tectonic velocity of this region and aid in increasing the accuracy of our volcano monitoring GPS networks. Our GPS data repository is available online through request. Additionally, one cGPS stations was installed in Bayfords Farm, St. Kitts in March of 2013. These stations were installed to augment the Centre's volcano monitoring capabilities on St. Kitts and to strengthen the Eastern Caribbean cGPS network. The SRC has fully adopted and implemented the GAMIT\GLOBK tool to produce high precision GPS solutions and velocities. The GPS acquisition and processing with this tool has been automated which allows for the production of daily reports and a many fold increase in precision for volcano GPS networks.

GPS Antenna set up at Brimstone Hill Fortress St Kitts

The Montserrat continuous GPS network was upgraded during the period March - May 2012, with the installation of 4 new stations (NWBL, RCHY, RDON, SGH1). NWBL and RCHY stations were funded by NASA, and RDON is part of the COCONet project and supported by UNAVCO. The data of these three stations are made publicly available on the UNAVCO website. ***This along with our Eastern Caribbean stations, highlights the need for GPS monitoring of ground deformation as an excellent medium to near real-time monitoring tool.***

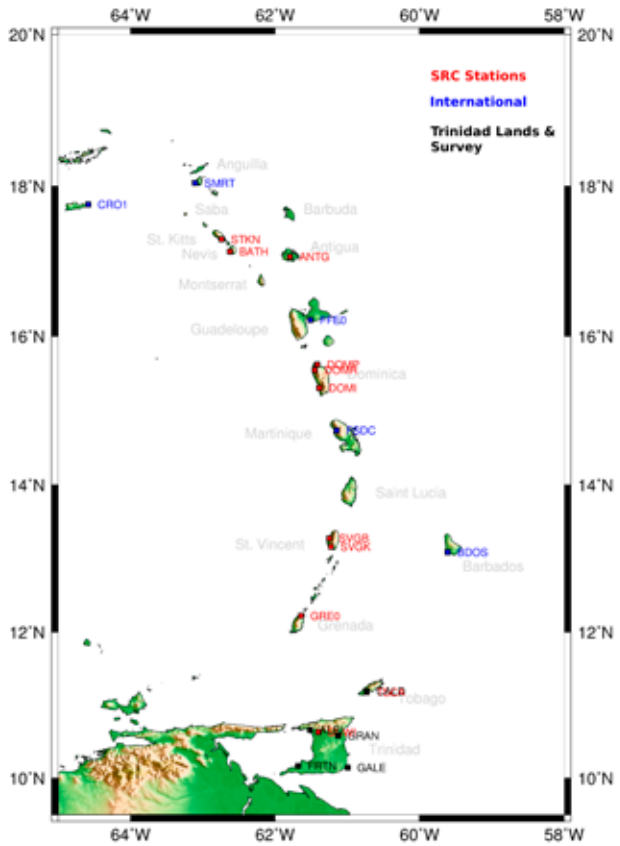


Figure 2: Eastern Caribbean continuous GPS network.

Geothermal Monitoring

The Seismic Research Centre initiated geothermal monitoring (measurement of temperature, pH, and chemical composition) of hot springs and fumaroles associated with Lesser Antilles volcanoes in 2001. Routine sampling in islands including Dominica, Saint Lucia, Grenada, St. Vincent, St. Kitts, and Nevis have taken place on an almost annual basis. Geochemical field investigations were conducted in Dominica during the reporting period (8th – 12th April 2013). Analysis of hydrothermal waters revealed no magmatic input to the geothermal systems on the island, consistent with what has been observed since 2008. This trip was joined by a research team from LMU München, Germany led by Dr. Bettina Scheu, consisting of Dr. Sebastian Wiesmaier, Laura Spina, Daniele Morgavi and Klaus Mayer as part of the Volcanic Unrest in Europe and Latin American Countries (VUELCO) project collaboration. Their main objective was to conduct field work and rock sampling at the geothermal areas in Dominica to constrain conditions needed to initiate phreatic eruptions and their explosive potential.

Figure 3: Sites of geothermal monitoring in Dominica.

Seismic Activity 2011 - 2013

ROUTINE EARTHQUAKE MONITORING

During the period, the TRN seismic network stations recorded a minimum of 3,889 earthquakes in the area of responsibility, of which a total of 2,798 events were located (72%), using our own data and the data contributions from Martinique, Guadeloupe, Puerto Rico and Venezuela. The number of earthquakes being recorded has been steadily increasing. There are two factors influencing the increase: network expansion is one factor and the other is that some zones are manifesting a somewhat elevated level of activity. The elevated pattern in the Antigua-Barbuda area has been maintained, as has that in the area east of Saint Lucia. The area between Grenada and Saint Lucia, which generates earthquakes at a low level relative to the rest of the arc, and is considered to be a seismic gap by some researchers, has been manifesting a somewhat elevated output since 2005. The daily generation and cumulative count of earthquakes for the period 2011/08/01-2012/07/31 and 2012/08/01-2013/07/31 are shown in Fig. 1a and Fig. 1b, respectively.

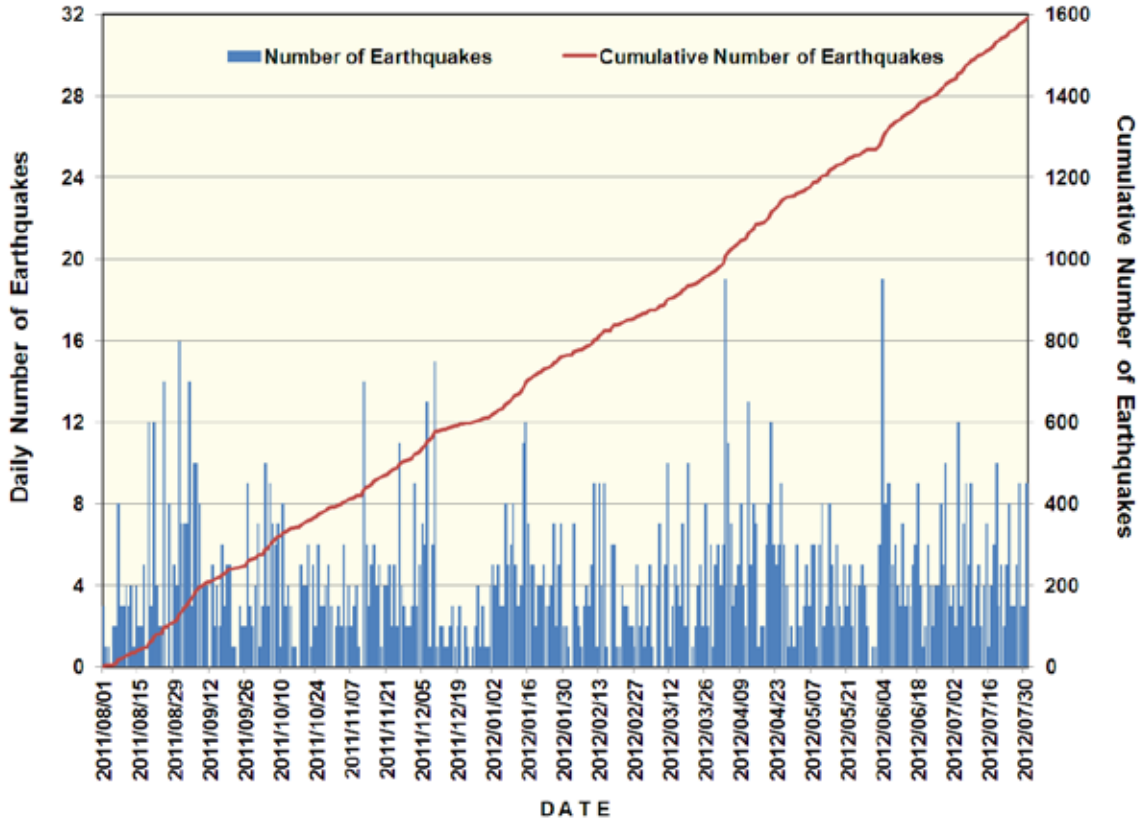


Fig. 1a: Daily and cumulative count of earthquakes in the East Caribbean during the period 2011/08/01 – 2012/07/31

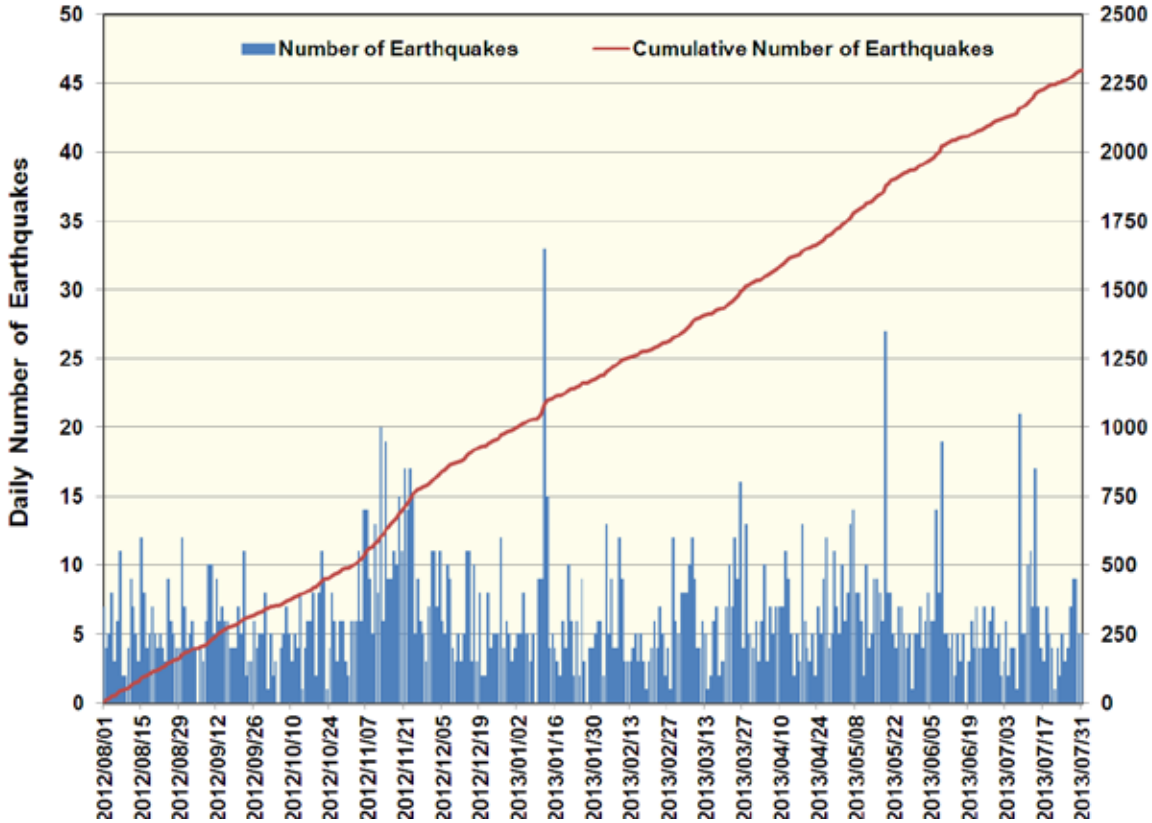


Fig. 1b: Daily and cumulative count of earthquakes in the East Caribbean during the period 2012/08/01 – 2013/07/31

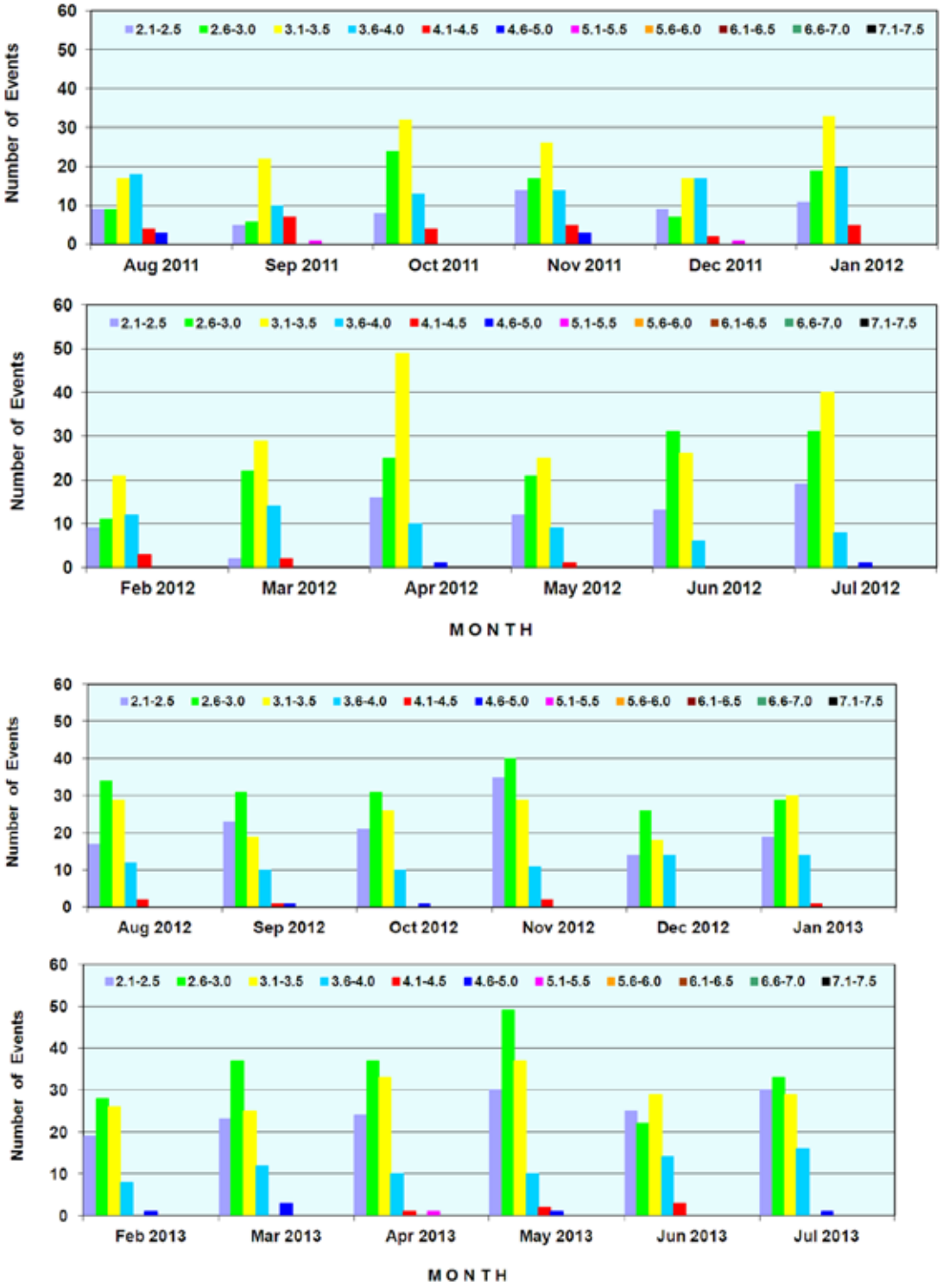


Fig. 2: Monthly magnitude distribution of earthquakes in the East Caribbean during the period 2011/08/01 – 2013/07/31

There were five events in the magnitude range 5.0-5.3, 25 earthquakes in the 4.6-4.9 magnitude range, 106 events in the 4.0-4.5 magnitude range and 265 in the 3.6-3.9 magnitude range; in general earthquake above magnitude 3.5 might be felt. The largest earthquakes for the period were of moderate magnitude in the range 5.0-5.3; three occurred in the area north of 16ºN latitude; the other two were located in the south: north of Venezuela and north-west of Trinidad. The magnitude distribution of located events with magnitude greater than 2.0 is shown in Fig. 2. There were at least 48 events reported felt for the period (Table 1).

Epicentres for the located earthquakes, for the period, are shown in Figs. 3a-3c. The maps show the earthquakes partitioned into three depth ranges: shallow (65% of total), intermediate (14% of total) and deep (21% of total), respectively. As noted earlier, the highest level of activity for the period was seen in the Leeward Islands, with 1753 of the 2798 located events (near 63%) occurring north of 16ºN latitude. The area within 12ºN - 16ºN latitude generated 402 events (approximately 14% of the total number) and south of 12ºN latitude there were 644 recorded events (23% of the total). Seismic activity in the Paria Peninsula area continues at a relatively reduced level when compared with that in the Leeward Islands; in the past the two zones exhibited levels of activity more on par. Fig 4 is a 3-D depiction of the earthquake locations. The plot allows an appreciation of the depth distribution of seismicity along the subducting slab.

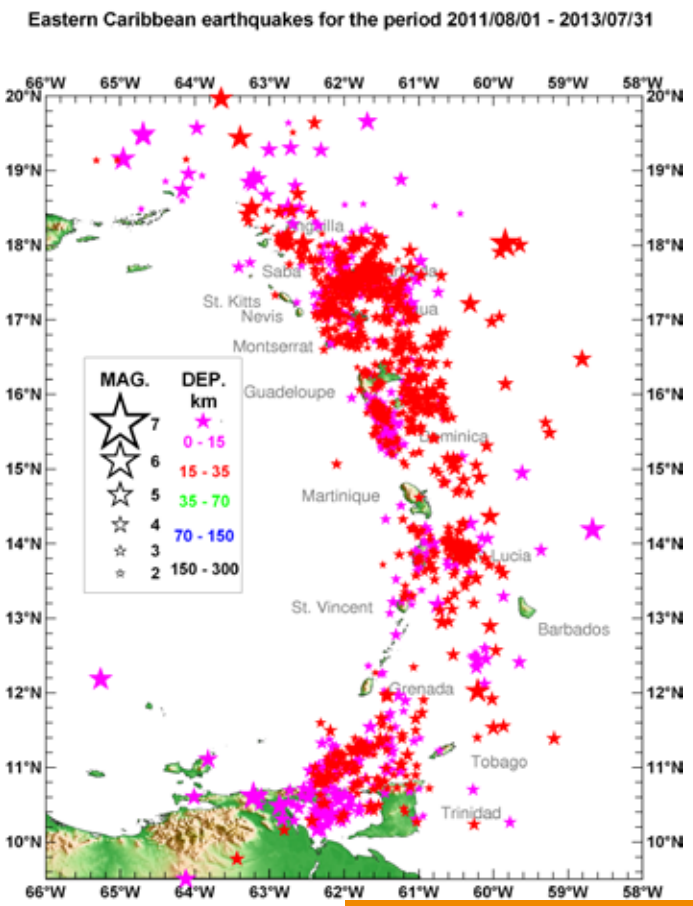


Fig. 3b (top right): Eastern Caribbean epicenters 35 - 100 km for the period 2011/08-2013/07

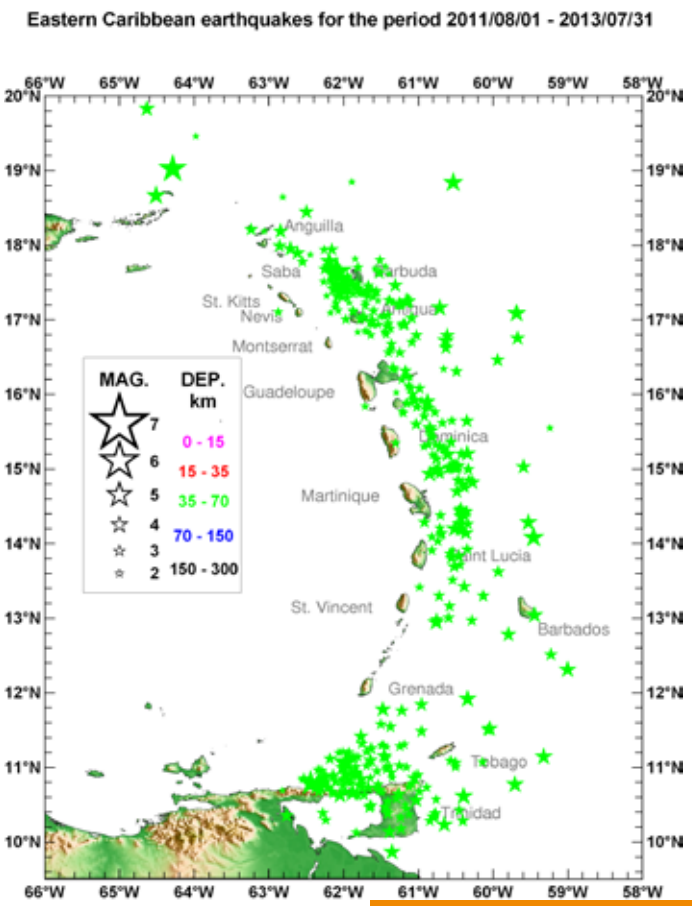


Fig. 3a(top left): Eastern Caribbean epicenters 0 – 35 km for the period 2011/08-2013/07

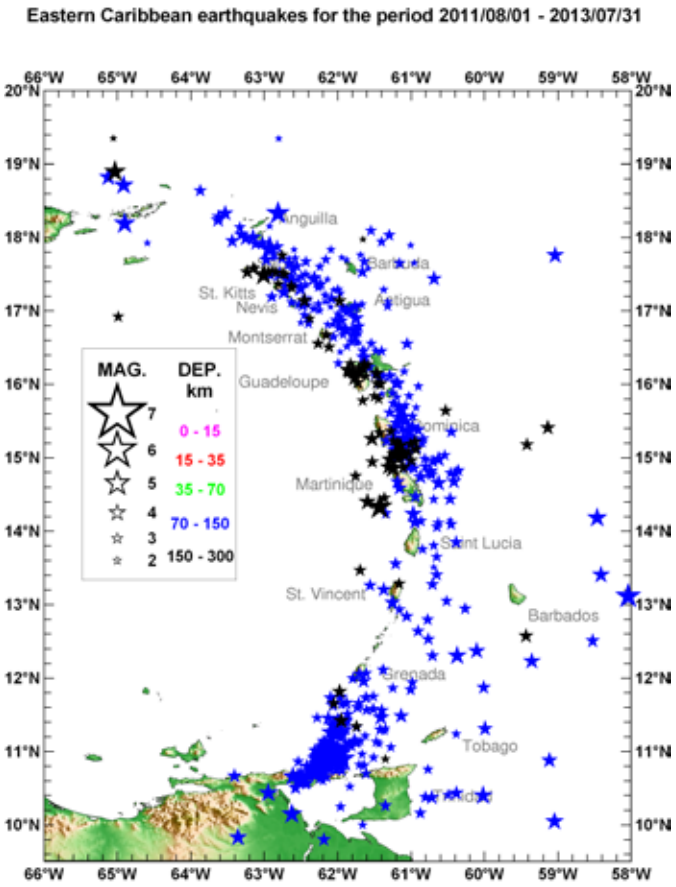


Fig. 3c: Eastern Caribbean epicenters 100 - 300 km for the period 2011/08-2013/07

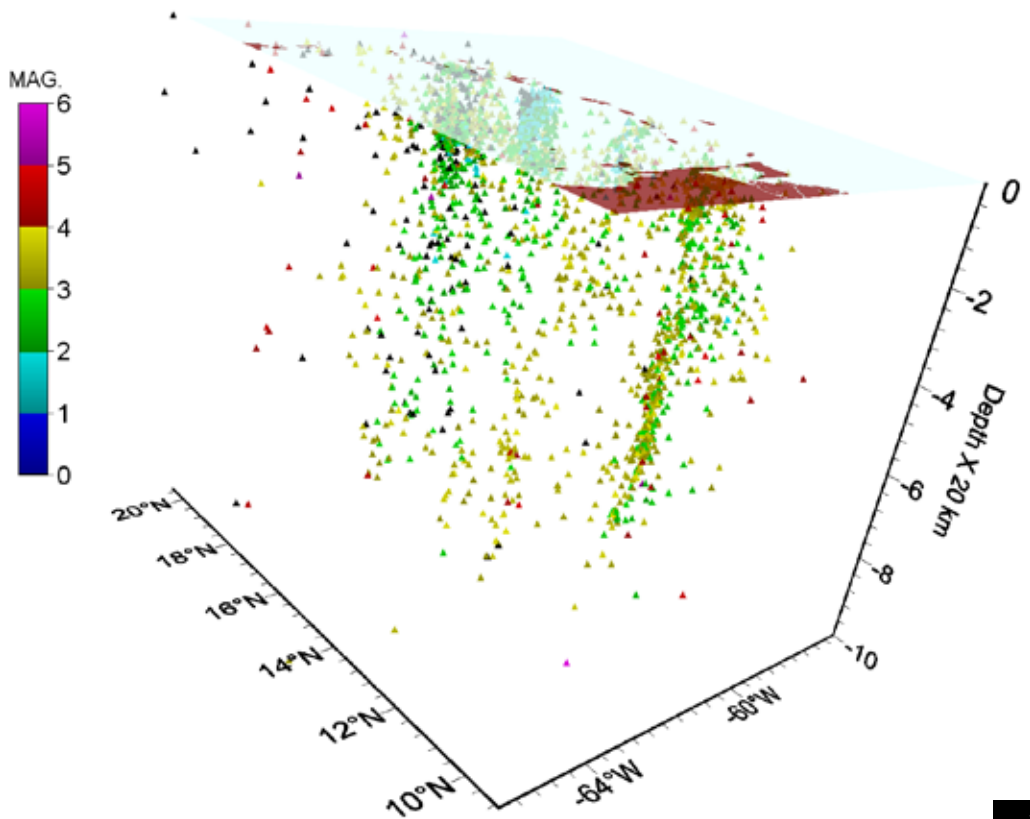


FIG. 4: 3-D PLOT OF EARTHQUAKES DURING 2011/08-2013/07

On land Trinidad the events are less diffusely distributed than obtained in the past..

Trinidad Seismicity for the Period

There are 152 earthquakes shown in Fig. 5, 23 of which were of magnitude greater than 3.5. The largest was of magnitude 5.0 and occurred north of the Paria peninsula, the most active zone in the vicinity, north-west of Trinidad, which is the general area, in which the largest known earthquake, at magnitude near 8, occurred in 1766. On land Trinidad the events are less diffusely distributed than obtained in the past, with clustering observed in the north-east and north-west, where there was a swarm in 2001 and a sequence in 2006, respectively. Overall, the activity seen is consistent with that expected.

*MM = Modified Mercalli

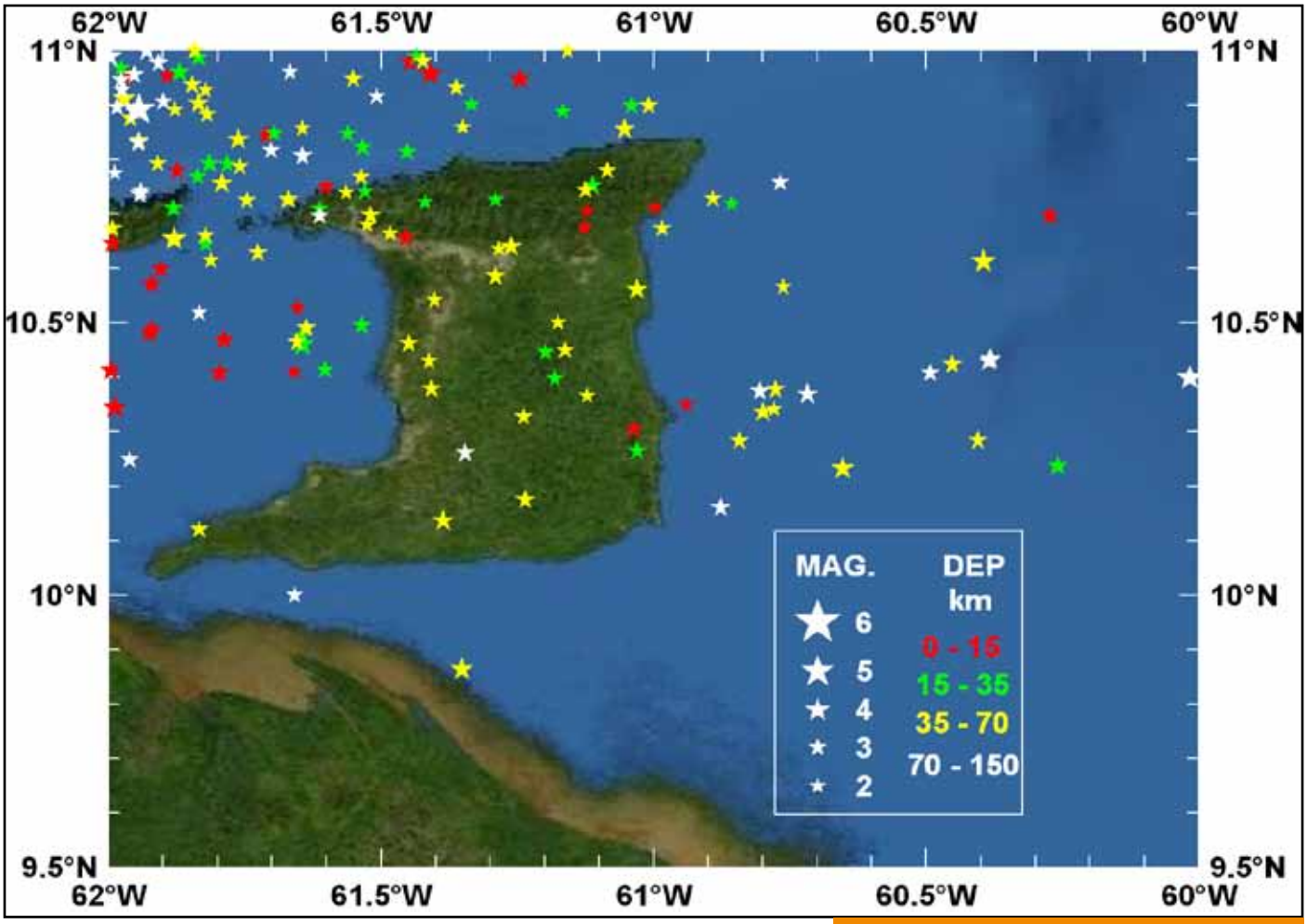


FIG. 5: EARTHQUAKES IN THE VICINITY OF TRINIDAD DURING 2011/08-2013/07 WITHIN THE BOUNDARIES SHOWN

Seismicity associated with volcanic centres

Volcanic centres have an associated low level of seismic activity, described as background, when they are at rest. Fig. 6 shows the volcanic earthquakes recorded in St. Vincent, Saint Lucia and northern Dominica during the reporting period. Since the high level activity of 2009 in northern Dominica, the number of events there has been steadily decreasing. It should be noted that volcanic centres may exhibit episodic periods of elevated seismicity for decades as symptoms precursory to eventual volcanic eruption. In the context of the big picture, therefore, such episodes should not be casually dismissed. The background seismicity at centres in the other islands was at much lower levels. The Kick-'em-Jenny submarine volcano, which is located about 8 km north of Grenada erupts on average every 10-11 years; the last eruption was in 2001. Activity from that centre in the near future, therefore, would not be a surprise.

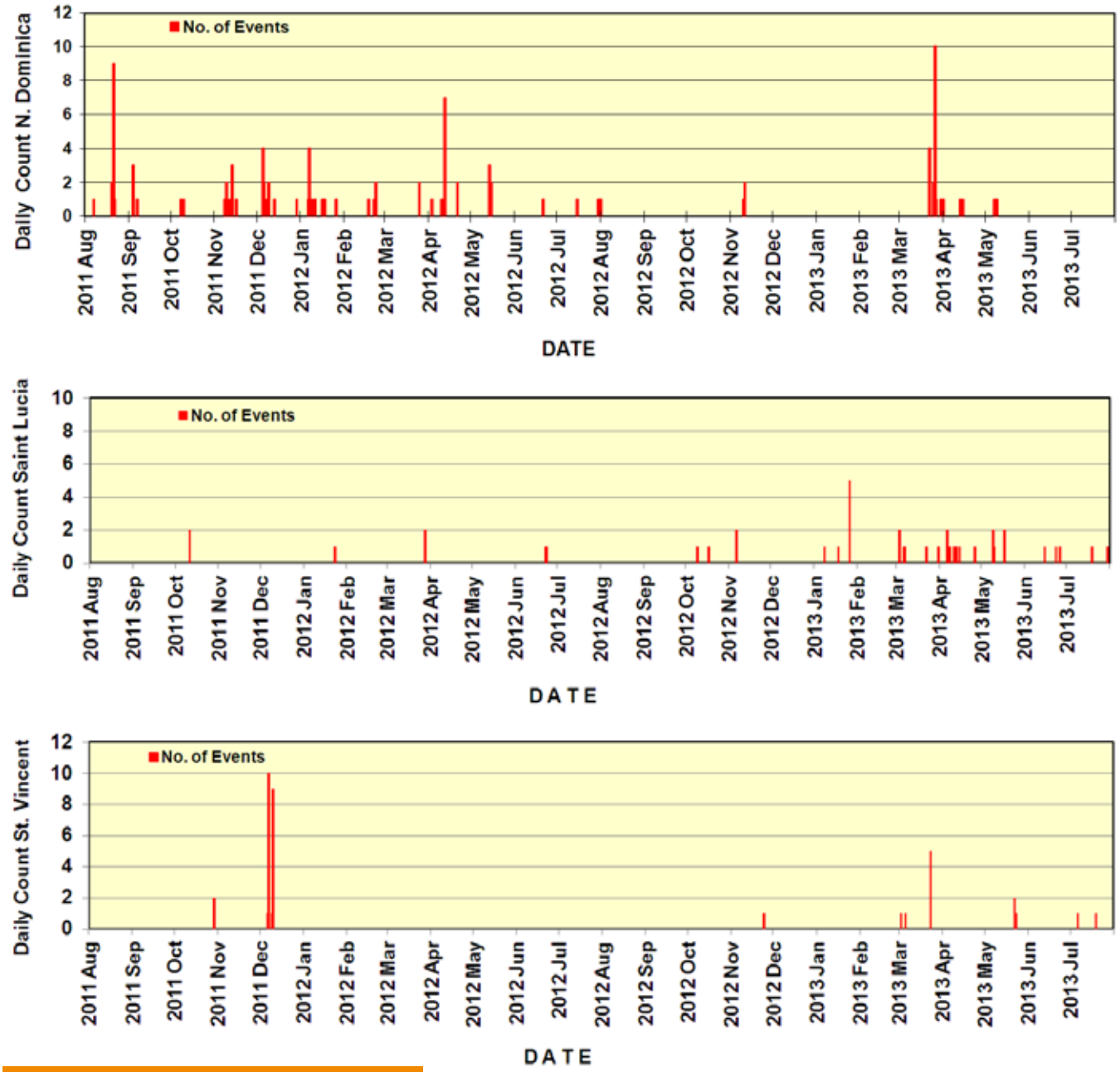


FIG. 6: DAILY VOLCANIC EARTHQUAKES IN ST. VINCENT, SAINT LUCIA AND NORTHERN DOMINICA DURING 2011/08-2013/07

Felt Events

There were 60 tectonic earthquakes reported felt during the period. These events ranged in magnitude from 2.1 for an earthquake near Antigua to 7.3

DATE YR MM DD	TIME (UTC)* HR MM SS.SS	LAT. ºN	LONG. ºW	DEP. KM	MAG. MT	REMARKS
2011/10/18	23:49:42.9	17.712	61.761	25	4.0	North of Barbuda. Felt in Barbuda, Antigua. Barbuda MMI: II Antigua MMI: II
2011/10/28	20:38:43.9	17.614	61.574	20	2.9	East of Barbuda. Felt in Barbuda, Antigua.
2011/10/28	21:05:13.1	16.947	61.81	3	-	South of Antigua. Felt in Antigua.
2011/10/28	22:33:56.5	17.424	61.954	28	2.1	Antigua. Felt in Antigua.
2011/10/29	00:45:15.5	17.724	61.485	25	2.8	East of Barbuda. Felt in Antigua.
2011/11/06	02:35:28.0	15.084	60.541	34	4.4	South-east of Dominica. Felt in Dominica, Saint Lucia, St. Vincent. Dominica MMI: II – Roseau III – Portsmouth, Bellevue Chopin. Saint Lucia MMI: II – Rodney Bay, Castries, Gros Islet, Vanard, Ti Rocher/ Micoud, Soufriere. III – Castries, Cap Estate. St. Vincent II - Hopewell
2011/11/12	12:52:03.1	10.786	62.441	64	4.9	North of Paria peninsula. Felt in Trinidad. MMI II – Barataria, San Juan, Aranguez, Morvant, St. James, Caroni, Mt. Hope, Maraval, Arima, Carenage, St. Clair, Valsayn, Cascade, Champs Fleurs, Curepe, Chaguanas, Arima, San Fernando, Cocorite. III – St. Augustine, Barataria, St. Anns, Diego Martin, Westmoorings, Moka, Curepe, Claxton Bay.

DATE YR MM DD	TIME (UTC)* HR MM SS.SS	LAT. ºN	LONG. ºW	DEP. KM	MAG. MT	REMARKS
2011/11/26	21:49:37.2	17.43	61.844	16	4.1	North of Antigua. Felt in Antigua.
2011/11/28	05:42:50.7	18.015	62.552	24	4.7	East of Saint Barthelemy. Felt in St. Kitts St. Barthelemy, Antigua, St. Eustatius, Anguilla, St. Martin, Sint Maarten, Nevis, Guadeloupe. MMI. II – St. Barthelemy St. Kitts MMI: II – Newton Ground, Basseterre III – Basseterre Antigua II – Cedar Valley St. Eustatius MMI: II – Pleasure Estate Anguilla MMI: II – West End III – Sandy Hill, George Hill. St. Martin III – Orient Beach, Mont Vernon 2 Sint Maarten MMI: IV – Cupecoy Nevis MMI: II - Hermitage
2012/01/23	16:32:14.33	16.577	61.263	20	4.1	North-east of Guadeloupe. Felt in Antigua. MM INT: II – St. John's III – Bethesda Village
2012/01/28	01:02:47.88	11.309	61.786	22	3.8	North-west of Trinidad. Felt in Grenada. MM INT: III – Carriacou, Prospect Hall
2012/01/29	11:33:11.26	14.268	60.308	8	4.0	East of Martinique. Felt in Saint Lucia. MM INT: II – Gros Islet

DATE YR MM DD	TIME (UTC)* HR MM SS.SS	LAT. ºN	LONG. ºW	DEP. KM	MAG. MT	REMARKS
2012/02/11	05:56:38.75	10.809	62.150	80	4.5	North of Paria peninsula. Felt in Trinidad. MM INT: III – Diego Martin, Maraval, West Moorings
2012/02/18	02:22:06.82	11.964	61.416	19	4.0	South-east of Grenada. Felt in Grenada. MM INT: II – St. Andrew's, St. George's III – Morne Rouge, St. George's Lance Aux Epines, Good Hope.
2012/03/03	08:40:26.92	15.093	61.176	148	4.5	South-east of Dominica. Felt in Dominica. MM INT: II – Bellevue Chopin.
2012/03/04	01:25:10.83	14.232	60.973	119	4.0	North of Saint Lucia. Felt in Saint Lucia. MM INT: II – Gros Islet
2012/03/17	21:44:18.90	10.750	61.602	3	2.9	Near north coast of Trinidad. Felt in northern parts of Trinidad. MM INT: II - Maraval, Cascade, Diego Martin.
2012/03/23	07:19:56.82	16.693	62.171	14	3.5	Southern Montserrat. Felt in Montserrat. MM INT: II
* UTC = LOCAL TIME + 4 HOURS						

Volcanic activity

With the exception of the Soufrière Hills Volcano (SHV) in Montserrat, the volcanic centres of the Eastern Caribbean exhibited low levels of activity throughout the review period. Since the beginning of the pause in lava extrusion in February of 2010, the SHV has shown a slow inflation of its edifice (~1 cm/year), which has been interpreted to be consistent with the pressurization of the magma chamber at depth.

Sunrise at the Soufriere Hills Volcano Monserrat - Photo courtesy MVO

Members of the UWI-SRC Electronics team install a Ray Dome and satellite dish as part of a new broadband seismic station in Bethesda Antigua.

Improvement in our ability to provide accurate and up-to-date information

Research and Innovation

The research effort of the Centre is focused primarily on seismology, volcanology and outreach with a view towards an improvement in our ability to provide accurate and up-to-date information about earthquake and volcanic activity in the Eastern Caribbean.

Ongoin Projects and Research in Progress

- **VUELCO (Volcanic Unrest in Europe and Latin America:** Phenomenology, eruption precursors, hazard forecast and risk mitigatiOn). This is a collaborative four (4) year project with 10 other institutions drawn from UK, Spain, Italy, Germany, France, Mexico and Ecuador. The broad aim is to significantly improve our understanding of the processes behind volcanic unrest and the ability to forecast its outcome aiding decision making and management in an unrest situation.

- **GFDRR Disaster Vulnerability and Risk Assessment Modeling Jamaica and the Greater Caribbean Basin Project:** This project is managed by the UWI Disaster Risk Reduction Centre (DRRC) and funded by the World Bank to produce a regional scale Risk Atlas for Flood, Hurricane and Earthquake and high resolution maps for similar hazards for four islands. SRC was involved in the seismic component of the project involving mainly the modification of earthquake loss estimation software for the region.

GEM Caribbean Regional Programme: This project initiated a Regional Programme for the Caribbean under the umbrella of the Global Earthquake Model (GEM) (see http://www.globalquakemodel.org/regional-programmes/caribbean for details). GEM is a global collaborative effort that brings together state-of-the-art science, national, regional and international organisations and individuals aimed at the establishment of uniform and open standards for calculating and communicating earthquake risk worldwide.

TSUnami Alert REGional (TSUAREG): A collaborative project with and funded by the Institut de Physique du Globe de Paris (IPGP) through their observatories in Martinique and Guadeloupe for the installation of four (4) VSAT stations in Antigua, Carriacou, Dominica and Saint Lucia. The objective is to enhance the regional seismograph network for tsunami detection and promote data sharing, which will feed into efforts to better understand the tectonics of the Eastern Caribbean.

Strong Motion studies in Trinidad and Tobago: While a network of seismometers, such as that operated by the SRC can be used to study the source processes and weak motion characteristics of earthquakes, a different set of instruments are needed for the study of strong ground motion. This project was conceived to provide the basic components of such a network. It

involves the deployment of five (5) strong motion instruments and the use of neural networks to identify and classify events.

REAKT (Real Time Earthquake RisK ReducTion): A collaborative three-year project with 23 countries, primarily in Europe. The general objective is improve the efficiency of real time earthquake risk mitigation methods and its capability of protecting structures, infrastructure and people. The Eastern Caribbean was a test region for the products developed.

A New Accelerometric Network to Evaluate and Mitigate Seismic Risk in the Eastern Caribbean and Jamaica. This project seeks to establish a core network of strong motin instruments in the Eastern Caribbean and Jamaica as a crucial element of implementation of effective disaster risk reduction measures for earthquakes in the region. The key beneficiary will be the people living in the Caribbean since it will build the database necessary for guiding in the construction of earthquake resistant buildings.

Seismic Microzonation Studies in Trinidad and Tobago: This project seeks to develop maps showing details of the different levels of a particular geotechnical hazard that may be triggered by an earthquake in areas of interest e.g. a city. Under the project, seismic microzonation studies will be conducted in strategic areas within Trinidad and Tobago and a programme will be established to enable the updating of such maps to promote the sustainability of this work.

Continuously Operating Caribbean GPS Observational Network (COCONet): This is a collaborative project with US colleagues to establish cGPS systems in the Eastern Caribbean in order to expand the SRC's capacity to provide monitoring in the islands.

STREVA (Strengthening Resilience in Volcanic Areas): This is collaborative project with UK colleagues. It is an innovative interdisciplinary project that aims to work collaboratively across different disciplines to develop and apply a risk assessment framework. It also involves looking at ways in which communities respond to volcanic emergencies and developing protocols for response. It brings together diverse researchers from universities and research institutes from within the UK and from those areas affected directly by volcanic activity.

Fluids geochemistry in the Lesser Antilles: the study of volcanic gases and hot springs chemistry and temperature as a tool for volcano monitoring:

The project involves the use of mineral equilibria studies and hydrothermal minerals to investigate the evolution of geothermal systems in the region. It will continue to build on the previous work carried out (2001 - present) to establish long-term patterns in behaviour of volcanic emissions associated with hydrothermal systems and how they respond to changes in magmatic input. This information will be used along with other tools (ground deformation and seismicity) to monitor volcanic activity in the region, thus providing information to island governments and the general public. PI: Dr. E. Joseph.

UWI-SRC Volcanologist Dr E. Joseph (right)collects geothermal gas samples in the Valley of Desolation Dominica.

Radon monitoring in Tobago: This research seeks to investigate the utility of radon monitoring as an additional technique that may reveal observable changes indicative of the imminence of an expected earthquake. Such monitoring, in the earthquake context, would be novel in the region. Monitoring for ^{222}Rn in earthquake precursor research could be potentially effective in the Tobago setting because of the experience of the significant impact on groundwater flow occasioned by the 1997 magnitude 6.1 event. Previous research indicate that groundwater in Tobago is principally held in a fracture network apparently dominated by the lithological boundaries in south-west Tobago. In 1997, the fracture network is considered to have narrowed or closed in response to the earthquake, thus driving water out of the system. Changes in strain on the fault system projected to carry the next significant earthquake near Tobago may, therefore, result in precursory changes in the local groundwater fracture network that might produce anomalies in radon output. Radon monitoring was scheduled to begin in early 2010 to establish a baseline of radon output for each well. Once baseline character is established, then monitoring for anomalous changes before the next anticipated earthquake will continue. PI: Drs. J. Latchman and E. Joseph.

Radon Monitoring project: UWI-SRC Seismologist Dr Joan Latchman (right) along with members of the well installation team.

Tephrochronology of IODP Expedition 340 Site U1396, SW Montserrat

The project seeks to further increase our knowledge of the origin and volcanic history of Montserrat and the evolution of the

NE Lesser Antilles island arc. Dr A. Stinton (MVO) is continuing to study a series of tephra layers recovered in a marine sediment core SW of Montserrat during a cruise expedition in 2010. As part of the research, Dr A. Stinton spent 3 months on Study Leave (UWI-funded) at the National Oceanography Centre, Southampton UK, in April-June 2013. This research is expected to continue through 2014/15. PI: Dr. A. Stinton.

Dynamics of Geothermal Systems in the Eastern Caribbean: A collaborative PhD research project commenced in January 2009 between the SRC and the Department of Earth Sciences at the University of Bristol UK (Dr. F. Witham). The rationale for this project is to gain a better understanding of the factors which significantly influence the behaviour of geothermal systems in the region. To that end, times series data, weather information and seismic activity surrounding the Boiling Lake in Dominica have been collected. The project focuses on the dynamics of regional geothermal systems on three scales. The first of which is well underway and the second phase commenced. The study will be helpful to Government and monitoring agencies such as the SRC both in terms of hazards mitigation and monitoring and in terms of potential use of geothermal systems for energy production in the Caribbean. PI: D. Robertson

Montserrat Volcano Observatory Management Contract:

The SRC/IPGP contract with the Government of Montserrat for management of the MVO for the period 2008 – 2013, is ongoing. During the period in review the full staff complement to manage the Observatory was achieved and the programme of work proposed by SRC/IPGP in their Technical Proposal nearing completion. In addition to managing the routine operations of the volcano the SRC team, based at the MVO effectively managed a significant period of elevated activity which occurred during the reporting period. PI: R. Robertson

New SRC building project

The preliminary design and estimates for the new building to house the Centre were completed. A completely new, purposefully designed building is urgently required to house the SRC, to address the present congestion and to halt deterioration of valuable equipment, books, records, journals and other materials that currently are not properly stored. The new building should allow for adequate accommodation of present activities and should also make provision for the planned developments in terms of geosciences at the Centre. PI: R. Robertson

The geology and volcanic island evolution of Antigua

Antigua is a small island at the north end of the Lesser Antilles chain known as the Limestone Caribbees. Its geology is largely limited to the Oligocene and it records with unusual fidelity the transition from island arc volcanism to quiescence and limestone deposition. Despite the apparent limitation of a rock record confined to a short stratigraphical interval, Antigua has a geodiversity that ranges from thick sequence of predominantly andesitic lavas and pyroclastic rocks (Basal Volcanic Suite) through silicified logs and freshwater snails in cherts and epiclastic rocks (Central Plain Group) to marine limestones (Antigua Formation) that include both shallow and deeper water facies, and fine karstic features. Principal Investigator: Prof. Trevor Jackson

UWI-SRC Geologist Dr Richard Robertson looks on as the MVO helicopter prepares to take off on an observation flight to the Soufriere Hills Volcano seen venting ash in the background.

...to address present congestion and to halt deterioration of valuable equipment...

The UWI-SRC's Photo exhibition for Earth Science Week 2011 at the NAPA building POS.

Providing the bridge between the science and societal application of improved knowledge and understanding of the geological hazards

Education & Outreach

Sci-TecKnoFest

From May 2nd-15th 2011 the SRC hosted an interactive booth at the National Institute of Higher Education, Research, Science and Technology (NIHERST) Sci-TecKnoFest which is held annually at the National Science Centre in Trinidad. Using information and activities on earthquakes, volcanoes and tsunamis students were educated about the earth sciences and the role that the SRC plays in monitoring those hazards. The booth was located within the Raging Planet section of the festival where over 2000 students participated during the course of the event for that year.

SRC Research Technician, Farrah Madoo, at NIHERST SciTechKnoFest 2011, explaining to students how earthquakes are recorded. Students were able to simulate their own 'earthquakes' recorded on a portable seismometer

Earth Science Week

Earth Science Week promotes understanding and appreciation of the value of Earth Science Research and its application and

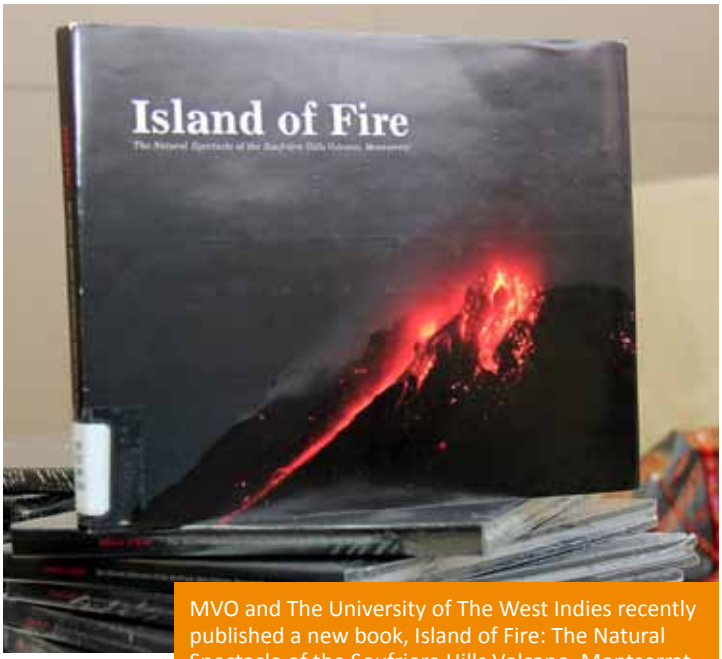
relevance to our daily lives. To commemorate Earth Science Week 2011, the UWI-SRC hosted a Photo Exhibition and Student Workshop. The exhibition was held at the University of Trinidad and Tobago (UTT) National Academy for Performing Arts (NAPA) from October 10th -15th. The theme "Our Ever Changing Earth" highlighted the impact of earthquakes, volcanoes and tsunamis in the Eastern Caribbean and around the Globe. Earth Science Week is an international event organized by the American Geological Institute since October 1998, to help the public gain a better understanding and appreciation for the application and relevance of Earth Science to our daily lives and to encourage stewardship of the Earth. The SRC has been participating in Earth Science Week since 2009 and this year's initiative, in Trinidad, was designed to promote awareness of the vulnerability of the region to geological hazards, including earthquakes, tsunamis and volcanoes. The exhibition was open for public viewing and workshop activities

Excited students make their own earthquake on the portable seismic recorder, guided by SRC Seismic Technician, Farrah Madoo, during the Earth Science Week Photo Exhibition and Student Workshop.

SRC Research Assistant, Monique Johnson, guides students around the Earth Science Week Photo Exhibition.

provided over 400 students with insight and information on the importance of understanding geological hazards and ways to preserve life, property and reduce risks.

During Earth Science Week, the SRC collaborated with the Montserrat Volcano Observatory (MVO) to launch the book "Island of Fire: The Natural Spectacle of the Soufrière Hills Volcano Montserrat", at the National Academy for the Performing Arts in Port of Spain, Trinidad. Complimentary copies of the book were donated to the Trinidad & Tobago Art Society and the National Library of Trinidad & Tobago. This coffee-table style book features photographs that the public rarely gets to see, such as close views of the lava dome and the devastation of Plymouth in the exclusion zone. As well as being a photographic book, Island of Fire is an educational resource to whet the appetite of future geoscientists. Island of Fire is now currently available online from the Montserrat Volcano Observatory website (www.mvo.ms) and from Amazon (www.Amazon.com).



MVO and The University of The West Indies recently published a new book, Island of Fire: The Natural Spectacle of the Soufriere Hills Volcano, Montserrat.

In 2012, the SRC chose to undertake a Tsunami Smart campaign in St. Vincent and the Grenadines as the main theme for Earth Science week celebrations. In collaboration with the National Emergency Management Office (NEMO), the campaign targeted various schools in the Grenadine islands. A display and photo exhibition was set up and student workshops were conducted highlighting the tsunami threat and promoting safety and awareness.

Volcano Awareness Week

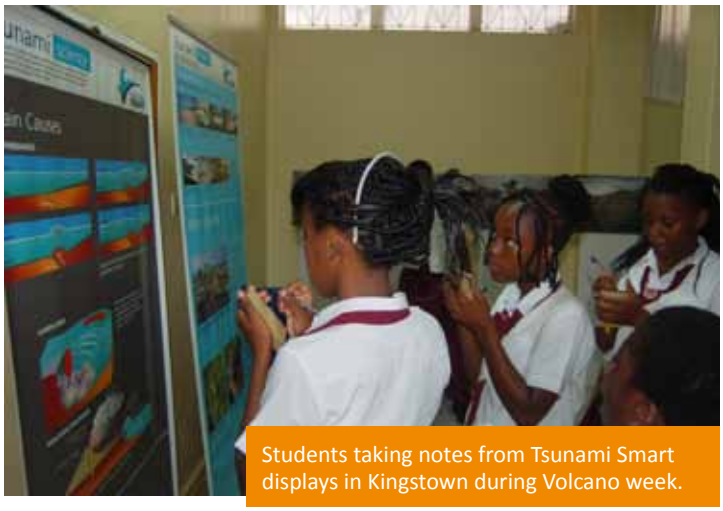
In collaboration with NEMO, Volcano Awareness Week was held in St. Vincent and the Grenadines during the period April 20th-25th 2012. This event marked the 33rd anniversary of the 1979 eruption of La Soufriere and aimed to raise and maintain awareness of the hazards associated with the volcano. During this week, stakeholder and student workshops were conducted. Interactive sessions were also held at schools to allow students to build model earthquake resistant structures.

Tsunami and Other Coastal Hazards Warning System Project

As a follow up to the Tsunami and Other Coastal Hazards Warning System Project (TCHWSP) a Tsunami Smart Teacher Training Workshop was conducted in collaboration with the Office of Disaster Preparedness and Emergency Management (ODPM) at the Rudranath Capildeo Learning Resource Centre, Couva, Trinidad. The workshop was a follow up activity under the TCHWSP, Public Education and Awareness Component. The workshop catered for secondary level Geography and Social Studies teachers from Trinidad and launched the teacher education products developed under the project. The material was designed to raise awareness of tsunamis and other coastal hazards in the Caribbean and to enhance material already being used within the formal school system.

Research Assistant, Monique Johnson, talking to secondary school students in Bequia for Volcano week.

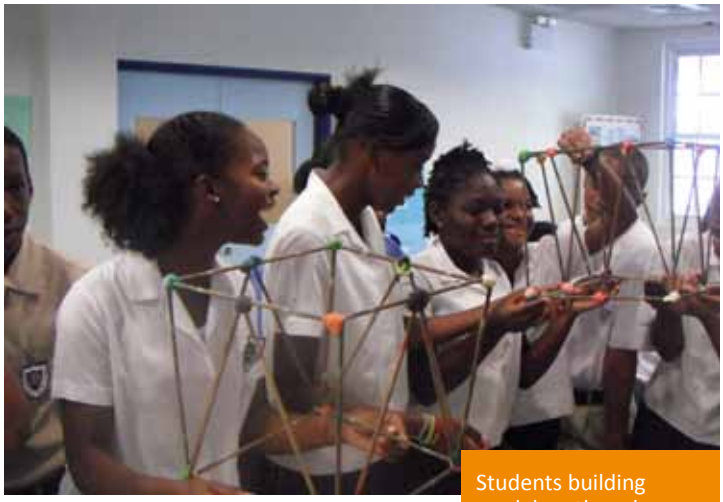
Director of the Montserrat Volcano Observatory, Dr. Paul Cole, giving a brief presentation about some of the phenomena shown in the Island of Fire photographic book at the launch.



Students taking notes from Tsunami Smart displays in Kingstown during Volcano week.

A Tsunami Smart session was also held the following month in Tobago with the staff of the Tobago Emergency Management Agency (TEMA). The session was conducted by Education Officer, Stacey Edwards and involved a series of presentations to introduce TEMA to the public education and awareness material developed under the project.

SRC Geologist, Richard Robertson, talking to primary school students about volcanoes.



Students building model earthquake resistant structures.

CORE Internship Programme

The Creating Opportunities from Research Experience (CORE) Internship programme is committed to identifying future geoscientists and communications practitioners from the region. This 8-week programme provides university level Caribbean students the opportunity to gain hands-on work experience that will further enhance their career development. The internship is designed to give successful candidates a full understanding of how the SRC reaches its objectives through collaboration between scientific, technical and administrative staff.

The 2011 CORE Internship brought two graduate students to SRC to assist in the reoccupation of GPS sites and in the compilation and processing of the data. This project sought to re-measure a network of 18 campaign stations in Trinidad and Tobago to improve the precision of past measurements. The data will ultimately lead to a better understanding of the nature of the tectonics in the area of Trinidad and Tobago

2011 CORE Interns, Michal Camejo (left) and Avinath Ramadhin (rear) learn about setting up a GPS spike mounted antenna.

SRC Education Consultant, Ms Shahiba Ali, delivers a presentation to introduce teachers to the Tsunami Smart Teacher Education Resource material at the Tsunami Smart Teacher Training Workshop

Public Awareness Seminars

During the reporting period, at least forty four (44) seminars and workshops, involving all members of the scientific staff, were given to various groups requesting them. This included primary and secondary schools, as well as offices in the private sector, national companies, diplomatic missions and other organizations based in Trinidad and Tobago.

Caribbean Youth Science Forum (CYSF)

The National Institute of Higher Education, Research, Science and Technology (NIHERST) hosted sixth form science students from across the region for the Caribbean Youth Science Forum (CYSF) 2011. The SRC facilitated one CYSF group of 25 students to the Centre on 12th August 2011. A presentation was delivered on earthquake science and safety and students were given a guided tour of the technical area of the SRC. An interactive session on designing buildings to withstand earthquakes was conducted with the group. The visit ended with career guidance talks from SRC scientists and technical staff.

Students participating in NIHERST Caribbean Youth Science Forum all smiles as they jump causing deflections on the portable seismic recorder.

STUDENTS

The SRC continues to develop its small postgraduate degree programme with one student enrolled in the PhD programme in Volcanology. Additionally, MPhil and MSc postgraduate research students are based at SRC working on collaborative projects with other UWI departments including Civil and Environmental Engineering, Lands and Surveys, and Geography.

Post-graduate students seen working on various projects.

60th Anniversary Activities

The Seismic Research Centre marked its 60th anniversary in 2013. The E&O section headed a 60th Anniversary Committee comprised of UWI-SRC staff volunteers, to commemorate this milestone with activities throughout the year held in at least four contributing islands in the region. The schedule of activities were finalized through discussion with all members of SRC staff.

The specially designed logo to commemorate the UWI-SRC's 60th year anniversary.

60th Anniversary Launch

Activities for the year began with the official launch of the Centre's 60th Anniversary celebrations. The Launch was held at the Centre, on January 29th, with various members of UWI staff, members of the diplomatic corps, media personnel as well as past and present SRC staff in attendance. Pro Vice Chancellor of Research, Professor Wayne Hunte and Pro Vice Chancellor and Campus Principal, Professor Clement Sankat delivered remarks at the event. The official logo, commissioned for the 60th anniversary, was unveiled by PVC Professor Sankat. Ms. Stacey Edwards, the Centre's Education Officer, revealed the slogan for the anniversary: 'Celebrating sixty years of service to the region' and detailed the year-long schedule of activities planned to commemorate this auspicious occasion.

Pro Vice Chancellor and UWI St. Augustine Campus Principal, Professor Clement Sankat assisted by SRC Research Assistant Alia Juman unveils the 60th Anniversary logo.

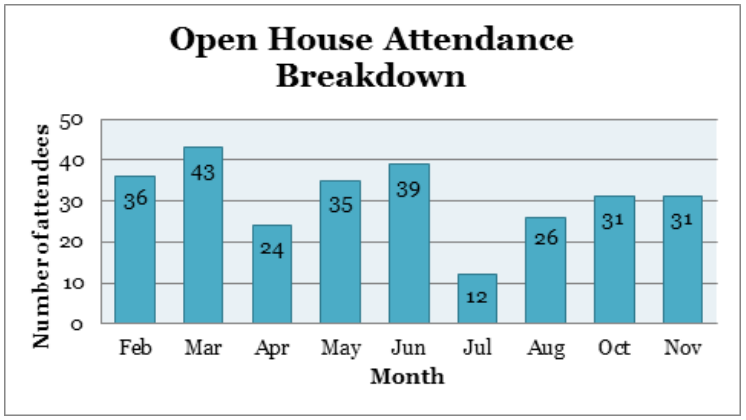
OPEN HOUSE

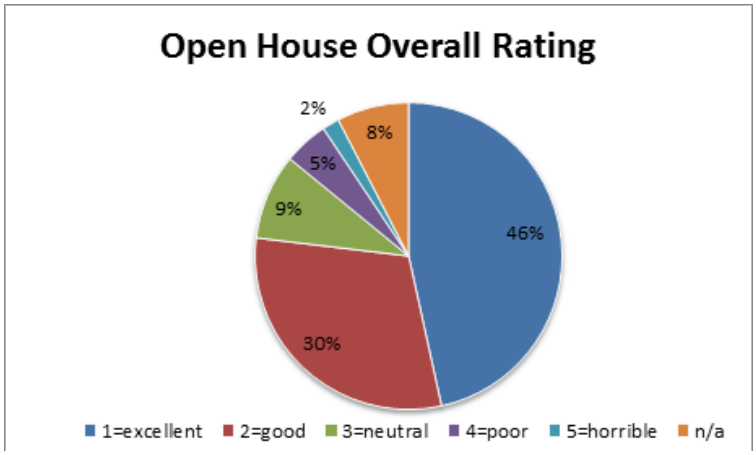
Monthly Open Houses at the SRC were planned for February to November 2013, and were held on the last Thursday of each month. The public, stakeholders and other interested parties were invited to visit the Centre and experience the inner workings of each department. Three tours were conducted throughout each Open House with the aim of debunking myths, increasing awareness of the various threats faced and providing valuable safety information. To foster and maintain a strong link to the main UWI Campus in St. Augustine, advertisements were placed in the Marketing and Communications Calendar of Events. Along with this, monthly reminders were disseminated to both UWI staff and students and banners were placed at both main entrances of campus. Invites were sent out to the public via the 'What's On' section in most local newspapers and 'Community Events' on local radio stations. The E&O team also used the Centre's Facebook page, Twitter feeds and website to invite members of the public. Banners were also placed at the entrance and on the perimeter of the Centre to attract as much attention as possible.

UWI-SRC Electronics Technician Stephen George talks to the public about the equipment used to monitor earthquakes during one of the Open House tours.

Certain sessions during the Open House were centered on sensitizing particular groups with respect to the SRC's mission and mandate. As such, members of the diplomatic corps were invited in May and the session was well attended. To foster better understanding of the Centre's work on the main campus, special invitations were sent to all members of UWI staff. Unfortunately, the response was quite poor and members of the public greatly outnumbered the University staff during these tours. The September Open House was targeted to children twelve years and under and the content was specifically altered to incorporate a morning tour of Standard 5 students from three specially invited schools around the Centre's geographical area. The Centre also attempted to raise its profile among local stakeholders and invitations were sent throughout the year to governmental and private corporations. The response however was again poor. At the close of each Open House assessment surveys were administered to all attendees. Analysis of the responses showed that they were generally positive and feedback from the participants indicated that the Open House was greatly appreciated and worthwhile.

UWI-SRC Staff: Volcanologist, Dr Rob Watts (top) and Seismologist, Dr Joan Latchman (bottom) talk to members of the public about monitoring earthquakes and volcanoes.





S3 Mall Tour: Science and Safety for Sixty Years

As part of this initiative, the E&O team visited different malls and public spaces both in Trinidad and Tobago. The objectives were to maintain and promote earthquake safety and awareness amongst the general public whilst attempting to de-bunk any misconceptions as well as to raise the Centre's public profile.

The first leg of the tour was a 2-day event in Tobago. An interactive display was set up at the Lowlands Mall, Lowlands

Gulf City Mall, Lowlands Tobago

and outside the Ferry Terminal in Scarborough. The public was invited to take part in the team's Hazard Cube/Wheel of Hazard quiz, where they tested their knowledge in five (5) categories: earthquakes, volcanoes, tsunamis, safety, history and a bonus section with the chance to win memorabilia prizes. Interactive liquefaction and seismometer displays aimed to engage all ages of the general public and sought to increase the Centre's profile along with enhancing earthquake safety amongst the public. The display was then mounted in Trinidad at the Gulf City Mall in La Romain, the Trincity Mall, in Trincity and finally on the Brian Lara Promenade in Port-of-Spain. This initiative also provided various SRC staff members from outside of the Education & Outreach section with opportunities to interact with the public and gain a better understanding of the work done by members of the E&O section.

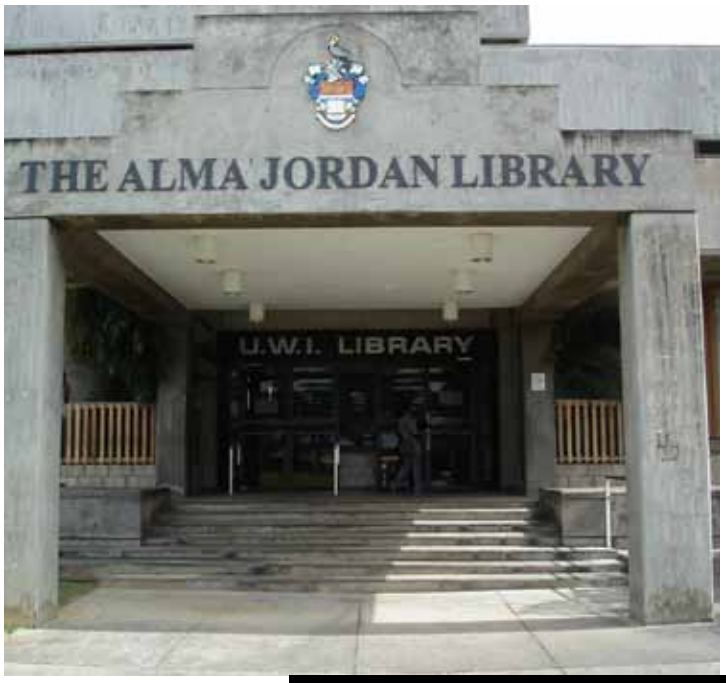
Gulf City Mall, San Fernando

Trincity Mall, Trinidad

Brian Lara Promenade, Port of Spain

Library Display

To further celebrate the Centre's 60th anniversary and to help promote the Centre's profile on the UWI St. Augustine Campus, a display was mounted at the Alma Jordan Library. Held during the last week of September, the display included a timeline highlighting key events throughout the Centre's history along with rock samples, instruments and special awards.



Staff Recognition Ceremony

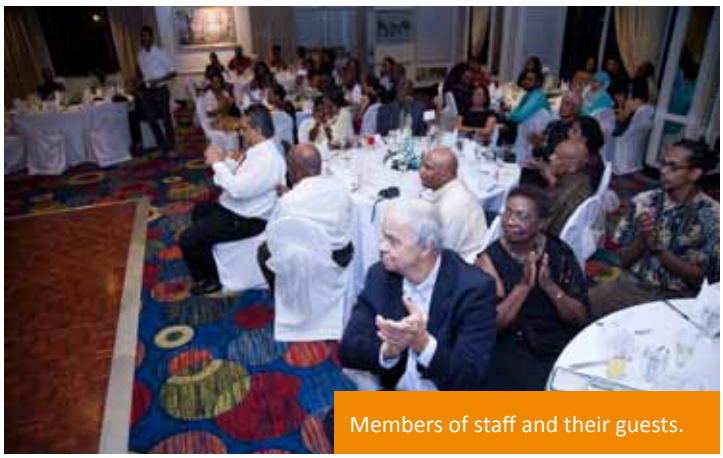
The Centre celebrated the end of its 60th year with a Staff Recognition Ceremony on December 8th at the La Boucad Room, Trinidad Hilton and Conference Centre. Director of Human Resources, Mr. Stephen Sheppard delivered the welcome remarks and greetings from the Campus Principal were brought by Deputy Vice Principal, Professor Rhoda Reddock. The Centre recognized long-serving staff members with awards to commemorate 15, 20, 30 and/or 40 more years of service. Prior to the event, the Centre's staff voted for individuals to be awarded the 'Spirit of SRC' award and three Novelty awards and these staff members were revealed and presented with their awards on the night. The evening culminated with dinner and dancing.

UWI-SRC Director Dr Richard Robertson.

Deputy Vice Principal Professor Rhoda Reddock (right) with UWI-SRC Secretary Mrs Yvonne Joseph

The 60th Anniversary cake.

UWI-SRC awards and tokens.



Members of staff and their guests.

Award receipients consisting of members of staff past and present.

UWI-SRC staff among the members of the Research Cruise by the RRS James Clark Ross.

PARTNERSHIPS & COLLABORATIONS

The Seismic Research Centre strengthened its capacity through collaborations with the following institutions:

Inter-Faculty

- The University of the West Indies, Department of Chemical Engineering, St. Augustine
- The University of the West Indies, Department of Surveying and Land Information, St. Augustine

Academic Institutions

- British Geological Survey
- The University of South Florida, USA
- The University of Southern California, USA
- The University of South Hampton, United Kingdom
- National Oceanography Centre, Southampton, United Kingdom
- The University of Trieste, Trieste, Italy
- California State University, Department of Geological Sciences, USA
- Coventry University, School of Science and the Environment, United Kingdom
- EUCENTRE
- Geological Survey of Canada, Pacific Division, Canada
- GNS Science, New Zealand
- Indiana University, Department of Geological Sciences, USA
- International Institute of Earthquake Prediction Theory and Mathematical Geophysics
- Instituto Nazionale di Geofisica e Vulcanologia, Italy
- Institut de Physique du Globe de Paris, France
- Laboratoire de Physique des Géomatériaux, IPGP, France
- Massachusetts Institute of Technology, USA
- National Oceanic and Atmospheric Agency, USA
- Naval Research Laboratory, USA
- Plymouth University, UK
- UNAVCO Inc, Boulder, Colorado, USA
- Rowan University, Computer Science Department, USA
- The University of Bristol, Department of Earth Sciences, UK
- Universidad de Chile
- University of East Anglia, School of Environmental Sciences, UK
- University of Miami, USA
- University of Northampton, UK
- University of New Mexico, USA
- University of Reading, UK
- University of Southampton, UK
- University of St. Andrews, UK
- University of Washington, Department of Geophysics, USA

Monitoring and Disaster Management

- Caricom Regional Organisation for Standards and Quality
- Montserrat Volcano Observatory, Montserrat
- Observatoire de Physique du Globe de Clermont-Ferrand, France

Funding Agencies

- CCRIF
- IDB, Barbados

Private Sector

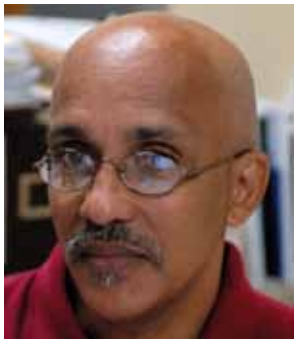
- Aspinall & Associates, United Kingdom

STAFF

Staff of the Seismic Research Centre, 2011-13. Absent from photo: Susan Carr, Kafele Reddock, Billy Burgoa, Paul Cole, Roderick Stewart, Thomas Christopher, Henry Odbert, Adam Stinton, Patrick John Smith, Karen Pascal, Caroline Murrell, Elizabeth Cole, Joenel Alexander, Jillian St. Bernard and Cassandra LaBarrie.

Joan Latchman	Director (Ag.)/Seismologist
Richard Robertson	Geologist
Walter Salazar	Earthquake Engineer
Lloyd Lynch	Instrumentation Engineer
Roderick Stewart	Volcano-Seismologist
Erouscilla Joseph	Volcanologist
Robert Watts	Volcanologist
Frederic Dondin	Volcanologist
Billy Burgoa	Junior Research Fellow
Trevor Jackson	Emeritus Professor
Myron Chin	GEM Operation Manager
Paul Cole	Director – MVO
Adam Stinton	Volcanologist – MVO
Thomas Christopher	Volcanologist – MVO
Henry Odbert	Volcanologist – MVO
Karen Pascal	Volcanologist - MVO
Patrick John Smith	Seismologist – MVO
Caroline Murrell	Environmental Officer - MVO
Elizabeth Cole	Outreach Officer - MVO
Machel Higgins	Software Engineer
Chandradath Ramsingh	IT Officer
Stacey Edwards	Education Officer
Deborah Robertson	Research Assistant – Volcanology
Michal Camejo	Research Assistant – Volcanology
Cassandra LaBarrie	Research Assistant – Seismology
Omari Graham	Research Assistant – Seismology
Alia Juman	Research Assistant – Seismology
Jillian St. Bernard	Research Assistant – Seismology
Kafele Reddock	Research Assistant – Seismology
Monique Johnson	Research Assistant – Outreach
Clevon Ash	Research Assistant – Outreach
Ian Juman	Electronics Technician
Garth Mannette	Engineering Technician
Stephen George	Engineering Technician
Nisha Nath	Chief ResearchTechnician
Amit Balchan	Research Technician
Farrah Madoo	Research Technician
Hannah Ramsingh	Research Technician
Lutchman Pollard	Research Technician
Yvonne Joseph	Secretary
Carol Liverpool	Clerical Assistant
Jacinta Seemungal	Administrative Assistant
Shaun Bhodoo	Office Assistant
Susan Carr	Librarian
Nolan Ali	Senior Maintenance Assistant
Margaret Nero	Custodian
Joenel Alexander	Groundsman

STAFFING – WELCOME AND FAREWELL



Dr. Richard Robertson stepped down from the post of Director of the Seismic Research Centre effective 31st August 2011. Dr. Joan Latchman was appointed to serve as Acting Director from 1st September, for one year in the first instance.

In November, 2011, the SRC welcomed Dr. Frédéric Dondin (left) back; this time on contract to work on modelling tsunami impact from a landslide following an eruption at the Kick-'em-Jenny volcano. Dr. Dondin was part of our team, while he was working on his Ph.D., which he completed in 2010. We are most pleased to have him with us again working on this most important study.

Ms Cassandra La Barrie, the Research Assistant, who provided the GIS support during the period July 2012, declined to renew her contract following her marriage. Another Research Assistant, Ms Jillian St. Bernard working with the projects under the Seismology Engineer, Dr. Walter Salazar, completed her contract. We wish both success in all their future endeavours.

In July 2012, Karen Pascal assumed duties of the Ground Deformation specialist at the Montserrat Volcano Observatory. She is from France and worked on her higher degrees in the United Kingdom. She will soon complete her Ph.D. looking at the role of magma properties in volcano deformation. We welcome her and are looking forward to a mutually beneficial association.

In January 2013, Michal Camejo joined the staff as a Research Assistant (Volcanology). She holds a Bachelor of Science degree in Geology with a minor in Environmental Chemistry from The University of the West Indies, Mona and a Master of Science degree in Geophysical Hazards from The University College London.

Ms Jacinta Seemungal joined the staff as an Administrative Assistant in January 2013 to assist in managing various projects undertaken by the SRC.

In March 2013, Ms Monique Johnson, who has been a member of our Education and Outreach (E&O) team since 2009, resigned as she moved into a new and exciting facet of life. She has been an asset in helping to strengthen our E&O efforts and we sincerely thank her for the contribution she has made in helping to build awareness of the geological hazards and promoting the image of the SRC. We wish her every success as she embarks on this phase of life.

In June, Mr. Kafele Reddock, a former seismology technician here at the SRC, was appointed Research Assistant to work with Dr. Walter Salazar on the Trinidad and Tobago Microzonation project. Kafele pursued a geology degree at The UWI, Mona Campus after leaving the SRC.

In July 2013 Mr. Billy Burgoa, a seismologist from Bolivia, joined our Staff on a short-term contract to work on developing our automatic earthquake location capability. Given the real time world of social media, the need for this in modern seismic monitoring agencies has become more pressing. Mr. Burgoa has worked on such systems in Costa Rica and we anticipate soon having our system operational. We are very happy to have him as part of our team and are looking forward to working with him on this important system upgrade.

Members of the head table including UWI-SRC Director (Ag.) Dr Joan Latchman (2nd from right) and Minister of Planning Dr Bhoe Tewarie (2nd from left) after a media briefing for the initiation of the Trinidad and Tobago Microzonation project.

MEETINGS, WORKSHOPS & CONFERENCE ATTENDANCE

Staff attended the following national and international meetings, workshops and conferences:

Date	Conference/Meeting/ Workshop/Presentation	Organized by	Location	Staff Member
20-24 July 2013	Forecasting Volcanic Activity	IAVCEI	Kagoshima, Japan	R. Robertson, F. Dondin, M. Camejo
23-27 July 2013	Commission of Volcanic Lakes Workshop 8	IAVCEI	Kagoshima, Japan	D. Robertson
20-21 May 2013	Consultation on the Development of Geothermal in St. Vincent and the Grenadines.	Government of St. Vincent and the Grenadines	Grenadine House, St. Vincent	J. L. Latchman
26 February 2013	REAKT Project Workshop	SRC	Arthur Lok Jack Graduate School of Business, Trinidad	E. Joseph, J. L. Latchman
11-12 December 2012	IUGS International Geoscience Project IGCP571 - Radon, Health and Natural Hazards meeting	IUGS	Bath, U.K	J. L. Latchman
27 November, 2012	Supporting National Response Disaster Management with Mobile Shelter Solutions		Normandie Hotel,Trinidad	J. L. Latchman

19-23 November 2012	Cities on Volcanoes 7	IAVCEI	Colima, Mexico	E. Joseph, R. Robertson, P. Cole
12-15 November 2012	Developing Sustainable Networks of Women Scientists for Addressing Issues of Tectonic Hazards	COACh	Santiago, Chile	J. L. Latchman, E. Joseph
21-24 October 2012	Scientific Advisory Committee (SAC) 17 Meeting	MVO	Montserrat	E. Joseph, J. L. Latchman, MVO-based staff
25-29 September 2012	STREVA Worshop	STREVA	Montserrat	J. L. Latchman, R. Robertson, PMVO-based staff
9-10 July 2012	Caribbean Volcanism and Crustal Structure Workshop	University of Bristol	Bristol, UK	R. Robertson, T. Christopher, D. Robertson
29 June 2012	Trinidad and Tobago Seismic Microzonation Project Workshop	SRC	Mt. Irvine Bay Hotel, Tobago	J. L. Latchman
24 February 2012	Seismic Hazard Perception	AAG	New York, USA	C. Ash
25 January 2012	Trinidad and Tobago Seismic Microzonation Project Workshop	SRC	UWI, St. Augustine	J. L. Latchman
9-13 January 2012	GPS Data Processing Using GAMIT/GLOBK and TRACK	MVO	Montserrat	H. Odbert, R. Robertson, M. Higgins, E. Joseph
January 2012	Civil Division Seminar	APETT	Port of Spain, Trinidad	A. Juman
5–9 December 2011	Caribbean Conference on Comprehensive Disaster Management		Hyatt Hotel, Trinidad	E. Joseph, R. Watts
5-9 December 2011	American Geophysical Union Fall Meeting	AGU	San Francisco, USA	A. Stinton, H. Odbert
14-17 November 2011	Scientific Advisory Committee (SAC) 16 Meeting	MVO	Montserrat	J. L. Latchman
20-22 September, 2011	Strategy and Tools for Real-Time Earthquake Risk Reduction (ReaKT) Kick-off Meeting		Naples, Italy	J. L. Latchman
5 September, 2011	GSTT Hazards Seminar	GSTT	Cara Suites, Trinidad	J. L. Latchman
19-24 August 2012	European Seismological Commission 33rd General Assembly: Seismology Without Boundaries	European Seismological Commission	Moscow, Russia	J. L. Latchman, S. Edwards
7-10 August 2011	Teaching Mineralogy, Petrology and Geochemistry in the 21st Century	University of Minnesota	Minneapolis, USA	E. Joseph
1-5 August 2011	Real-Time Seismic Inversion Short Course	Puerto Rico Seismic Network, University of Puerto Rico,	Puerto Rico	J. L. Latchman

PUBLICATIONS

SRC authors in bold text

Refereed Journals

Joseph, E.P., N. Fournier, J.M. Lindsay, **R. Robertson**, D.M. Beckles (2013) Chemical and isotopic characteristics of geothermal fluids from Sulphur Springs, Saint Lucia. Journal of Volcanology and Geothermal Research 254: 23 – 36.

Latchman, J.L., L. Lynch, S. Edwards (2013) 60 years of monitoring volcanic and earthquake activity in the English-speaking Eastern Caribbean. Caribbean Geography 3-17.

Ash C., P. Shaw, **R. Robertson.** 2013. Religious viewpoint as a factor in earthquake hazard perception in Tobago. Caribbean Geography 17(1&2).

Watt, S.F.L., P.J. Talling, M.E. Vardy, V. Heller, V. Hühnerbach, M. Urlaub, S. Sarkar, D.G.Masson, T.J. Henstock, T.A. Minshull, M. Paulatto, A. Le Friant, E. Lebas, C. Berndt, G.J. Crutchley, J. Karstens, **A.J. Stinton**, F. Maeno (2012) Combinations of volcanic-flank and seafloor sediment failure offshore Montserrat, and their implications for tsunami generation. Earth Planetary Science Letters 319–320: 228-240.

Darnell A.R., Barclay J., Herd R.A., Lovett A.A., Phillips J.C., **Cole P.D.** (2012)Geographical information system approaches for hazard mapping of dilute lahars on Montserrat, West Indies. Bulletin of Volcanology 74: 1337-1353.

OramasDorta D., **P.D. Cole,** Wadge G. (2012) Pyroclastic flow hazard at Arenal Volcano, Costa Rica, Part I: Identification of hazard patterns. Journal of Volcanology and Geothermal Research 225-226: 45-64.

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Joseph, E.P., N. Fournier, J.M. Lindsay, T.P. Fischer (2011) Gas and water geochemistry of geothermal systems in Dominica, Lesser Antilles island arc. Journal of Volcanology and Geothermal Research 206: 1-2.

Cioni, R., A. Bertagnini, D. Andronico, **P.D. Cole,** F. Mandula (2011) The 512 AD eruption of Vesuvius Italy: complex dynamics of a small scale subplinian event. Bulletin of Volcanology 73:789–810.

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Stewart, R., V. Bass, **T. Christopher, P. Cole, F. Dondin, M. Higgins, E. Joseph, K. Pascal, P. Smith, A. Stinton**, R. Syers, P. Williams (2013) MVO Scientific Report for Volcanic Activity between 13 October 2012 and 30 April 2013. MVO Open File Report 13-06, 59p. Montserrat Volcano Observatory, Flemmings, Montserrat.

Cole, P., V. Bass, ***T. Christopher,*** S. Melander, **K. Pascal, P. Smith, R. Stewart, A. Stinton,** R. Syers (2012) MVO scientific report for volcanic activity between 1 May 2012 and 12 October 2012, Open File Report OFR 12-02, 47p. Montserrat Volcano Observatory, Flemmings, Montserrat.

Cole, P., V. Bass, **T. Christopher,** S. Melander, **K. Pascal, P. Smith, R. Stewart, A. Stinton**, R. Syers, P. Williams (2012) MVO Scientific Report For Volcanic Activity Between 1 May 2012 and 12 October 2012. MVO OFR 12-02, 47pp.

Cole, P., V. Bass, **T. Christopher, H. Odbert, P. Smith, R. Stewart, A. Stinton**, R. Syers, P. Williams (2012) MVO scientific report for volcanic activity between 1 November 2011 and 30 April 2012, MVO OFR 12-01, 61pp.

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Ash C., P. Shaw, **R. Robertson** (2012) Seismic Hazard Perception – A case for Tobago in the Eastern Caribbean. (Oral Presentation) Association of American Geographers Annual Conference, New York City.

Camejo, M. (2013) A quantitative assessment of explosivity patterns using Holocene eruption time series: Applications to Eastern Pacific and Caribbean volcanic arcs. IAVCEI Scientific Assembly, Kagoshima, Japan.

Camejo, M and **R. Robertson** (2013) Estimating volcano hazard and exposure in the Lesser Antilles. IAVCEI Scientific Assembly, Kagoshima, Japan.

Macfarlane, D., G. Wadge, **H.M. Odbert, A.J. Stinton, D. Robertson,** M. James, H. Pinkerton (2012) Millimetre wave FMCW radar as a tool for 3D Terrain mapping of volcanic topography. AGU Fall Meeting, San Francisco, California, USA.

Cole, P., V. Bass, **T. Christopher, H. Odbert, P. Smith, R. Stewart, A. Stinton,** R. Syers, P. Williams (2012) Soufriere Hills Volcano, Montserrat: 1995 – 2012 - understanding and managing a long term, multiphase andesitic eruption. Cities on Volcanoes 7, Colima, Mexico.

Cole, P., P. Smith, J-C Komorowski, F. Alfano, C. Bonadonna, A. Stinton, T. Christopher, S. Loughlin (2012) Ash Venting – a precursor to lava extrusion and explosive events at Soufriere Hills Volcano, Montserrat. Cities on Volcanoes 7, Colima, Mexico.

Latchman, J. L., S. Edwards (2012) Delivering the Message on Geological Hazards in the Eastern Caribbean. Poster displayed at European Seismological Commission 33rd General Assembly: Seismology Without Boundaries. Session EO-1 Communicating about earthquakes - new challenges in a sensitised society. Presidium, Russian Academy of Sciences, Moscow, Russia.

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