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Researcher investigates the most lethal volcanic phenomena on earth

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The large-scale eruption simulator facility in action . Credit: Massey University

Like many who grew up in East Germany, Dr. Gert Lube always yearned to travel and explore different places. Ten years after the fall of the Berlin Wall, when he was a first-year geology student at the University of Greifswald, he heard about a field trip to Iceland and seized the opportunity.

Notwithstanding that the trip was only open to second- and third-year students, Dr. Lube managed to talk his way into tagging along. It was a journey that would change the course of his life forever and spark his interest in volcanology.

"I was brought up in a country with closed borders and so I grabbed every opportunity that came my way to go abroad and see landscapes that I hadn't seen before. I saw my first volcano on this field trip, and I was quite astounded by how different a volcanic landscape was to anything I had experienced up until then.

"I knew extremely little about volcanoes at this stage, but that Iceland fieldtrip was a bit of a start. When I got back, I asked my professor if I could do a research project in the area and I looked for people who could tell me more about volcanoes," Dr. Lube says.

His quest for more knowledge led to several fellowships in the UK at the University of Bristol and the University of Cambridge—including a stint as a volcanologist at the Montserrat Volcano Observatory in the West Indies—before completing his Ph.D. at Kiel University in the the northern German state of Schleswig-Holstein.

Just over two decades later and Dr. Lube is now Associate Professor in Physical Volcanology at Massey University, where he leads the Physical Volcanology and Environmental Fluid Mechanics research group. Dr. Lube's research interests include explosive volcanism, physics and sedimentology of natural granular-fluid flows, volcano stratigraphy and natural hazard science.

Fast-moving lethal waves of hot, toxic gasses and ash

At Massey, Dr. Lube also heads the large-scale eruption simulator, the pyroclastic flow eruption large-scale experiment facility—PELE for short—housed in the old boiler house at the Manawatū campus.

Pyroclastic flows—also known as pyroclastic density currents (PDCs) – are fast-moving avalanches of hot, toxic gasses and ash, that can reach temperatures of 700C and destroy everything in their path during volcanic eruptions. It was pyroclastic flows that destroyed the Roman city of Pompeii in AD 79.

Earlier this year, Dr. Lube published a paper in the prestigious peer-review journal *Nature Reviews Earth & Environment*, having been invited to sumit the article. The paper, Multiphase flow behavior and hazard prediction of pyroclastic density currents, co-written by Dr. Lube and his colleagues from the University of Oregon (U.S.), the National Institute of Geophysics and Volcanology in Italy and Boise State University (U.S.) considers how our understanding of pyroclastic density currents has advanced in the last decade.

The lethal nature of pyroclastic density currents makes development of robust hazard models a priority. However, in the paper Dr. Lube outlines how the complexity of gas–particle interactions inside PDCs, as well as their hostile nature, makes quantitative measurements of internal flow properties, and the validation of hazard models, challenging.

Within the last decade, major advances from large-scale experiments, field observations and computational and theoretical models have provided new insights into the enigmatic internal structure of PDCs and identified key processes behind their fluid-like motion.

The forward-looking review also outlines future research pathways and challenges on how the recent progress in understanding must be used to develop robust hazard models that can be deployed confidently for public safety.

Developing robust hazard models

It is this very need for public safety, hazard forecasting and mitigation that guides Dr. Lube's research. He combines his field work with volcanic activity pre- and post-eruptions to quantify what's happening in the air and then using computational and experimental methods to synthesize volcanic processes to understand them better and to develop hazard models.

"In volcanology the area that I like most is the process that involves any kind of flowing material. It is mostly very explosive processes such as volcanic avalanches that race down mountains or volcanic plumes that descend from volcanic vents at a rate of several hundreds of meters per second and then do some crazy things in the atmosphere, while they interact with the landscape and infrastructure.

"Trying to understand these complex and chaotic processes in a way that you can forecast them is something that really drives me because that's where I see the opportunity to do something useful with our science."

His research involves working with numerous longstanding stakeholders including the Ministry of Civil Defense and Emergency Management, the Department of Conservation, the Army, and Police, on evacuation plans and procedures straight after eruptions for New Zealand's central plateau volcanoes.

"Pyroclastic density currents occur on all New Zealand's volcanoes, they cause more than a third of all volcanic fatalities, they directly endanger more than 500 million people globally, which makes them the most hazardous volcanic phenomena known," Dr. Lube says.

Awakening volcanoes

The last major eruption of Mt Taranaki, one of New Zealand's high-risk volcanoes occurred around 1854, and while it may be dormant now, Dr. Lube says it's not a question of if it will erupt, but when.

Whakaari / White Island eruption 9 December 2019. Credit: Massey University

"Taranaki is one of the most active volcanoes that we have in New Zealand on geological timescales and its twin brother in Indonesia, Mt Merapi, is the most dangerous volcano in the world. That is why some of my research is centerd in Indonesia to understand not how the Merapi volcano is operating per se, but how we can translate this knowledge into predicting what will definitely happen most likely in our generation. Even if Taranaki is dormant now, there's a very high chance that it will awaken and have eruption phases that will last decades in our lifetime."

Indonesia is the nation with the largest number of active volcanoes—over 120 active volcanoes and around five million people within the danger zones—but its vulnerability to natural hazards does not end there, says Dr. Lube. It is also prone to earthquakes, floods, and tsunamis.

"It's very sad how people get struck by natural disasters again and again, and they lose everything and then they very bravely rebuild their lives again. Over my decade of work in Indonesia I have become good friends not only with the researchers there but also the locals. It is very different to New Zealand where we are relatively safe; even if we have natural hazards, we can deal with these much better than in a third-world country like Indonesia."

One-of-a-kind eruption simulator

Over the past decade, Dr. Lube and Massey colleagues have been at the forefront of the development of new volcanic hazards models. At the PELE, the large-scale eruption simulator facility, the researchers synthesize the natural behavior of volcanic super-hazards and generate these flows as they occur in nature, but on a smaller scale.

The team has made important discoveries of the complex processes behind the motion and the internal structure of the hot currents

The limited knowledge on volcanoes and the difficulties in developing mathematical models prompted Dr. Lube to build Massey's one-of-a-kind eruption simulator. "The problem with volcanoes is that they are extremely violent and so wild that we know in fact very little about them. We know very little about how they operate inside and that makes it extremely difficult to develop mathematical and physical models to inform decision-makers and forecast what kind of damage they can do, and how they interact with natural topography, with buildings and infrastructure."

The simulator scales down all the physical properties of a large event so they can be safely observed and measured. It is composed of a 13-meter high tower, where volcanic material is heated inside a hopper and released down a 12-meter channel, while high-speed cameras and sensors capture the data. The experimental eruptions typically only last 10 to 20 seconds but take about one month to prepare.

"The pyroclastic flow simulator is unique in the world and is the only place where we can synthesize conditions just as they would occur in a volcanic eruption. It's been very cool for volcanology in New Zealand and globally and has led to international experts visiting us in Manawatū and wanting to collaborate and do research with us."

Kiwi ingenuity

Perhaps the most surprising thing about the simulator was how relatively easy it was to get it built with the help of local engineers and some Marsden funding. "I've been quite lucky in that I got to know some local engineers at the time, who were excited enough about this project to help in designing, building and testing a facility at a scale for which there was no previous blueprint and scientific experience out there. Over the years, we continued to work with the same engineers to advance our measurement capabilities and to add scenarios for a large number of volcanoes and hazard scenarios," Dr. Lube says.

Since 2019, Dr. Lube and his team lead an international initiative to intercompare and advance current volcanic flow hazard models. In a just started Marsden-funded project "Turbulent volcanic killers—how volcanic eruptions become ferocious," the volcanologists plan to investigate the physical processes behind the destructiveness of pyroclastic flows.

As part of the Marsden research, the team will investigate the exact processes that occurred on Whakaari / White Island last year. When the island erupted in December 2019 the tragic death of 21 people and major injuries of 26 people visiting the island was caused by the pyroclastic density currents.

Whakaari / White Island

So, does Dr. Lube think the eruption on White Island could have been foreseen? Although the volcanologists at earth-science research and monitoring body GNS Science had seen an increase in volcanic activity in the months preceding its massive eruption, Dr. Lube says with current knowledge the timing of the eruption on 9 December 2019 could have not been predicted with any certainty.

He points out that White Island had been and continuous to be in a very active state with several outbreaks in the past decade, the last of which in 2016 was very similar to the one in 2019—the main difference being the lack of tourists on the island at the time.

Rather, he says, the big question is whether people should be allowed to be anywhere near the vent sides of a volcano [the opening through which lava and gasses erupt]. "In my opinion, definitely not and I see a lot of change in legislation as a result of this disaster."

Dr. Lube says White Island was unusual in that the pyroclastic was slow and low in energy: "Despite this, the pyroclastic density current was the only killer which just goes to prove how extremely lethal these phenomena are and it drives me more to try and understand how they work."

Our scientific understanding of how volcanoes work is changing, in part fuelled by numerous collaborations by experts in the field and a desire to help prepare for future eruptions and save lives.

Far from being a narrow field, Dr. Lube explains, the study of volcanology is broad and involves mathematics, physics, chemistry and computational science. "You can't be an expert in all these fields and working with these experts who come to Massey is really important."

"It is very collegial, and we have to work as a large global research community because these volcanic hazards are real hazards and many of us, especially those working in New Zealand have to inform decision-makers of what to do in certain situations. It is important for public safety."

More information: Gert Lube et al. Multiphase flow behavior and hazard prediction of pyroclastic density currents, *Nature Reviews Earth & Environment* (2020). DOI: 10.1038/s43017-020-0064-8

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