

60 years of monitoring volcanic and earthquake activity in the English-speaking Eastern Caribbean

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***Summary:** The history of the Seismic Research Centre of The University of the West Indies is documented, from its origins as the Volcano Research Department in downtown Port-of-Spain in 1953, through its move to St Augustine in 1959, as the Seismic Research Unit, to its present status as a University Centre. The story of its slow but steady development describes the work of the pioneering staff, and records staff changes over the years. The gradual improvements in scientific instrumentation and monitoring systems in the Eastern Caribbean is described and notable monitoring successes with respect to seismic events are highlighted. The Centre has contributed to international and regional scientific research, to the production of regional hazard maps, and to educational outreach material.*

Key Words

HISTORY OF SCIENCE SEISMOLOGY EASTERN CARIBBEAN

Introduction

The countries bounding the Caribbean Basin were known to be vulnerable to devastating earthquakes from the time of the first European settlements, with accounts of the first such events beginning to appear early in the 16th Century. All the countries in the region were colonies of one or other of the European colonising powers, which brought with them not only their languages and culture, but their architecture. Within the first few decades, the islands had been transformed into villages, towns and cities patterned after the various European models, including the beautiful stone structures known there. The devastation that could be wrought by the large earthquakes that sometimes occurred in the region soon became well known.

The volcanic threat, on the other hand, was well known on the western side of the Caribbean Basin. More slowly a similar threat on the eastern side emerged as several of the islands experienced episodic high level seismic activity associated with volcanic centres. Then two catastrophic eruptions took place, in Martinique and St Vincent in 1902, claiming more than 30,000 lives. It was one such episode, occurring in Nevis in 1951-1952, following a similar episode in Montserrat in the 1930's that prompted the

recommendation by Dr Patrick Willmore that an agency for monitoring the regional volcanic activity be established. This recommendation became the Volcano Research Department, later renamed the Seismic Research Unit to reflect that earthquakes in general would be investigated and then, to more accurately reflect its status within The University of the West Indies hierarchy, 'Unit' was changed to 'Centre'. From 2008 the agency responsible for monitoring earthquake and volcanic activity in the English-speaking Eastern Caribbean and also an integral part of the effort to establish a tsunami warning centre became known as the Seismic Research Centre.

The SRC of today has benefitted from the input of scientists from around the World and many of these former staff members, who helped to lay the foundation for the very important pursuit of earthquake and volcano monitoring and understanding in the English-speaking Eastern Caribbean, have gone on to also make important contributions in their field internationally and have continued to promote the work of the SRC whenever possible.

Need for an Agency

Between 1690 and the end of World War II, the British West Indies experienced at least eight episodes of volcanic unrest as well as several damaging and/or fatal earthquakes. Volcanic eruptions in 1812 and 1902 in St Vincent resulted in many fatalities and the Mount Pelée eruption, in the French island of Martinique, killed more than 29,000 people in 1902. Mt Pelée also erupted from 1929 to 1932. In Jamaica, another British West Indian island, the fatally destructive force of earthquakes was experienced in 1692 (Port Royal) and 1907 (Kingston). In the aftermath of the Martinique eruptions, the French established the first permanent observatory at Morne Des Cadet in 1947. Seismo-volcanic unrest on Montserrat from 1898-1902 and in the 1930's caused significant consternation among colonists there. The 1930's episode attracted scientists linked to the Carnegie Institution (Frank Perret) and The Royal Society (C. F. Powell and A. G. MacGregor). During a Royal Society expedition to Montserrat, Powell and MacGregor established a seismograph network comprising a 3-component Wiechert seismograph and six shock recorders. The network ran from 1938 to 1945 when the seismometer was accidentally destroyed during attempts to ship it to St Vincent to monitor an earthquake swarm near the volcano.

Dr Gerald Lenox-Conyngham was the senior scientist involved in the study of the 1930's Montserrat volcanic earthquake activity and, in the following years, was knighted and became the Head of the Department of Geodesy and Geophysics at Cambridge University, England. Therefore, in the context of the known historical volcanic and seismic episodes, when in the early 1950's another series of damage-causing volcanic earthquakes occurred, this time in St Kitts and Nevis, coming just 20 years after the Montserrat crisis, sufficient concern was aroused to cause the Secretary of State for the Colonies to seek scientific advice. Dr Lenox-Conyngham was the scientist consulted. A researcher in his department, Dr Patrick Willmore was assigned to the project. Patrick Willmore is well known in the seismological world as the designer of the Willmore seismometer, and had to hurriedly design (and have constructed) simple shock recorders, which were not ready for field deployment until 1951. By that time the activity was



*PLATE 1: Dr. Patrick Willmore atop the Soufrière of St Vincent
(Courtesy Prof. P.J. Willmore)*

declining. As the crisis subsided, Dr Willmore (Plate 1) suggested to the Colonial Office that monitoring during periods of crisis was insufficient to gain a proper understanding of the cause of the activity. He was commissioned to make recommendations on the surveillance of the volcanoes in the English-speaking Eastern Caribbean, with the understanding that funds were available to maintain eight seismographs in the British volcanic islands, and locate earthquakes. Dr Geoffrey Robson (Plate 2 and in Plate 3), who had studied under Dr Willmore, was identified as suitable for the job.

Home for the Agency

There are 11 primary islands in the English-speaking Eastern Caribbean and a decision had to be taken on where the proposed agency would be located. There was significant reservation over its establishment in one of the volcanic islands, where volcanic activity could compromise the sustainability of the agency during a period when its resources would be most needed. In selecting a non-volcanic island, Trinidad and Barbados were the final contenders. Trinidad was chosen as the site of the headquarters for the new unit, the Volcano Research Department, because of its air communications to the other islands and community of geologists and geophysicists in the oil fields. In 1953, it was set up as part of the regional Research Centre at the Imperial College of Tropical Agriculture in Trinidad (forerunner to the St Augustine Campus of the UWI) and supported by British Colonial Development and Welfare funds. Accommodation was first provided in the Treasury Building on the then Marine Square (now Independence Square), Port of Spain, Trinidad, and later in Whitehall, Queen's Park West, by the government.

In 1959, construction of a permanent home for seismo-volcanic studies, at the corner of Bates Trace and Gordon Street, St Augustine, began.



PLATE 2: Dr. Geoffrey Robson supervising site preparation for the Unit's headquarters on Gordon Street, St Augustine. The site was an abandoned cocoa research plot. (SRC Archive)

Staffing

The Unit began operations with one scientist, Dr Geoffrey Robson, on staff. Dr Willmore, however, continued to be involved in establishing the fledgling Unit. In 1958, the provision of additional funding allowed for the recruitment of Dr Ken Barr, who was a seismologist with specialization in instrumentation. In 1961, he moved to Jamaica to establish the monitoring there and Mr Desmond Woo, a Trinidadian national, joined the staff as seismologist and instrumentation specialist. The Unit then had three members of academic staff.

Dr John F. Tomblin, a British national, was appointed to the newly created post of geologist, in 1964, which brought the total to four members of academic staff. However, Ken Barr then resigned and the vacant post of seismologist was filled by Dr John B. Shepherd, a graduate in physics, from Manchester, England, with a specialty in optics.

At the request of UNESCO, Dr Robson led a reconnaissance mission to report on the destructive Caracas earthquake, which occurred on 29 July 1967. By 1968, the Unit had in addition to its four members of scientific staff, 14 members of support staff comprised of Seismology, Electronics, Workshop and Geochemistry technicians, Draughtsman, Secretary and Clerical and Office assistants, and a Grounds man, who also attended to the cleaning needs of the Unit (Plate 3). At this time, with the Unit



PLATE 3: Staff photograph taken in 1968 at the retirement function for Dr Robson (Courtesy Lutchman Pollard)

Academic Staff (seated, l to r): Desmond Woo, Geoff Robson, John Tomblin

Support Staff (standing l to r): Lutchman Pollard (seismology technician), Peter LeBlanc (partly hidden, rock slide assistant), Rampersad Singh (gardener), Rosalind Mark (secretary), Anthony Providence (almost hidden, office assistant), Sherma Edwards (seismology technician), Floyd Archer (workshop technician), Luis Canales (visiting from Venezuelan seismic monitoring agency FUNVISIS), Godfrey Almorales (almost hidden, draughtsman), Ruby McDonald (typist), Desmond Seupersad (geochemistry technician), Judy Tomblin (part-time librarian), Hensen Almorales (Chief Technician), Ronny Roach (seismology technician).

established, functioning and delivering as originally envisioned, Dr Robson resigned to take up a position at the United Nations Development Programme (UNDP) and Dr Tomblin was appointed the new Head of the Unit.

In 1969, Dr Haraldur Sigurdsson, a native of Iceland, was appointed geologist to fill the vacancy created by the departure of Dr Robson and in 1970, a fifth scientific staff position was created. Dr William Aspinall, an atmospheric electricity physicist from the United Kingdom with important instrumentation expertise, was appointed the second seismologist on staff. In 1972, Dr Tomblin undertook the supervision of a Master's student, Mr Keith Rowley, who became the first local student to be associated with the Unit and was in time, on completion of his degree in 1974, to assume the geologist duties for a brief period before the position was filled, when Dr Sigurdsson resigned at the end of 1973. In 1974, Dr Marion Michael, an Australian volcanologist joined the staff.

In 1980, Dr Tomblin resigned to take up a position at the United Nations Disaster Relief Organisation. At that time, following the 1979 eruption of the Soufrière volcano in St Vincent, the Unit was examining ways to improve response to volcanic crises. Dr John B. Shepherd was appointed the new Head of the Unit. In 1981, Dr F. Dale Morgan, a

Guyanese national and a former member of staff of the UWI, Physics Department, who had been funded to pursue a Ph.D programme in geophysics at the Massachusetts Institute of Technology, returned to Trinidad and was appointed to the Unit's staff, filling the existing vacancy and, at the same time, fulfilling his obligations to the Government of Trinidad & Tobago.

The next big staff turnover took place when Dr Aspinall resigned at the end of 1982 to return to the U.K. and Dr Morgan during 1983 to return to the United States. Those vacancies were filled by an Instrumentation Engineer, Mr Lloyd Lynch, and two Geologists, Dr Geoff Wadge and Mr Michael Isaacs. Mr Lynch was originally based at the Earthquake Unit in Jamaica, which had become responsible for its own operations and, therefore, was familiar with the instrumentation in use at the Unit. Dr Wadge came to the Unit from the U.K. and Mr Isaacs from Jamaica.

Due primarily to the economic climate, but also other factors, the Unit experienced the most volatile phase of staffing during the period 1985-2000. There was a net overall decline in the total number of Staff until 1990, with a marked increase in the ratio of academic to non-academic positions. Dr Wadge, Mr Isaacs, and Dr Shepherd left in 1987, 1988 and 1989 respectively. Dr Rowley, a Tobagonian volcanologist mentioned earlier, returned to the Unit in 1988 to fill the void left by Dr Wadge and Mr Isaacs, but he resigned in 1991 to pursue a political career. Dr William Ambeh, a University of Leeds trained seismologist from Cameroon joined in 1990. Non-academic posts also declined through a voluntary retrenchment programme, employee transfer and secondment. In the latter case, one long-serving, seismic data analyst took up a two-year appointment at the International Seismological Centre between 1988 and 1990. By 1990, the number of Staff (both academic and technical) declined to the lowest level in several years. As economic fortunes in the contributing territories reversed in the 1990's, the academic positions that had to be frozen in the mid-1980's to early 1990's were filled. Mr Richard Robertson, a Vincentian Geologist, was recruited in 1993; Dr Paul Jackson, a British Geologist and Dr Sayadul Arafin, a Bangladeshi Geophysicist, were recruited in 1996. The latter two personnel spent only three years on staff. Dr Ambeh resigned in 1999.

It was not until early in the 2000's that the creation of additional senior staff positions resumed. These included professional posts and served to address changes in technology and the need to disseminate information. The current staff complement consists of 10 senior staff members, seven of whom are scientific, plus another six based at the Montserrat Volcano Observatory, and three professional, supported by 19 technical, clerical, research assistants and housekeeping and maintenance members of staff.

As can be seen, the SRC of today (Plate 4) has benefitted from the input of scientists from around the World and many of these former staff members, who helped to lay the foundation for the very important pursuit of earthquake and volcano monitoring and understanding in the English-speaking Eastern Caribbean have gone on to make important contributions in their field internationally and have continued to promote the work of the SRC whenever possible.

The support Staff, essential to the efficient operations of the SRC, is generally recruited locally and facilitates the SRC's achievements. They serve to provide the



Pla

PLATE 4: Staff of the Seismic Research Centre in 2012

(seated, l to r): Joenel Alexander (Groundsman), Stephen George (Electronics Technician), Yvonne Joseph (Secretary), Lutchan Pollard (Contract Seismology Technician), Emeritus Professor Trevor Jackson

(1st row standing, l to r): Monique Johnson (RA – E&O), Dr. Richard Robertson (Geologist), Nisha Nath (Chief Seismology Technician), Farrah Madoo (Seismology Technician, Erouscilla “Pat” Joseph (Volcanologist), Margaret Nero (Cleaner), Susan Neverson (Part-Time Library Assistant), Deborah Robertson (RA – Volcanology), Amit Balchan (Seismology Technician).

(2nd row standing, l to r): Stacey Edwards (Education & Outreach Officer), Roderick Stewart (Volcano Seismologist), Dr. Walter Salazar (Seismology Engineer), Ian Juman (Chief Electronics Technician), Nolan Ali (Senior Maintenance Assistant), Chandradath Ramsingh (IT Officer), Hannah Ramsingh (Seismology Technician), Dr. Robert Watts (Physical Volcanologist), Garth Mannette (Electronics Technician), Carol Liverpool (Clerical Assistant), Shaun Boodhoo (Office Attendant), Dr. Joan Latchman (Director (Ag.)/Seismologist), Lloyd Lynch (Instrumentation Engineer), Clevon Ash (RA – E&O) .

continuity of institutional memory that is so essential in work of this nature. The highly specialised and unique nature of the work of the SRC means that Technical Staff must be carefully trained in-house and through regional and international custom workshops; the learning curve is, of necessity, long, before the ideal level of competence is attained. The Clerical Staff must become familiar with some of the science involved and also extend their vocabulary to include the language of the field.

The personality trait that appears to be the common denominator of those who have made a positive contribution in building the agency is calm, level headed, meticulous and dedicated competence. They have had an appreciation of the importance of the institution



PLATE 5: Willmore seismograph (Courtesy Prof. P.J. Willmore)

in regional development and have sought to position the SRC to deliver at the highest level.

Monitoring

As far as is known, John Milne was the first to attempt to monitor earthquakes in the Eastern Caribbean. John Milne is considered the father of modern seismology and was a pioneer of instrumental seismology. He was an Englishman with a vision of a world-wide seismograph network. He developed his own seismograph and established a seismological observatory in the Isle of Wight, U.K. He installed the first seismometer in the Eastern Caribbean in St Clair, Port of Spain, that operated until sometime during World War I (1914-1918).

The first seismograph deployed in the new Eastern Caribbean network in the early 1950's was the Trinidad station, and it was first installed in St Clair in the same building used by John Milne. However, the site proved too noisy and the station was moved to North Post Signal Station, at the head of the Diego Martin Valley, which although a quiet site was difficult to access. A location suitable for both office and station would be the ideal solution, but the station remained there until August 1958, at which time it was moved to the Main Building at the Imperial College of Tropical Agriculture.

The network began with three seismograph stations with one located in each of the islands of Trinidad, St Vincent and Dominica. These were Willmore seismographs (Plate 5), which were photographic recorders and were installed in dark rooms. The system consisted of a seismometer, the instrument that senses earth movements, electronics for conditioning the recorded signals, which were received by a galvanometer, which is an instrument that responds to input signals, with an attached mirror. A light beam reflected off the mirror served as the instrument for writing on the photographic paper that was mounted on the drum. The drum rotated making a complete revolution in a little over six



*PLATE 6: Dome erupted in Soufrière Crater Lake, St Vincent, 1971-1972
(SRC Archive)*

minutes; the galvanometer took 24 hours to translate from the left side to the right side. At the end of that period, the record was removed and processed to reveal a day's recording of the ground movements at that location.

Records from St Vincent and Dominica were collected and mailed to Trinidad in weekly or twice weekly batches. Two additional seismograph stations in Grenada and St Lucia were soon added to the network, quickly followed by Barbados, but for several months only two, Trinidad and St Vincent, were operational. The challenges were the relatively primitive conditions in the West Indies, the tropical climate and the poor design of some of the equipment components. Visits outside Trinidad were infrequent, which hindered installation and maintenance of equipment and training of station operators. In spite of these challenges, in 1961, the Jamaica network became operational, initially with two seismographs. Ken Barr was stationed in Jamaica to set up and supervise the operations there.

Then, in 1962, the Americans began installation of the global World Wide Standardized Seismograph Network [WWSSN] principally as a means of surveillance of Russian nuclear testing. However, seismology has greatly benefited by the tremendous increase in consistent, calibrated data. One of those instruments was installed in Trinidad co-located with the existing station, whose identifying station code was and is TRN. The systems consisted of 3-component, short-period, and long-period instruments. Through this WWSSN station, the Unit became more internationally recognised as it was established as part of the global seismic monitoring network. The recordings from these instruments, like those produced by the Willmore seismograph, were written by a light beam on photographic paper requiring dark room facilities for processing.

In 1970, the first radio-linked seismographs (Geotech telemetry with Motorola VHF radios) were installed at Pointe-à-Pierre and Brigand Hill, Trinidad, to give real-time readout on pen recorders at the SRU, which could be regularly inspected during working hours. This was the introduction of real-time monitoring, which was a most significant development and is especially critical in the surveillance of live volcanoes. Accuracy in the time being imprinted on earthquake records is essential in producing reliable earthquake locations and in an effort to improve time control, crystal-controlled electric clocks and recorder drum motors were installed.

Dr Tomblin, with Dr David Beckles, of the Mathematics Department, St Augustine campus, and Peter Jutsum, of the Computer Centre, developed the first computer-based hypocentre location and bulletin printing programmes used in the Unit. Its use was short-lived, however, as a result of the installation of new ICL 1902A computer at the Computer Centre UWI, which necessitated a complete rewrite of the data processing package for regional hypocentres and seismological bulletin production. Dr David Beckles and Dr Aspinall did most of the reprogramming, with every rewrite requiring the punching of a new batch of 'computer cards', which had to be taken to the Computer Centre to be queued in the processing runs.

Staff members were deployed over several months to monitor the non-explosive eruption of a lava dome at the Soufrière volcano, St Vincent during 1971-1972 (Plate 6) and to investigate seismo-volcanic unrest in Dominica in 1976. These events strongly influenced the decision to install long-range radio links to connect earthquake monitoring instruments in the Lesser Antilles continuously with a multi-channel magnetic tape recorder and visual displays in St Augustine. This would allow real-time capability, with a consequent improved response time; a common time calibration system leading to improved accuracy of earthquake locations. This technology proved its worth in the lead up to the 13th April, 1979 Good Friday eruption of the Soufrière volcano, St Vincent, when there was less than 12 hours of precursory seismicity, but the ability to track the escalation in real-time allowed the Prime Minister of St Vincent to be alerted by 10:00 p.m. that evening that a volcanic crisis appeared to be developing. By dawn the next day, the volcano was in full-scale eruption.

In 1982, with the support of Dr Robson and Dr Tomblin, the Unit received a grant from UNDP for upgrading the St Vincent volcano monitoring system. The project also included the funding of two students, one at the undergraduate level, for a Vincentian and the other at the post-graduate level, for a Trinidadian. In the end, two Vincentian students were able to take advantage of the opportunity, with one, Richard Robertson, mentioned earlier, joining the Staff in 1993, going on to complete his Ph.D. and become the Head/Director from 2004 to 2011.

The first in-house computer facilities, a twin set of Digital Corporation PDP 11/34 mini-computers, were provided under this grant. Dr David Beckles, undertook development of the WURSTMACHINE, data processing and Soufrière Monitoring System. These systems replaced the use of the main frame computing facilities, ICL 1902A, of the main campus. By 1988, the PDP 11/34 computers had become obsolete and the Soufrière system was, therefore, upgraded to operate on personal computers.

Although these systems were the backbone of data acquisition and processing for more than a decade, the data communication system was cost ineffective. Data circuit tariffs were almost prohibitively high and the system suffered substantial degradation in data quality when the regional telecommunications provider upgraded their media to digital microwave in the late 1980's. This led to a re-design of the system. Whereas, in the original network all data were streamed for collection centrally in Trinidad, the emergence of dial-up and internet technology allowed for a more cost effective strategy, in which the network was distributed into nine nodes. Data were streamed to each node, from which the data were downloaded. In reducing cost and enhancing data quality, however, in 2000 the real-time capability for the area north of Grenada, so important in the surveillance of volcanoes and earthquakes, was lost.

In 2007, a technology upgrade was initiated that involved satellite communications and transition to a new data acquisition and processing system. Although work on the transition to the new processing system continues, the real-time capability has been restored.

While changes in seismic output are often precursory to significant seismic and volcanic events and there is strong emphasis on this monitoring tool, other tools are employed to assess the status of volcanic systems in the region. During the volcano-seismic unrest in Montserrat in 1967, tests for ground deformation were regularly made using a water tube tiltmeter (wet tilt method). Some 10 years later, in cooperation with Drs. Fiske and L. Siebert of the Smithsonian Institution, Washington, and using their equipment, a Wild N-3 optical level, a new method of measuring ground tilt was set up in St Vincent and Montserrat to replace the water-tube tilt system used previously in Nevis, Montserrat and St Vincent. GPS is the technology in use today. Geochemistry is another important surveillance tool.

Research and Outreach

Understanding the geological processes at work in the Eastern Caribbean is data-driven. Therefore, databases must be assembled. Current data are essential, but a context in which these data exist is equally important. Therefore, one of the first significant projects undertaken by the new Unit saw Dr Robson and Dr Willmore completing the first measurements of heat flow in all the major soufrières of the British volcanic islands. The next priority was compiling a catalogue of all known historical earthquake accounts in the region. This work led to its first major publication in a refereed journal by G.R. Robson, *An Earthquake Catalogue for the Eastern Caribbean* (Robson, 1964). An updated version of this resource is available at <http://www.uwiseismic.com/General.aspx?id=16>.

By 1971 the Unit had a strong scientific team well able to respond to unrest at the Soufrière volcano, St Vincent, when on 31st October a pilot of a light aeroplane reported that the 600' deep Soufrière Crater Lake was steaming. The Unit instituted on-the-spot investigation and surveillance deploying four seismograph stations, one of which was 250m from the crater. Geotech-Motorola radio-linked equipment was set up at two outstations powered by air-cell batteries.

While such episodes provide ready material for publication, the Unit sought to expand its scope, and research moved into a new phase. In April 1972, the Lesser Antilles Seismic Project (LASP) was conducted under the auspices of Combined Investigation into the Caribbean and Adjacent Regions (CICAR). It involved the Universities of Durham, Dublin, Leicester and Paris. An array of seismometers was set up by Drs Shepherd and Aspinall and technicians in St Vincent, Grenada, Barbados and Dominica. The aim was to capture signals from depth charges fired by the Royal Navy. The data were to be used to improve the knowledge of the crustal structure of the island arc and refine velocity models for the earthquake location programmes.

Towards the end of May of that same year, Drs Sigurdsson and Shepherd led a cruise on the oceanographic research vessel HMS Hecla to carry out detailed investigations on the submarine Kick-'em-Jenny volcano. The side-scan sonar technology employed allowed an image of the volcano to be created and information on its depth below sea level to be ascertained. This proved a most opportune investigation, when, on 6th July, real-time recording of T-phases, which are acoustic phases from an earthquake or volcanic eruption that travels through the ocean, signalled the eruption of the Kick-'em-Jenny volcano.

To further enhance the research capability of the Unit, Dr Tomblin undertook the supervision of a Master's student, Keith C. Rowley, whose project analysed the pyroclastic fall deposits in St Vincent. While the Unit had supported the research efforts of international investigators to work on various volcanoes in the region as a strategy for building a database of eruption histories, with a view to recognising patterns of volcanic behaviour, this move provided an opportunity to develop local expertise. In 1974, Mr Rowley became the Unit's first Master's graduate. He moved onto a Ph.D. programme that looked more deeply into the activity of the Soufrière, St Vincent and in 1978 became the Unit's first Ph.D. graduate. In this same vein, in 1977, one of the Research Technicians, Joan Latchman, on Staff from 1972 was encouraged to pursue a B.Sc. under a flexi-time arrangement, with a view to becoming part of the research endeavours. In 1998, she completed Masters degree, which investigated the Seismic Potential of the South-West Tobago Fault System and a Ph.D. in 2009, on Tobago and Earthquakes. Erouscilla Joseph completed her Ph.D. in 2008 while studying at the Unit. The topic of her investigations was the Geochemistry of Geothermal Systems in St Lucia and Dominica, Lesser Antilles: Implications for Volcanic Monitoring. Currently, the SRC has three Research Assistants undertaking postgraduate work.

The Unit has been there to anticipate, respond to and/or manage all the significant geological episodes that have occurred in the Eastern Caribbean since its inception, starting with the 1954 magnitude 6.5 earthquake, near north-east coast of Trinidad. The instruments were able to detect the eruption of the Kick-'em-Jenny volcano in 1965; the 1967 volcano-seismic unrest in Montserrat was closely monitored, with staff serving several tours of duty until activity subsided; the 1971-1972 Soufrière volcano, St Vincent, as described above; the damaging, 1974 magnitude 7.4 Antigua earthquake; involvement, on the request of the French Observatories, in the 1976 phreatic eruption of the Soufrière volcano, Guadeloupe; followed by the 1979 Soufrière, St Vincent eruption



PLATE 7: A 1979 eruption at the Soufrière St Vincent volcano in 1979 with skirt clouds. Captured by Dr. Keith Rowley during in a reconnaissance flight. (Courtesy Prof. W. P. Aspinall)

described earlier. Here again, scientists and technicians served several tours of duty at the Observatory in St Vincent until the seismic activity associated with that eruption subsided to background. One scientist making use of a crop duster for a reconnaissance flight was able to capture one of the eruptions in that episode, just as they were preparing to fly over the crater (Plate 7).

After almost 30 years, earthquake activity again was the focus of concern this time during the 1982 Tobago sequence, when an earthquake forecasting technique being explored was tested. Authorities were put on alert for the possible occurrence of a potentially damaging earthquake of magnitude 5 or larger, three days before the mainshock earthquake at magnitude 5.2 occurred, causing minor damage in south-west Tobago.

This earthquake served to reveal that the seismic hazard near Tobago was higher than historical seismicity suggested.

Early in the 1980's the Unit became involved in the effort to develop a Building Code and pursued research that would support the parameters needed in the definitions in such a document. Several assessments on the hazard in individual islands and the Eastern Caribbean as a whole were published. A major advancement took place in this area with the Unit's participation in a regional project to develop hazard maps for Latin America and the Caribbean (1989-1994). The first homogenous earthquake catalogue for the Caribbean region was produced and hazard maps at a quarter degree resolution were produced. Using the database and software that were also created for the project, it was possible to prepare higher resolution maps at the sub-regional level.

In 1985, Dr Wadge and Mr Isaacs undertook an investigation of the volcanic hazard in Montserrat and produced a hazard map showing the areas that would be threatened in the event of volcanic eruption at the Soufrière Hills volcano in the south of the island. Around the time this work was being conducted, there was a magnitude 6.6 earthquake in the Leeward Islands that caused minor damage in St Kitts, Nevis and Montserrat. In 1988, a magnitude 6.3 earthquake east of Trinidad, also causing minor damage showed that in this area also, the seismic hazard was higher than originally assessed. In 1989, volcano-seismic activity in Montserrat increased above background, persisted into 1995, when the volcano began erupting. In the lead up, the local network was densified to enhance the capability to locate the earthquakes that were being recorded. The assessment was that the activity was indicative of magma movements, which had the potential to culminate in eruption.

In 1997, in another earthquake series near Tobago, the earthquake forecasting technique developed in 1982 was tested and found useful. The technique has been further developed and introduced to the wider seismological community in a total of three publications and several conference presentations.

In 2001, funding was secured from USAID/Office of U.S. Foreign Disaster Assistance (OFDA) to support a regional public awareness campaign on volcanic and seismic hazards. This marked the largest public education effort to be undertaken by the Unit and led to the creation of a post for an Education and Outreach Officer to address outreach, which had come to be recognized as essential in helping to communicate information on the geological hazards, to which the region is vulnerable. Ms Stacey Edwards was appointed to the position on completion of her temporary appointment managing the USAID/OFDA project. Around this time, with increasing use of IT in the work of the Unit, a post for an IT Specialist was created and Mr Chandradath Ramsingh, already on Staff in the Electronics section, was appointed to the position.

In 2005, the Unit published the Volcanic Hazard Atlas of the Lesser Antilles, which is a comprehensive compilation of all available information, to that time, on all the volcanoes in the Eastern Caribbean (Lindsay *et al.*, 2005). This volume is an important resource for planners in all the volcanic islands.

Tsunami Smart education material was developed by the Unit under a CDERA project (www.uwiseismic.com/EducationalResources.aspx). This material is used by

Disaster Management practitioners and teachers throughout the region to increase awareness and understanding of the tsunami hazard.

In 2008, the SRC took a decision to fill an existing vacancy with a Seismology Engineer to strengthen capacity in Hazard Analysis. Dr Walter Salazar, who is from El Salvador, is now the specialist in this area and in 2010, in collaboration with the EUCENTRE, Pavia, Italy was able to complete new Seismic Hazard Maps for the Eastern Caribbean.

Earthquakes know no boundaries and, in this context, there is routine collaboration with like regional and international agencies. Since early 2000, identifying projects that advance the science and/or public education has been the strategy employed to promote development in knowledge gaps. In this context, the SRC has been involved and continues to be involved in several projects, locally, regionally and internationally to achieve its goals of developing an understanding of seismo-volcanic processes in the Eastern Caribbean that promote sustainable development. The routine operation of the SRC is funded by governments of the English-speaking Eastern Caribbean, with the first point of contact being the local Disaster Management Agency.

Conclusion

The account of the development of the Seismic Research Centre is instructive. It has been deliberately presented with dates to provide insight on how slowly (and still fortuitously timely), but steadily, development has come. The SRC can by no means be considered to have arrived, it continues to grow, develop and explore strategies to communicate information on the importance of factoring the geological hazards into national and regional planning and development. It has, however, come a very long way in the 60 years since it was established. Its achievements have come through genuine commitment by its Staff. There were periods when instruments were constructed in-house to allow available funds to go further, and equipment considered obsolete in other environments being made to continue in service. The facility, at the time of writing, is a perfect example. It was constructed in 1959, without the benefit of appropriate seismic resistant design and has long been inadequate to the needs, but the Staff, without public protest, has continued to function and produce at the highest possible level. Patience is soon to be rewarded, however, with a new facility that is currently under construction. The SRC has a lean, but strong team; each specialist is fully committed to advancing his particular area of responsibility, with a view to maintaining the momentum of the whole; doing all in its power to promote continuity and excellence in basic services, as well as cultivating valuable research insights, so that the Seismic Research Centre continues to play an important role in future regional development and resilience.

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