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# Unconventional Computation

8th International Conference, UC 2009
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# Preface

The 8th International Conference on Unconventional Computation, UC 2009, was held in Ponta Delgada during September 7–11, 2009, and was organized under the auspices of the European Association for Theoretical Computer Science (EATCS) by the University of Azores (Ponta Delgada, Portugal) and the Centre for Discrete Mathematics and Theoretical Computer Science (Auckland, New Zealand).

The venue was the University of Azores, with its modern and well-equipped auditoria, next to the magnificent rectory, and surrounded by a pleasant and peaceful garden. The university is located in the city of Ponta Delgada, on São Miguel Island, in the Archipelago of the Azores. São Miguel is famous for its beautiful landscapes and exceptional volcanic lakes. Depending on the surrounding countryside, some appear peaceful and relaxing, while others are more dramatic. Ponta Delgada has many magnificent buildings of tremendous architectural value portraying the urban architecture of the sixteenth to nineteenth centuries. The majority of these are presently used to accommodate various political, administrative, religious and cultural offices. There are several churches that are authentic works of art, with Gothic structures and Manueline exteriors. Others are in the baroque style, with interior embroideries in gold thread and rare wood pieces. Famous paintings are also easily found in Ponta Delgada.

The International Conference on Unconventional Computation (UC) series is devoted to all aspects of unconventional computation — theory as well as experiments and applications. (See https://www.cs.auckland.ac.nz/CDMTCS/conferences/uc/.) Typical, but not exclusive, topics are: natural computing including quantum, cellular, molecular, membrane, neural, and evolutionary computing, as well as chaos and dynamical system-based computing, and various proposals for computational mechanisms that go beyond the Turing model.

The first venue of the Unconventional Computation Conference (formerly called Unconventional Models of Computation) was Auckland, New Zealand in 1998. Subsequent sites of the conference were Brussels, Belgium in 2000, Kobe, Japan in 2002, Seville, Spain in 2005, York, UK in 2006, Kingston, Canada in 2007, and Vienna, Austria, in 2008. The proceedings of the previous UC conferences appeared as follows:

1. Calude, C. S., Casti, J., Dinneen, M. J. (eds.): Unconventional Models of Computation, Springer, Singapore (1998);
2. Antoniou, I., Calude, C. S., Dinneen, M. J. (eds.): Unconventional Models of Computation, UMC 2K: Proceedings of the Second International Conference, Springer, London (2001);
3. Calude, C. S., Dinneen, M. J., Peper, F. (eds.): UMC 2002. LNCS 2509, Springer, Heidelberg (2002);

4. Calude, C. S., Dinneen, M. J., Păun, G., Pérez-Jiménez, M. J., Rozenberg, G. (eds.): UC 2005. LNCS 3699, Springer, Heidelberg (2005);
5. Calude, C. S., Dinneen, M. J., Păun, G., Rozenberg, G., Stepney, S. (eds.): UC 2006. LNCS 4135, Springer, Heidelberg (2006);
6. Akl, S. G., Calude, C. S., Dinneen, M. J., Rozenberg, G., Wareham, H. T. (eds.): UC 2007. LNCS 4618, Springer, Heidelberg (2007);
7. Calude, C. S., Costa, J. F., Freund, R., Rozenberg, G. (eds.): UC 2008. LNCS 5204, Springer, Heidelberg (2008).

The eight keynote speakers at the 2009 conference were:

- Edwin Beggs (Swansea University): "Experimental Computation"
- Jarkko Kari (University of Turku): "Cellular Automata"
- Carlos Lourenço (University of Lisbon): "Brain Dynamics"
- Jonathan Mills (Indiana University): "Awakening the Analogue Computer: Rubel's Extended Analog Computer Workshop" (Action Event)
- James M. Nyce (Ball State University and Indiana School of Medicine): "Artifice, Interpretation and Nature: Key Categories in Radiology Work" (Action Event)
- Przemyslaw Prusinkiewickz (University of Calgary): "Developmental Computing"
- Lukáš Sekanina (Brno University of Technology): "Evolvable Hardware: From Successful Applications to Implications for the Theory of Computation"
- Philip Welch (University of Bristol): "Relativistic Computers and Transfinite Computation"

The conference also included three tutorials:

- Manuel Lameiras Campagnolo (Technical University of Lisbon): "Analogue Computation"
- James Crutchfield (University of California at Davis): "Computational Mechanics: Natural Computation and Self-Organization"
- Martin Davis (New York University and Visiting Scholar, Berkeley): "Diophantine Equations"

In a special lecture, Gabriela Queiroz, from the Volcanology and Geological Risks Evaluation Centre of University of Azores, spoke on "The Geology of the Island." In this talk, the geological evolution of São Miguel Island was characterized in the context of the Azores geodynamic setting. The main active volcanic systems of the island were described, covering their eruptive history, volcanic hazard and historical eruptions.

In addition, UC 2009 hosted three workshops — one on "Hyper-computation" organized by Mike Stannett (University of Sheffield ), one on "Novel Computing Substrates" organized by Andrew Adamatzky (University of the West of England, Bristol), and one on "Physics and Computation" organized by Olivier Bournez (École Polytechnique), and Gilles Dowek (École Polytechnique and INRIA).

The Program Committee consisting of Andrew Adamatzky (Bristol, UK), Selim G. Akl (Kingston, Canada), Masashi Aono (Tokyo, Japan), Edwin Beggs (Swansea, UK), Olivier Bournez (Paris, France), Mark Burgin (California, Los Angeles, USA), Cristian S. Calude (Auckland, New Zealand), Luca Cardelli (Cambridge, UK), S. Barry Cooper (Leeds, UK), José Félix Costa (Lisbon, Portugal and Swansea, UK, Co-chair), James Crutchfield (California, Davis, USA), Martin Davis (New York and Berkeley, USA), Nachum Dershowitz (Tel Aviv, Israel, Co-chair), Michael J. Dinneen (Auckland, New Zealand), Gilles Dowek (Paris, France), Rudolf Freund (Vienna, Austria), Dina Q. Goldin (Providence, USA), Masami Hagiya (Tokyo, Japan), Mark Hogarth (Cambridge, UK), Natasha Jonoska (Tampa, FL, USA), Lila Kari (London, Ontario, Canada), Julia Kempe (Tel Aviv, Israel), Yasser Omar (Lisbon, Portugal), Ferdinand Peper (Kobe, Japan), Mario J. Pérez-Jiménez (Seville, Spain), Petrus H. Potgieter (Pretoria, South Africa), Kai Salomaa (Kingston, Canada), Hava Siegelmann (Massachusetts, USA), Darko Stefanovic (Albuquerque, USA), Susan Stepney (York, UK), Christof Teuscher (Portland, USA), and Jon Timmis (York, UK), selected 18 papers (out of 40), 2 posters (out of 3), and 3 papers converted to posters to be presented as full-length talks.

The Program Committee is grateful for the highly appreciated work done by the additional reviewers, and for their help in improving the papers for this volume. These experts included: Jack Copeland, Felipe Cucker, Bo Cui, Michael Domaratzki, Emmanuel Hainry, Carlos Lourenço, Benoit Masson, Marius Nagy, Naya Nagy, Mark Olah, Shinnosuke Seki, Petr Sosik, Karl Svozil, Klaus Weihrauch, Damien Woods, and Martin Ziegler.

The Steering Committee of the International Conference on Unconventional Computation series comprised Thomas Bäck (Leiden, The Netherlands), Cristian S. Calude (Auckland, New Zealand, Co-chair), Lov K. Grover (Murray Hill, NJ, USA), Jan van Leeuwen (Utrecht, The Netherlands), Seth Lloyd (Cambridge, MA, USA), Gheorghe Păun (Bucharest, Romania), Tommaso Toffoli (Boston, MA, USA), Carme Torras (Barcelona, Spain), Grzegorz Rozenberg (Leiden, The Netherlands, Co-chair), and Arto Salomaa (Turku, Finland).

We extend our thanks to all members of the local Conference Organizing Committee, particularly to José Félix Costa (Chair) of the Technical University of Lisbon and Swansea University, and Elisabete Freire, Matthias Funk, Luís Mendes Gomes, and Hélia Guerra of the University of Azores for their invaluable organizational work.

The conference was partially supported by the University of Azores, Centro de Matemática e Aplicações Fundamentais of the University of Lisbon, the Regional Government of Azores, FLAD – Acordo Mobilidade Antero de Quental, Fundação para a Ciência e a Tecnologia (FCT), and Banco Internacional do Funchal (BANIF). We extend to all of them our deep gratitude.

It is a great pleasure to acknowledge the developers of the Easychair system, and the fine cooperation with the *Lecture Notes in Computer Science* team of

Springer which made possible the production of this volume in time for the conference.

Finally, we thank all the authors for the high quality of their contributions.

June 2009

Cristian S. Calude
José Félix Costa
Nachum Dershowitz
Elisabete Freire
Grzegorz Rozenberg

# Venue

# Geology of São Miguel Island

## Introduction

São Miguel is the largest of the nine volcanic islands that constitute the Azores archipelago, located in the North Atlantic Ocean between $36^o$ – $43^o$ latitude north and $25^o$ – $31^o$ longitude west. The islands are situated in a complex geodynamic setting dominated by the interplay between Eurasian, African and American tectonic plates. Accordingly, main tectonic structures affecting the region are the Mid-Atlantic Ridge (MAR), which crosses the archipelago between the islands of Faial and Flores with a general N–S direction, the East Azores Fracture Zone, which extends E–W from the MAR to the Strait of Gibraltar, including the Gloria Fault, and the Terceira Rift [1], which, in a strict approach, trends NW–SE along a line defined by Graciosa, Terceira and São Miguel islands, and in a larger scale comprises, the WNW–ESE fracture systems of Faial, Pico and São Jorge islands.

## Historical Volcanism and Seismicity

Despite some uncertainties about the exact date of the discovery, it is known that the Azores were settled by the Portuguese in the second quarter of the 15th century. Throughout more than 500 years of history, the region experienced about 27 volcanic eruptions and more than 20 strong earthquakes, due to this complex geodynamic environment. The initial reports of volcanic manifestations go back to the fifteenth century and are related to an eruption at Furnas Valley, at about the time of the São Miguel island settlement, sometime between 1439 and 1443 [2]. The last volcanic event with serious social-economic repercussions took place on the NW end of Faial Island, during $1957-1958$, and gave rise to the Capelinhos Volcano [3]. More recently, a submarine eruption occurred about 10 km west of Terceira island, between 1998 and 2002 [4] with no direct consequences for the community. The Azores region is frequently affected by earthquakes, either linked to tectonic movements or related with volcanic activity. The first strong earthquake reported took place on October 22, 1522 and reached the maximum intensity of $X$ (Modified Mercalli Scale, MM–56) on São Miguel Island [5, 6]. Vila Franca do Campo, the capital of the Azores at that time, was destroyed by the earthquake, and, subsequently, was buried by a large landslide produced by the collapse of an adjacent hill [7]. About 5,000 people died, houses were destroyed and all the existing infrastructures were disrupted. The most recent event with social-economic impact occurred on July 9, 1998 and reached a maximum intensity of $VIII$ (MM–56) on Faial Island. It caused eight deaths and significant destruction in most of the rural villages, due to the fragility of the constructions and some recognized geological site effects.

## São Miguel Geology

At present, about 250,000 people live in the Azores, the São Miguel island being the most populated, with approximately 132,000 inhabitants. The island has an area of about 745 km$^2$ and its highest point reaches 1,103 m at Pico da Vara, north of Povoação Caldera. Volcanic structures and the morphological expression of some fractures and scarp faults dominate the landscape in São Miguel. Also notorious are the erosion processes, particularly in the streamlines and sea cliffs. Six distinct volcanic regions can be defined in São Miguel island, which are from east to west (1) Nordeste/Povoação Volcanic Region, (2) Furnas Central Volcano, (3) Achada das Furnas Volcanic System, (4) Fogo Central Volcano, (5) Picos Region Volcanic System, and (6) Sete Cidades Central Volcano (Fig. 1).

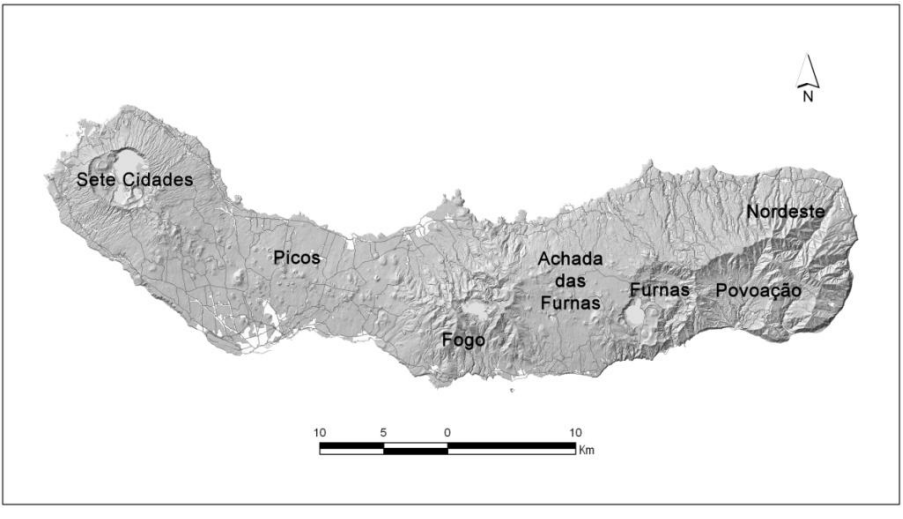


**Fig. 1.** Location of the different volcanic systems in São Miguel island

The Nordeste/Povoação Volcanic Region comprises the thick sequences of lava flows of the Nordeste region and the Povoação Caldera. With about 4 million years [8], the oldest volcanic structures and deposits in the island can be observed at this region. The landscape shows deep valleys resultant from erosion processes. At the southeastern part of the area the Povoação Caldera is a volcanic depression with 6 km × 8 km across and walls as high as 700 m. The Povoação Volcano is considered to be extinct and its surface is mantled by deposits originating mainly in the adjacent Furnas Volcano. Furnas, Fogo and Sete Cidades are the three active central volcanoes in São Miguel. They have recent eruptive histories marked by a predominance of explosive activity and all of them developed summit calderas that are now partially occupied by lakes. Unlike the other two, Furnas does not have a well-defined edifice, but consists of a steep-sided caldera complex 7 km × 4.5 km across (Fig. 2). The eruptive history at Furnas appears to have been essentially explosive, producing thick deposits of pumice, and registering at least two

major caldera collapses [9]. There have been 10 recognized eruptions over the last 5,000 years, of which two occurred in historical times, the first, as previously mentioned, in 1439 – 1443 AD and the second in 1630 AD. During the latter about 100 people lost their lives due to the formation of pyroclastic surges [10]. Moreover, pumice and ash covered almost the entire island, reaching as far as Santa Maria island about 80 km to the south.

**Fig. 2.** View of Furnas Caldera in the area of the village. The hill present at the top of the picture is the eastern wall of Povoação Caldera.

Fogo is a central volcano formed by a series of hills, with the summit truncated by a depression with a diameter of about 3 km, partially occupied by the Fogo Lake (Fig.3). The main edifice was built by the accumulation of lava flows, domes and pyroclasts. One major caldera-forming eruption was recognized between 46,500 and 26,500 years ago [11]. In the last 5,000 years 7 explosive eruptions marked the activity of this volcano, including the historical event of 1563 AD originating inside the caldera, which produced ash deposits that mantled the eastern part of the island.

Sete Cidades is the westernmost central volcano of the island. It has an approximately circular summit caldera of about 5 km diameter partly occupied by two connecting lakes — Lagoa Azul and Lagoa Verde, and several secondary pumice cones and tuff cones (Fig. 4). The oldest dated rocks revealed more than 200,000 years of age. The actual caldera is interpreted as been formed in three main phases as a result of three paroxysmal eruptions at about 36,000 years, 29,000 years and 16,000 years ago [12]. In the last 5,000 years at least 17 intracaldera eruptions occurred, the latest of which formed the Caldeira Seca

**Fig. 3.** Partial view of Fogo Caldera and Fogo lake

**Fig. 4.** View of Sete Cidades Volcano with Azul and Verde lakes and the caldera steep northern wall

cone, some 700 years ago [13]. The recent eruptive history of Sete Cidades makes it one of the most active volcanoes of the Azores.

The two volcanic systems of the Achada das Furnas and Picos Region occupy the area between Furnas and Fogo volcanoes and Fogo and Sete Cidades volcanoes, respectively. Achada das Furnas is a relatively flat region with dispersed cinder cones. The smooth landscape is made up of lava flows intercalated with scoria deposits from the closest cinder cones and pumice layers from the adjacent central volcanoes. The Volcanic System of the Picos Region is dominated by the presence of numerous alignments of cinder cones. From these eruptive centers were several lava flows produced and built large low-slope surfaces which extend toward the north and south seashores. This volcanic system is strongly affected by a fault system, trending NW–SE, clearly made evident by the spatial distribution of the eruptive centers and the direction of important eruptive fissures [14]. In this region historical eruptions occurred (1) in 1563, on Pico do Sapateiro, three days after the explosion centerd inside Fogo's caldera, and (2) in 1652, on Pico do Fogo, in three eruptive vents aligned along a NW–SE fracture.

**Fig. 5.** Asmodeu fumarole in Furnas village

## Hydrothermal Activity

The current normal levels of volcanic activity in São Miguel are displayed in several fumarolic fields, hot springs and extensive soil degassing, particularly well expressed in some areas of Furnas and Fogo volcanoes. In general, the

fumaroles present temperatures close to the boiling point of the fluids and their compositions are $CO_2$ dominated (Fig. 5).

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