Implementation of a geothermal monitoring program for the islands of the Lesser Antilles: Challenges and preliminary results

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Regional Tectonic Setting

- The Lesser Antilles island arc extends 850 km along the eastern edge of the Caribbean Plate.
- The islands of the arc have been largely built by volcanism above a subduction zone, as the Atlantic Plate is being subducted under the Caribbean Plate.
Active volcanic centres of the Lesser Antilles

• The islands of the arc that make up the axis of active volcanoes in the Lesser Antilles are collectively called the ‘Volcanic Caribbees’ (Martin-Kaye, 1969)
• There have been 33 historical eruption in the LA, and 21 volcanoes are now considered potentially active
• Most islands have one main centre, however, Dominica has 9
The SRU is responsible for monitoring earthquake and volcanic activity in islands of the Lesser Antilles, from Saba to Grenada.

Monitoring techniques include the use of:

- Seismicity
- Geodesy
- Geothermal monitoring
What are geothermal systems?

- Geothermal systems are closely linked to volcanic activity.
- They are found where the earth is hotter than surrounding areas, due to the presence of hot rock or magma near the earth’s surface.
- Deep subterranean faults and cracks allow rainwater and snowmelt to seep underground where the water is heated by the hot rocks and circulates back up to the surface, to appear as crater lakes, hot springs, mud pots, geysers, or fumaroles.
Why monitor geothermal systems?

Changes in the chemical composition and physical appearance of geothermal gas and water can:

- Indicate movement of magma closer to the earth’s surface
- Show if magma is rich or poor in dissolved gases, therefore give indications on the potential violence of volcanic eruptions
- Provide information on the sources of the gas e.g. mantle, subducted material, sedimentary rocks, or meteoric contributions
- Provide data to help forecast eruptive activity and monitor health hazards
The SRU geothermal monitoring program

• Program was reinstated in November 2000
• It involves the collection and analysis of:
  - Temperature data
  - pH data
  - Volcanic gases
  - Geothermal waters
Islands and sites monitored

Islands monitored on a regular basis (once or twice per year):

- **Dominica**
  - Morne aux Diables
  - Sulphur Springs
  - Watten Waven
  - Galion
  - Champagne
  - Sulphur Springs
  - Valley of Desolation/Boiling Lake

- **Saint Lucia**
  - Sulphur Springs

- **St. Vincent**
  - La Soufriere dome

- **Grenada**
  - Peggy’s Whim
  - River Sallee
  - Byland
Volcanic gases

Gases are analyzed using gas chromatography and titration techniques. Components analyzed include:

- Water vapour
- Carbon dioxide
- Carbon monoxide
- Hydrogen chloride
- Hydrogen sulphide
- Sulphur dioxide
- Helium
- Hydrogen
- Argon
- Oxygen
- Nitrogen
- Methane
Geothermal waters

Atomic absorption spectroscopy and ion chromatography are used to analyze water samples. Constituents analyzed include:

CATIONS
- Calcium
- Magnesium
- Iron
- Aluminium
- Potassium
- Sodium

ANIONS
- Fluoride
- Chloride
- Bromide
- Nitrate
- Nitrite
- Phosphate
- Sulphate
Sampling methodology

- Gas samples collected from fumaroles, bubbling pools and hot springs using evacuated Giggenbach flasks containing 50 mls of 5 M sodium hydroxide.
- Water samples collected in Nalgene LDPE narrow mouth bottles and glass Qorpak bottles.
- Sample times coincide with wet and dry seasons of the islands.
- Variety of features are consistently sampled at each site.
Variations in chemical composition of Boiling Lake, Dominica

Results: water

- Variations over time in concentrations of Fe, Na, K, Al, and Ca.
- Peaks in Fe and Na concentrations during Nov-02 and Apr-03.
- Steady increase in Ca concentration from Nov-00 to May-03.
Results: water

Variation in chemical composition of Yellow Pool, Watten Waven

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Variations in chemical composition of Lake Placid, St. Lucia

Concentration (mg/L) vs. Date

- Mg (blue)
- Fe (purple)
- Na (yellow)
- K (cyan)
- Ca (violet)
- Al (red)
Gas results

• Results are typical of gases in arc-type settings for Dominica and Saint Lucia

• Gases are dominated by water vapour, carbon dioxide, hydrogen sulphide, hydrogen chloride and/or hydrogen

• Gases generally have a strong hydrothermal signature

• However, gases from the Valley of Desolation (VoD), Dominica have higher concentrations of sulphur and hydrogen giving them a more magmatic signature
Gas results

• During the rainy season there is an influx of meteoric water into the hydrothermal system at the VoD and the vapour cap is smaller, suggesting the increased likelihood of a phreatomagmatic eruption

• Saint Lucia gases are richer in carbon dioxide than Dominica gases but concentrations of other components are generally similar

• Similarities in the gas results suggest that they show normal background parameters
Challenges encountered

- Changes due to meteoric influences rather than heat source

Boiling Lake, Dominica

17th April 1988

July 1990

24th April 2003

30th May 2003
Challenges encountered

• Huge differences in chemistry between wet and dry seasons for many features will make it difficult to establish baseline levels of activity

• Difficulty in accessing some of the sites may limit the frequency of sampling e.g. Dominica’s VoD, St. Vincent’s La Soufriere

• Financial and logistical constraints of flying to various islands and coordinating sampling times

• Lab facilities for analysing gases and anion concentrations in water samples are lacking at UWI and will take some time to be properly established
Further work

• Continue to collect geothermal samples and conduct geochemical analyses towards establishing baseline activity levels
• Characterize geothermal systems of the Lesser Antilles
• Establish sustainable lab facilities for monitoring geothermal activity in the Lesser Antilles
• Conduct further investigations on the health effects of long term exposure to volcanic gas emissions
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