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Ana Malheiro • Francisco Fernandes •
Helder I. Chaminé
Editors

Advances in Natural Hazards and Volcanic Risks: Shaping a Sustainable Future

Proceedings of the 3rd International Workshop on Natural Hazards (NATHAZ'22), Terceira Island—Azores 2022

Springer

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Foreword by João Luís Gaspar

The geographic location of the Azores in the middle of the Atlantic Ocean, where so often adverse weather conditions occur, and the complex geodynamic environment of the archipelago, characterized by the interaction of the American, Eurasian, and Nubian lithospheric plates under the influence of a mantelic plume, make this Portuguese region an exceptional natural laboratory for the development and promotion of Earth and Space Sciences, namely in what concerns the study of Natural Hazards.

Volcanic eruptions, earthquakes, steam explosions, gaseous emanations, landslides, floods, and tsunamis, among other occurrences, marked the History of the Azores since its discovery and settlement by the Portuguese in the mid-fifteenth century, causing deaths, severe injuries, and extensive property destruction.

These events often occurred in association, ones facilitating or even triggering others, posing special challenges to risk assessment and spatial planning, monitoring and surveillance of natural systems, and emergency response. In this context, the 3rd International Workshop on Natural Hazards (NATHAZ'22) took place on Terceira Island, in the Azores, aimed at scientific advances and human response to Natural Hazards and Volcanic Risks.

The observation and attempt to understand natural hazards were always present in the Azoreans' conscience. The testimonies reported by Gaspar Frutuoso, in the sixteenth century, and the famous works of naturalists Afonso Chaves and José Agostinho, from the end of the nineteenth century to the first decades of the twentieth century, testify to it. But, the introduction of Volcanology as a Science in the Azores is due to Frederico Machado, considering the remarkable scientific and technical work he carried out during the Capelinhos volcanic eruption, on the island of Faial, in 1957/58, and his scientific papers published in national and international journals.

The creation of the Azores Meteorological Service, in 1901, the installation of the Magnetic and Seismological Observatory on the island of São Miguel, in 1911, the emplacement of the first seismological stations in the islands of Faial and Terceira, in the mid-1950s, and the creation of the Azores University Institute, in 1976, which would acquire the name of the University of the Azores in 1980, were decisive steps towards the observation framework that currently exists in the Azores concerning natural phenomena.

However, it was only after the earthquake of 1 January 1980, which particularly affected the island of Terceira, but had significant repercussions on the entire central group of the archipelago, that the course of the Azores' response to the problems posed by natural hazards gained special expression. Civil Protection in the Azores, as a public service for responding to disasters and safeguarding people and goods, was created after this earthquake, and the concept of civil protection was gradually extended to local authorities. Furthermore, the Regional Civil Engineering Laboratory (LREC) was also created in 1980 for technical support, assessment, and quality control of civil construction in the Azores, and in the scope of the

regional administration, planning bodies were then reinforced to apply public prevention policies in spatial planning and water resources management.

In terms of technical and scientific advice to civil protection authorities, the Portuguese Institute for the Sea and Atmosphere (IPMA), formerly the Institute of Meteorology, guarantees in our days the meteorological and geophysical observation of the archipelago on a national scale. In addition, the University of the Azores, through the Institute for Research in Volcanology and Risk Assessment (IVAR) and the Center for Seismovolcanic Information and Surveillance of the Azores (CIVISA), is responsible for managing the multiparametric surveillance network of the active volcanic systems of the archipelago.

The articulation between the monitoring and scientific research structures and the entities responsible for civil protection is fundamental regarding crisis management, and their actions must be developed with total independence. World history shows us that decision-making has been impaired whenever this has not happened, communication to the public has been deficient, and the response of populations has been insufficient. The 3rd International Workshop on Natural Hazards (NATHAZ'22), organized by LREC (Regional Civil Engineering Laboratory—Azores), allowed an integrated approach to these topics, based on the experience of experts from various scientific fields and the practical knowledge acquired in different regions and countries.

While this event took place on Terceira Island, the Azores were facing an important seismovolcanic crisis on the island of S. Jorge. This fact limited the participation in NATHAZ'22 of some of the scientists and civil protection officials directly involved in the management of the crisis, but it underlined the relevance of the matters under analysis in the field of risk mitigation. From the discussion, it remained clear that although the human response to paroxysmal events requires a global approach, it also must consider regional and local specificities and constraints.

July 2022

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Preface

The morning was cool, but the dawn slowly began to reveal the curves of the mountains and the contours of the sea cliffs. Despite the choppy seas and a little veil of fog hovering over the mountain, the day looked promising.

—Nemésio 1944 (translated by Fagundes 2019)

This volume comprises the proceedings of the 3rd International Workshop on Natural Hazards (NATHAZ'22), held in Angra do Heroísmo City, Terceira Island, Azores, during 26–27 May 2022. The book follows the second edition of the NATHAZ'19 Workshop (Pico Island, Azores) successfully published, in 2020, by IEREK Springer ASTI Series (details in Fernandes et al., 2020). Thus, both spots are unique for discussing and sharing problems to advance knowledge of natural hazards and risks.

The Azores plateau is positioned as a unique geodynamic framework at the triple junction among the American, Eurasian, and African tectonic plates (e.g., Self 1976; Kueppers and Beier 2018). Many natural hazards impact the geodynamic setting of the Azores archipelago in the middle Atlantic Ocean, such as earthquakes, volcanic eruptions, landslides, floods, coastal erosion, and damage to engineering works (e.g., Malheiro 2006; Malheiro and Nunes 2007; Fernandes et al., 2020; and Chester et al., 2022). The volcanological testimonies from 1586 to 1590 by Gaspar Frutuoso (1522–1591) remain a crucial milestone in the natural framework of the Azores and Macaronesian region (see Frutuoso 2022). Terceira island includes various volcanic systems and a fissural deep zone delineated by alignments of small volcanic cones, lava domes, and fault zones. Terceira island is also unique because of the rural landscape, the natural reserves, and the natural lakes. Additionally, the historic downtown of Angra do Heroísmo city has been a UNESCO world heritage since 1983.

The book provides a comprehensive overview of topical advances on multi-hazard issues highlighting volcanic contexts, including the bridges between volcanic crisis, disaster management, societal concerns, and geoethics. In addition, the 3rd edition NATHAZ international workshop offered an excellent chance to debate natural hazards, particularly volcanic risks and other hazards, such as seismological, hydrological, and geotechnical issues. Finally, the volume underlines current volcanic risks and other hazards research trends, i.e., risk mapping, assessment and management, forecasting catastrophic events, societal impacts, and geoethical issues. That approach is the key milestone in the natural hazards studies pointing out a harmonious design with nature, sustainability, and society, but with geoethics (McHarg 1992, González de Vallejo 2010, Pepolloni and Di Capua 2022).

Natural hazards result from a threat of natural events that will endanger societies and ecosystems. Risks underline processes or actions, natural or technological, that gain socio-economic significance and territorial representation. However, until the 1970s, the international community understood natural and technological disasters as exceptional circumstances to which it was generally necessary to respond with emergency foreign aid. Natural disasters have a destructive impact. The natural hazards and disasters are various, such as earthquakes, volcanic eruptions, landslides, rock falls, floods, and coastal erosion.

Anthropogenic hazards result from anthropic interactions with nature. Finally, technological hazards happen because of exposure to hazardous substances (IASC 2006).

The data, processes, and dynamics of geosystems in a volcanic context include a thorough knowledge and assessment of climate, geology, morphotectonics, hydrology, volcanology, and social sciences. Hence, it is essential to encourage comprehensive studies on hazard and risk assessment and disaster management to undertake multi-hazard mitigation. Also, it underlined the climate variability and change in Earth's systems. Furthermore, the book highlights the role of geoethics and social geosciences as the missing piece to a clear understanding of the responsibility between hazard volcanologists and policy and decision-makers dealing with natural crises.

This volume is expected to outline natural hazard learnings from Europe, America, Asia, and the Atlantic islands. The case studies highlight new understandings of the description, evaluation, and modelling of georisks, multi-hazard systems, engineering, and geoethical issues. The scientific committee comprises lead geoscientists, natural hazards-related practitioners, and academics worldwide.

Key topics comprise the following: (i) Multi-hazards and risks: sustainable society and disasters; (ii) Natural hazards and assessment: rock falls, landslides, and urban planning and management; (iii) Sustainable Earth systems, hazards, and climate change; (iv) Terceira island geology and geodiversity: volcanological hazards.

The volume has a set of 37 chapter books, including the field trips around geology, geodiversity, and natural hazards of Terceira island led by João Carlos Nunes and Adriano Pimentel and four remarkable keynote lectures by Silvia Pepolloni (Italy), Joan Martí (Spain), Gordon Woo (UK), and David Chester (UK). The book was assembled over 154 authors from the academy, research centres, agencies, and companies. In addition, it was involved in a peer-review process with more than 68 reviewers.

The volume is a useful source for researchers and professionals in geosciences, volcanology, natural hazards, geomorphology, geotechnics, engineering, geoethics, and social sciences. So, it is a valuable asset to experts, students, and natural hazard-related practitioners.

Ponta Delgada, Azores, Portugal — Ana Malheiro
Ponta Delgada, Azores, Portugal — Francisco Fernandes
Porto, Portugal — Helder I. Chaminé
July 2022

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Our warmest gratitude to João Luís Gaspar for the insightful foreword and Paulo Melo for the stunning cover photo. A word of appreciation to all assistance of the IEREK and the Springer production team.

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About the Editors

Ana Malheiro is a skilled Geologist with 38 years of experience in practice and research in engineering geology, geotechnics, natural hazards, and geological risks. She studied Geology at the Faculty of Sciences of the University of Lisbon in 1983 and received her master's degree at the University of Azores in Volcanology and Geological Risks in 2002.

She has worked since 1984 in the Regional Laboratory of Civil Engineering (LREC) in the Azores, where she is responsible for engineering geology, in situ geotechnical investigations, volcanic geotechnics, natural hazards, and geological risk studies. She was Head of the Division of Ports (1995/1998), and from 1998 until now, she has been Director of Services of the Department of Geotechnics, Sustainability and In Situ Investigations at LREC—Azores. She participated in several Coordination Commissions for Management Plans (namely Regional Plans and Municipal Plans). In addition, she was also invited assistant lecturer (1985/1990; 1996/1999) at Azores University.

She has co-authored several publications in indexed journals, conference proceedings/full papers, book chapters, technical and professional papers, and technical reports. In addition, she co-edited 2 special volumes, "Volcanic Rocks" (Balkema+Taylor & Francis) and "Advances in Natural Hazards and Hydrological Risks: Meeting the Challenge" (IEREK+ASTI Springer). In general, technical reports focus on the field of in situ geological-geotechnical investigations to support the larger constructions built in the Azores region, coastal erosion, and slope stability, as well as the evaluation of resources in quarries, evaluation of geological and/or geotechnical problems and the assessment of geological hazards. In addition, she has integrated some research projects in the geotechnical characterization and evaluation of volcanic materials, slope stability, unstable areas monitoring, etc.

She participated in several organizing committees for national and international Conferences and Workshops, as well as Scientific Committees (e.g., 15th World Conference on Seismic Engineering, 2012; 5th, 9th, and 10th Portuguese Congress of Seismology and Seismic Engineering, respectively in 2001, 2014, and 2016; 16th Portuguese Congress of Geotechnics, 2018; 1st, 2nd, and 3rd International Workshop on Natural Hazards, Azores, NATHAZ'2016, 2019, and 2022). Currently, she is the Chair of the scientific committee of the 4th

International Workshop on Natural Hazards—NATHAZ'25 (Azores, May 2025), focused on geotechnical hazards and risks.

Francisco Fernandes is a skilled Engineer with over 26 years of experience in practice and research in civil engineering. After an internship at the "Sociedade de Empreitadas e Trabalhos Hidráulicos", he began his career in 1997 in budgeting and cost control at Engil. He was also a controller and was responsible for several management areas at Eng. Luís Gomes company. He worked as a project manager in the Marques, Engil, and Eng. Luís Gomes companies, and as director of production.

Senior Member of the Institution of Portuguese Engineers, he has a master's degree in Business Administration and Management from the University of the Azores (2003), and is a Qualified Expert in the Energy Certification System (SCE—RCCTE) and ADENE (Agency for Energy and Technical Superior of Safety and Hygiene of Work—Level 5). Other activities include participation in various courses, seminars, and vocational training actions in engineering, safety and hygiene at work, energy certification, and management as a designer and qualified expert in the energy certification system.

Presently, since 2012 he has been Head of the Regional Laboratory of Civil Engineering (LREC) in the Azores. Currently, he is a board member of the Portuguese Seismic Engineer Society (SPES), the Fiscal Council president at the Portuguese Geotechnical Society (SPG), and a Fiscal Council member of the Fund for the Development of Construction Sciences (FUNDCIC). In addition, he has been responsible for some research projects in monitoring unstable areas, masonry wall reinforcement, endogenous construction materials catalogue and idea contest, energy and water efficiency in public buildings, and circular economy and waste management in construction.

He has co-authored publications in journals, conference proceedings, book chapters, professional papers, and technical reports. Furthermore, he co-edited the special volume of the Springer ASTI series (Advances in Natural Hazards and Hydrological Risks: Meeting the Challenge—Proceedings of the 2nd International Workshop on Natural Hazards (NATHAZ'19), Pico Island—Azores 2019).

As president of the organizing committee, he was responsible for several scientific events, namely the 10th Portuguese Congress of Seismology and Earthquake Engineering, the 16th Portuguese Geotechnical Congress, the 6th Luso-Spanish Geotechnical Conference, and the 1st, 2nd, and 3rd International Workshop on Natural Hazards (NATHAZ'2016, 2019, and 2022). He also participated in the workshop "Azores Earthquakes, Rocks and Volcanoes" organized in the Azores, part of the 15th World Conference on Seismic Engineering, Lisbon, 2021, and in the 43rd World Symposium on building water networks CIB W062, Azores, 2018. Presently, he is the

Head of the organizing committee of the 4th International Workshop on Natural Hazards—NATHAZ'25 (Azores, May 2025), focused on geotechnical hazards and risks.

Helder I. Chaminé is a skilled Geologist and Professor of engineering geosciences at the School of Engineering (ISEP) of the Polytechnic of Porto, with over 32 years of experience in multidisciplinary geosciences research, consultancy, and practice. He studied geological engineering and geology (B.Sc., 1990) at the Universities of Aveiro and Porto (Portugal), respectively. He received his Ph.D. in geology at the University of Porto in 2000 and spent his postdoctoral research in applied geosciences at the University of Aveiro (2001–2003). In 2011, he received his Habilitation (D.Sc.) in geosciences from Aveiro University. Before joining the academy, he worked for over a decade on international projects for mining, geotechnics, and groundwater industry and/or academia related to geodynamics and regional geology, hard-rock hydrogeology and water resources, engineering geosciences and applied geomorphology, rock engineering, and georesources. His research interests span fundamental to applied fields: GIS mapping techniques for applied geology, structural geology and regional geology, engineering geosciences and rock engineering, slope geotechnics, mining geology and hydrogeomechanics, hard-rock hydrogeology, exploration hydrogeology, urban groundwater, and hydromineral resources. In addition, he has interests in mining geoheritage, history of cartography, military geosciences and higher-education dissemination, skills, and core values.

He is Head of the Laboratory of Cartography and Applied Geology (LABCARGA|ISEP), the Senior Researcher at Centre GeoBioTec|U.Aveiro and Centre IDL|U.Lisbon, and also belongs to the executive board of the M.Sc. + B.Sc. Geotechnical and Geoenvironmental Engineering programmes (OE+EUR-ACE Label) and the Department of Geotechnical Engineering (ISEP). Furthermore, he belongs to the board of the Technical Committee of Environmental Geotechnics of SPG (2020–2024). Moreover, he was a board member of APGeom—Portuguese Association of Geomorphologists (2009–2013), SPG—Portuguese Geotechnical Society (2016–2020), and AIH-GP—Portuguese Chapter of the International Association of Hydrogeologists (2019–2023).

Furthermore, he was a consultant and or responsible for over 70 projects of applied geology, hydrogeomechanics, slope geotechnics, mining geology, exploration hydrogeology, hard-rock hydrogeology, water resources, urban groundwater, and applied mapping (Mozambique, Portugal, and Spain).

He co-authored over 220 publications in indexed journals, conference proceedings/full papers, book chapters, and technical and professional papers. He co-edited over 15 special volumes and is presently involved in editing themed issues for some international journals or ASTI Springer Series (e.g.,

Springer Nature Applied Sciences, Water MDPI, Arabian Journal of Geosciences—Springer). In addition, he has wide activity as a reviewer for several international journals. In 2021, Springer Nature Applied Sciences awarded him an outstanding guest editor and editorial board member. Furthermore, he served as invited Expert Evaluator of the Bologna Geoscience programme for DGES (Portugal) and Scientific Projects Evaluation for NCST, 2017–2019 (Kazakhstan), and NRF|RISA, 2019 (South Africa), as well as Coordinator of "Geology on Summer/Ciência Viva" programme at ISEP (2005–2019) for geoscience dissemination. He has also been active in teaching and supervising many Ph.D., M.Sc., and undergraduate students.

He has been on the editorial board, among others, of the *Springer Nature Applied Sciences, Arabian Journal of Geosciences, Hydrogeology Journal, Geotechnical Research, Mediterranean Geoscience Reviews, Discover Water, Euro-Mediterranean Journal for Environmental Integration, Journal of Geoethics and Social Geosciences, Revista Geotecnia, and Geología Aplicada a la Ingeniería y al Ambiente*. In addition, he integrates as a moderator or session chair in several conferences, workshops, and meetings. Currently, he co-chairs the scientific committee of the 4th International Workshop on Natural Hazards—NATHAZ'25 (Azores, May 2025), focused on geotechnical hazards and risks.