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Gathering insights into volcanic risk from Auckland to the Andes, Antilles, and Arabia: an unexpected journey to professorship in volcanology

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In 2020 I was promoted to Professor at Waipapa Taumata Rau the University of Auckland (UoA), joining the small circle of women (now three, the others being Kathleen Campbell and Philippa Black, also from UoA) who had achieved promotion to Professor in Geology in Aotearoa New Zealand, and the first ever in the field of volcanology. This promotion was a gratifying and somewhat unexpected achievement for me considering that I had started out studying languages and linguistics! In this contribution, which is based on my "inaugural" lecture as Professor in 2021, I provide an overview of my journey, framed primarily through the work of my doctoral students. I pay particular focus on the Andes where I worked on large silicic caldera systems, the Lesser Antilles, characterised by andesite and dacitic dome complexes and stratovolcanoes, and the distributed basaltic volcanism in Auckland and Saudia Arabia. I share some insights gained along the way and describe how these have influenced a shift in my research from more fundamental petrology to more applied volcanology over the course of my career.

KEYWORDS

reflections, doctoral students, academic career, applied volcanology, volcanic risk

Introduction

My ancestors arrived in Aotearoa from Ireland, Scotland, and England in the 1800s, settling primarily in the South Island. I grew up in Rotorua, surrounded by the volcanoes and geothermal areas of the region, and Apia, Samoa (SW Pacific), where I spent two formative years. I completed my secondary schooling at Glenfield College in Tāmaki Makaurau Auckland, where I was introduced to rocks and minerals through a general science module at age 15. Perhaps an Earth Science spark was ignited then, however I did not immediately consider studying geology when I started university in 1990. I had just completed a year-long AFS[1] student exchange to Hildesheim in West Germany (1988–1989; yes, before reunification!) and I had decided to study German and English, with the vague notion of becoming a language teacher. I filled a gap in my timetable with two geology courses that sounded interesting, and ended up loving them so much that I transitioned over the course of

1 See https://www.afs.org.nz/afs-student-exchange-programmes/

FIGURE 1
(A) Photograph taken at my inaugural lecture as Professor, with some of my current and former PhDs students and postdoctoral fellows. I am third from the left in the back row. If you would prefer to watch a presentation version of my story, the lecture is available to view here: https://youtu.be/v_5Fq_-vWHI. **(B)** Photograph of the core members of the IAVCEI Working Group on Hazard Mapping at a writing retreat in 2023. After years of meeting via video conference due to the COVID-19 pandemic it was wonderful to get together in person. I am second from the right in the front row.

my undergraduate degree from a BA in German to a BSc in Geology. In 1995 I completed an MSc in Geology at UoA, working on the petrology, geochemistry and geochronology of Hauturu Little Barrier Island, identifying that this dacitic volcano near Auckland formed in two main phases during the late Miocene (Lindsay et al., 1999). I loved the adventure of field work, and the geological detective work back in the laboratory to unravel the volcano's history. From there I went on to hold several different positions, summarised in later sections of this paper.

My research and the people involved

A professor's body of work has typically been carried out in collaboration with a wide network of people: students, postdoctoral fellows, colleagues, stakeholders and funders. This concept is captured in the Māori whakataukī (proverb, or saying):

Ehara taku toa i te toa takitahi, engari he toa takitini

My success is not mine alone, but is based on the success of many.

For my inaugural lecture I decided to tell the story of my research by focussing on my PhD students and postdoctoral fellows (Figure 1A). Through my work with them, I could show how my research has become more applied with time, and illustrate, within a volcanic risk framework, how the various strands of my research contribute to improved understanding of, and hopefully ultimately reduction in, volcanic risk. This is also the framing I use in this paper.

Over my career to date, I have co-supervised 22 PhD students: 19 to completion, three still underway. I was the main supervisor on 13 (~60%), 13 (~60%) are female, and they span 13 different nationalities (a different 13 in each case!). I have also mentored seven post-doctoral fellows (five females, two males). These students and postdoctoral fellows were supported by a variety of internal and external funding mechanisms, including internal funding made available to me by taking on major service roles within the university.

A framework for understanding my volcanic hazard and risk research

I find diagrams like Figure 2 quite helpful to communicate to students the idea that impacts and risk associated with natural hazards come about due to the interaction of a hazard with exposed elements of our society or the environment that are vulnerable, to different degrees, to a given hazard. Potential impacts and risk can be reduced by decreasing the hazard, and/or decreasing exposure and vulnerability (Figure 2). Decreasing the hazard is difficult if not impossible for most large geophysical hazards such as tsunami, volcanic eruption, and earthquakes, thus in those cases risk reduction measures focus on understanding the hazard and reducing the vulnerability of exposed elements. I realise this is a vast oversimplification of some very complicated and interconnected concepts, and that there are many ways to conceptualise risk. Nevertheless, Figure 2 also provides a useful conceptual framework for my research. At the beginning of my career, I focussed strongly on the eruptive history of volcanoes, which contributes to understanding magnitude and frequency relationships, and what hazardous phenomena to expect in a future eruption. In the latter part of my career, I have focussed more on applied volcanology, i.e., exploring how knowledge related to hazard and vulnerability informs our understanding of impacts and risk, which in turn can increase resilience to natural hazards.

It all went downhill from the Andes . . . . . . or did it?

After my MSc in Geology, I worked as a research assistant at GNS Science (then IGNS) at the Wairakei Research Centre, Taupō, in the geothermal team under Bruce Christenson. My tenure at GNS

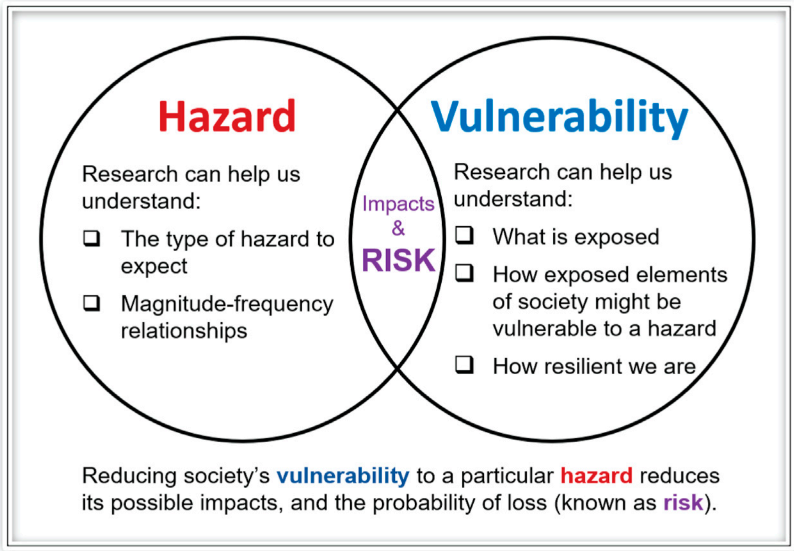

FIGURE 2
A conceptual illustration of the relationship between hazard, vulnerability, and risk, which I find useful to explain these concepts to students. This diagram also provides a useful conceptual framework for my research.

coincided with the 1995/96 eruption of Ruapehu, and the intense experiences of being involved (even if only peripherally) in the response made me realise that I wanted to continue in volcanology.

In 1996 I moved to the by then reunified Germany to carry out a PhD under the supervision of Robert Trumbull at the GeoForschungsZentrum (GFZ) Potsdam, with fieldwork in Chile. At the time, several people advised me against this ("GFZ? Never heard of it! Better to work somewhere famous for its volcanology") but I was excited by the prospect of returning to Germany and experiencing life in the former East Germany and visiting the Andes of 'andesite' fame. My project was part of the collaborative research programme 'Deformation processes in the Andes' (SFB 267), funded by the German Science foundation. It was an exciting and vibrant time to be living in Potsdam, and my PhD project, which involved fieldwork in the Altiplano-Puna Volcanic Complex, was interesting and well supported, including by previous workers Shanaka de Silva and Moyra Gardeweg. In 1999 I received a Dr. rer. nat. in Geowissenschaften (the equivalent of a PhD in Geoscience) from the Justus-Liebig-Universität Giessen for my work on the large La Pacana caldera volcano in the Central Andes. I unravelled the stratigraphy (Lindsay et al., 2001a) and contributed to the emerging idea that some large silicic systems are underlain by largely "uneruptible" crystal mushes requiring an external trigger to erupt (Lindsay et al., 2001b).

A recent highlight for me has been to rekindle my interest in the Central Andes by co-supervising a Chilean PhD student, Daniel Bertin, who developed a comprehensive volcanic database and volcanic hazard assessment for the region (Bertin et al., 2022; Bertin et al., 2023). It was particularly rewarding to co-supervise Daniel with Shan de Silva, my former adviser.

Since my doctoral work in the Andes, my research has diversified to encompass a wide range of projects in numerous volcanic settings in the broad area of applied volcanology. For example, in the context of large, intermediate to silicic systems my recent PhD students have worked on exploring how the characteristics and distribution of tephra deposits can constrain numerical tephra hazard models (Constantinescu et al., 2021; Constantinescu et al., 2022), how hydrothermal alteration of rocks affects shallow plumbing systems and edifice stability (Kanakiya et al., 2021a; Kanakiya et al., 2021b; Kanakiya et al., 2022), and how pasture can be rehabilitated following large tephra falls (Sivarajan et al., 2020). A current student, Annahlise Hall, is exploring the explosive eruption history and hazards of the Tongan Volcanic Arc.

A senior male Professor once told me that my work on La Pacana was excellent, but my research had really "gone downhill" from there. For a long time after that I felt like I should be an "expert" in something, rather than a Jack-of-all-trades volcanological (and master of none!). I even orchestrated an attempt to relaunch my research career in igneous petrology by immersing myself in petrology and geochemistry again, during a sabbatical in 2015. However, my heart was not in it, and I felt out of my depth. I came to recognise that I far prefer the variety of applied volcanology, the broad understanding of many aspects of volcanism that it requires, and the wide range of collaborations that it brings.

The Lesser Antilles—towards independence

Between 2000 and 2003 I was a Research Fellow at the University of the West Indies (UWI) in the Seismic Research Unit (now Centre) in Trinidad, under the then director John Shepherd. I worked in the islands of the Lesser Antilles with the general aim of improving volcanic hazard assessments in the region, underpinned by detailed petrological, geochemical and geochronological studies (e.g., Lindsay et al., 2003; Lindsay et al., 2005a; Lindsay et al., 2005b). Whilst in the Caribbean I supervised my first PhD student, Erouscilla (Pat) Joseph. Her comprehensive evaluation of volcanic gas and water geochemistry enabled us to identify background geochemical characteristics, including seasonal variations, leading to geothermal monitoring being incorporated as a volcano surveillance tool in this region for the first time (Joseph et al., 2011; Joseph et al., 2013). Pat was the first ever student to graduate with a PhD in Volcanology from UWI and is now the Director of the UWI Seismic Research Centre.

Between 2003 and 2006 I remained somewhat active in academia through an Honorary Research Associate position at UoA whilst otherwise having a break to have two children. Upon returning to full-time academia at UoA in mid-2006, I needed to re-establish old and develop new research directions, one of which was a collaboration based on zircon dating, with former colleagues from the GFZ-Potsdam (my fellow PhD student Axel Schmitt) and UWI (Richie Robertson), and Phil Shane at UoA. This new collaboration included work by PhD student Tracy Howe to use cutting-edge U-Th and (U-Th)/He zircon dating of eruptions and magmatic processes to understand magma generation in Dominica (Howe et al., 2014; Howe et al., 2015a; Howe et al., 2015b). Another student, Sonja Storm, applied zircon geochronology to the Okataina volcano, New Zealand, and was able to put time constraints on rejuvenation processes in silicic crystal mush zones (Storm et al., 2011; Storm et al., 2012; Storm et al., 2014). This "zircon collaboration" was instrumental in restarting my career after almost 3 years' break.

Volcanic hazard maps: my passion project

Most of my work in the Eastern Caribbean is summarised in the 2005 *Volcanic Hazard Atlas of the Lesser Antilles* (Lindsay et al., 2005c), which included a suite of volcanic hazard maps. (It was a special moment for me to see a volcanic hazard map from the Atlas being successfully used during the 2021 eruption of La Soufrière, St Vincent). Shortly after the publication of our hazard maps, Haynes et al. (2007) published a study that investigated maps as a communication tool on Montserrat. A survey of map reading preferences revealed that participants had better success in location and orientation tasks when presented with perspective photographs than when presented with contour maps and 3D projections. Along with other studies of how design elements can significantly affect the way in which users interpret information on a map, this got me thinking about the process of hazard map development, in particular the importance of consulting with potential map users throughout the map making process to ensure that outputs are evidence-backed and user-optimised. In hindsight, we should have asked our map users and stakeholders what they would prefer our hazard maps to look like, and whether our maps were even fit-for-purpose from their perspective! These thoughts are described in Lindsay and Robertson (2018), in which we reflect on our hazard map making process and the associated challenges, mistakes, and learnings.

My interest in volcanic hazard maps and hazard communication was thus sparked, and this has been a strong thread of my work since. Doctoral student Mary Anne Thompson (now Clive) worked on an interesting topic at the intersection of volcanology and social science, carrying out a hazard and risk assessment for Okataina volcano, New Zealand (Thompson et al., 2015a; Thompson et al., 2017) and exploring, through interviews and surveys, how stakeholders and scientists drew information from a series of associated volcanic hazard maps (Thompson et al., 2015b). Interestingly, we faced some push-back during this multidisciplinary project, with colleagues having trouble categorising her work (as it "did not seem to fit" within a geology nor a geography degree). We persevered and continued the work through a postdoctoral fellowship focussing on hazard maps for Taranaki Mounga in New Zealand (Clive et al., 2021). I am so pleased that nowadays such cross-disciplinary studies are becoming more common, and people with skills at the disciplinary interface, such as Mary Anne, are highly valued.

A major highlight of my career over the past 10 years has been working with colleagues within the IAVCEI Working Group on Hazard Mapping (Figure 1B), which Eliza Calder and I set up in 2014. The aim of this initiative was to undertake a comprehensive review of past and current volcanic hazard mapping practices and associated lessons learned through a series of workshops and related initiatives with volcanologists and stakeholders interested in volcanic hazard maps. Nine workshops, one major database (the Volcanic Hazard Maps Database https://volcanichazardmaps.org) and two publications (Lindsay et al., 2023a; Ogburn et al., 2023) later, we are still going strong. We are on track to publish the culmination of our efforts, the open access '*IAVCEI Companion to Volcanic Hazard Maps and Map Making: Considerations drawn from international community experience*' next year. This slow-burn project has been a labour of love, as all participants are self-funded (with support for our activities from our respective institutions). It has been incredibly rewarding, especially to see some of the insights gained through our workshops making their way into the development of operational volcanic hazard maps, for example, through the Framework for Volcanic Hazard Mapping for Aotearoa New Zealand being developed by Danielle Charlton at GNS Science.

Distributed volcanism in Auckland and Arabia

In 2006 I received an EQC-funded research fellowship at UoA to establish a programme of work in volcanic hazards. It was challenging returning to work with two small, very active boys under five, and I distinctly remember realising one day that I had just given a lecture unawares that the back of my shirt was covered in stickers. It is all a bit of a blur now, a feeling I am sure other working mums will be familiar with!

I remained on 1–2-year fixed term contracts for several years until my role was made permanent in 2011 and I moved into the (now) School of Environment. I decided to focus my research on the Auckland Volcanic Field (AVF), so that I would not have to travel for long periods away from home while my children were small. During 2006 and 2007 I led discussions about establishing a comprehensive research project focussed on the AVF, and the resultant Determining Volcanic Risk in Auckland (DEVORA) Programme was launched in 2008 (Lindsay et al., 2023b under review). I co-lead DEVORA, alongside a colleague from GNS Science (initially Gill Jolly, then Graham Leonard) with long-term stable funding provided by Toka Tū Ake EQC (Earthquake Commission) and Auckland Council. In 2010 the work being carried out within DEVORA caught the eye of volcanologist Mohammed Rashad Moufti in Saudi Arabia, which led to a collaboration between the King Abdulaziz University (KAU), Kingdom of Saudi Arabia, and UoA, which we named the VORISA (Volcanic Risk in Saudi Arabia) project. That project explored volcanism in the northern part of Harrat Rahat, a distributed volcanic field in Saudi Arabia and ran for 3 years (2011–2013). Colleagues from Massey and Canterbury universities were also involved, and the project supported two PhD students and postdoctoral fellow Kate Kenedi (now Lewis), who was instrumental in supporting me with project management.

My strong interest in volcanic hazard and risk assessment in monogenetic volcanic fields has meant that many of my doctoral students have been in some way involved with research into intraplate basaltic magmas and their hazards. Lucy McGee worked on the petrogenesis of Auckland basalts (McGee et al., 2012; McGee et al., 2013; McGee et al., 2015a; McGee et al., 2015b) and current PhD student Elaine Smid is building on this work by exploring the volatile content of Auckland magmas to infer ascent rates and degassing characteristics. Nico LeCorvec, Melody Runge (now Whitehead) and Daniel Bertin developed novel techniques to evaluate spatio-temporal patterns in monogenetic fields (LeCorvec et al., 2013a; LeCorvec et al., 2013b; LeCorvec et al., 2013c; Runge et al., 2014; Runge et al., 2015; Runge et al., 2016; Bertin et al., 2019). Hugo Murcia carried out a comprehensive study of volcanism in the northern part of Harrat Rahat, including lava flow morphology, eruption history, and hazard implications (Murcia et al., 2014; Murcia et al., 2015; Murcia et al., 2017).

Massey University-based PhD students Gabor Kereszturi and Javier Agustín-Flores carried out detailed volcanological studies of styles and sizes of past Auckland eruptions, informing likely magnitude, style and location of future eruptions (e.g., Kereszturi et al., 2012; Kereszturi et al., 2013; Agustín-Flores et al., 2014; Agustín-Flores et al., 2015a; Agustín-Flores et al., 2015b). A detailed cryptotephra investigation by Alexandra Zawalna Geer shed light on how often Auckland has been impacted by tephra in the Holocene (Zawalna-Geer et al., 2016), and interrogation of ambient noise recorded on Auckland seismometers allowed Josiah Ensing to identify crustal structures (Ensing et al., 2017).

To aid planning for an Auckland eruption, Daniel Blake modelled the potential impacts of an eruption on Auckland's transportation network, including roads (Blake et al., 2017a; Blake et al., 2017b). Sophia Tsang focused on lava flow hazard and crisis management and explored the impacts of lava on buried infrastructure (Tsang et al., 2019; Tsang et al., 2020a; Tsang et al., 2020b; Tsang et al., 2020c). Alec Wild explored evacuation demand and the potential use of cost-benefit analysis in evacuation decision making (e.g., Wild et al., 2021; Wild et al., 2022; Wild et al., 2023).

Discussion: reflecting back and looking forward

Reflecting back on the conceptual framework shown in Figure 2, I believe the research carried out by my students and me has improved understanding of: magnitude-frequency relationships and hazards to expect in the Andes, Antilles, Auckland and Arabia; how elements of society are vulnerable to specific hazards such as lava flows and tephra; and how communication of hazard and risk information affects peoples' understanding of messages and their behaviour. Collectively this research can inform measures (such as hazard maps, monitoring networks, evacuation plans) to reduce societal vulnerability to volcanic eruptions and thus reduce volcanic risk.

In this contribution I have focussed on the work carried out by my PhD students, to make the point that "my success is not mine alone but based on the success of many". Whilst I acknowledge that academic publications are just one metric of a career, they do provide a useful illustration of the extent to which my success has been supported by my research students. Of my 99[2] peer-reviewed journal articles to date, 56 (~57%) are with a student as a lead author. Of these student-led publications, 48 are from my doctoral students, representing almost half of all my publications. All 48 have been cited here as an acknowledgement of their importance to my career. Of course, I have worked on other projects and with other collaborators, and would like to also acknowledge all the Honours and Masters students, research assistants, colleagues, stakeholders and funders who have worked with me.

Finally, a word on other non-research related aspects of my career. A large part of my time these days is spent in various service roles, both internationally (I have had terms as the Editor-in-Chief of the Journal of Applied Volcanology and on the IAVCEI Executive Committee) and within my university (most recently as Associate Dean Research in the Faculty of Science). I enjoy these roles as they provide opportunities to be part of a team, and to introduce improvements to our academic ecosystem. I also teach, typically into first year geology courses and postgraduate geohazard courses. In terms of my research, I am still enjoying forging ahead with applied volcanology, and am particularly excited about the work of my current PhD student Sylvia Tapuke and postdoctoral fellow Kate Mauriohooho, who are exploring the interface between volcanology and Mātauranga Māori (Māori knowledge). Alongside this I am learning te reo Māori and reflecting on the long-lasting damaging effects on Māori of settler colonialism in Aotearoa, which includes reflecting on my own positionality as a pākehā (New Zealander of European descent). I continue to be on an interesting journey, and leave you with the thought that sometimes, the unexpected journeys end up being the most interesting!

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

2 So awesome that this article, if published, will be my 100th!

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

JL: Writing–original draft.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Agustín-Flores, J., Németh, K., Cronin, S. J., Lindsay, J. M., and Kereszturi, G. (2015a). Shallow-seated explosions in the construction of the Motukorea tuff ring (Auckland, New Zealand): evidence from lithic and sedimentary characteristics. *J. Volcanol. Geotherm. Res.* 304, 272–286. doi:10.1016/j.jvolgeores.2015.09.013

Agustín-Flores, J., Németh, K., Cronin, S. J., Lindsay, J. M., and Kereszturi, G. (2015b). Construction of the north head (maungauika) tuff cone: a product of surtseyan volcanism, rare in the auckland volcanic field, New Zealand. *Bull. Volcanol.* 77 (2), 11. doi:10.1007/s00445-014-0892-9

Agustín-Flores, J., Németh, K., Cronin, S. J., Lindsay, J. M., Kereszturi, G., Brand, B. D., et al. (2014). Phreatomagmatic eruptions through unconsolidated coastal plain sequences, Maungataketake, Auckland Volcanic Field (New Zealand). *J. Volcanol. Geotherm. Res.* 276, 46–63. doi:10.1016/j.jvolgeores.2014.02.021

Bertin, D., de Silva, S. L., Lindsay, J. M., Cronin, S., Caffe, P. J., Connor, C. B., et al. (2023). Magmatic addition rates differentiate periods of steady-state versus flare-up magmatism in the Central Andean arc. *Commun. Earth Environ.* 4, 75. doi:10.1038/s43247-023-00744-2

Bertin, D., Lindsay, J. M., Becerril, L., Cronin, S. J., and Bertin, L. J. (2019). MatHaz: a Matlab code to assist with probabilistic spatio-temporal volcanic hazard assessment in distributed volcanic fields. *J. Appl. Volcanol.* 8, 4. doi:10.1186/s13617-019-0084-6

Bertin, D., Lindsay, J. M., Cronin, S. J., de Silva, S. L., Connor, C., Caffe, P. J., et al. (2022). Probabilistic volcanic hazard assessment of the 22.5–28°S segment of the central volcanic zone of the Andes. *Front. Earth Sci. Volcanol.* 10, 875439. doi:10.3389/feart.2022.875439

Blake, D., Wilson, T., Cole, J., Deligne, N., and Lindsay, J. (2017b). Impact of volcanic ash on road and airfield surface skid resistance. *Sustainability* 9 (8), 1389. doi:10.3390/su9081389

Blake, D. M., Deligne, N. I., Wilson, T. M., Lindsay, J. M., and Woods, R. (2017a). Investigating the consequences of urban volcanism using a scenario approach II: insights into transportation network damage and functionality. *J. Volcanol. Geotherm. Res.* 340, 92–116. doi:10.1016/j.jvolgeores.2017.04.010

Clive, M. A., Lindsay, J. M., Leonard, G. S., Lutteroth, C., Bostrom, A., and Corballis, P. (2021). Volcanic hazard map visualisation affects cognition and crisis decision-making. *Int. J. Disaster Risk Reduct.* 55, 102102. doi:10.1016/j.ijdrr.2021.102102

Constantinescu, R., Hopulele-Gligor, A., Connor, C. B., Bonadonna, C., Connor, L. J., Lindsay, J. M., et al. (2021). The radius of the umbrella cloud helps characterize large explosive volcanic eruptions. *Commun. Earth Environ.* 2, 3. doi:10.1038/s43247-020-00078-3

Constantinescu, R., White, J. T., Connor, C. B., Hopulele-Gligor, A., Charbonnier, S., Thouret, J.-C., et al. (2022). Uncertainty quantification of eruption source parameters estimated from tephra fall deposits. *Geophys. Res. Lett.* 49, e2021GL097425. doi:10.1029/2021GL097425

Ensing, J. X., van Wijk, K., and Spörli, K. B. (2017). Probing the subsurface of the Auckland Volcanic Field with ambient seismic noise. *N. Z. J. Geol. Geophys.* 60, 341–352. doi:10.1080/00288306.2017.1337643

Haynes, K., Barclay, J., and Pidgeon, N. (2007). Volcanic hazard communication using maps: an evaluation of their effectiveness. *Bull. Volcanol.* 70, 123–138. doi:10.1007/s00445-007-0124-7

Howe, T. M., Lindsay, J. M., and Shane, P. (2015a). Evolution of young andesitic–dacitic magmatic systems beneath Dominica, Lesser Antilles. *J. Volcanol. Geotherm. Res.* 297, 69–88. doi:10.1016/j.jvolgeores.2015.02.009

Howe, T. M., Lindsay, J. M., Shane, P., Schmitt, A. K., and Stockli, D. F. (2014). Re-evaluation of the Roseau Tuff eruptive sequence and other ignimbrites in Dominica, Lesser Antilles. *J. Quat. Sci.* 29 (6), 531–546. doi:10.1002/jqs.2723

Howe, T. M., Schmitt, A. K., Lindsay, J. M., Shane, P., and Stockli, D. F. (2015b). Time scales of intra-oceanic arc magmatism from combined U-Th and (U-Th)/He zircon geochronology of Dominica, Lesser Antilles. *Geochem. Geophys. Geosystems* 16 (2), 347–365. doi:10.1002/2014GC005636

Joseph, E. P., Fournier, N., Lindsay, J. M., and Fischer, T. P. (2011). Gas and water geochemistry of geothermal systems in Dominica, Lesser Antilles island arc. *J. Volcanol. Geotherm. Res.* 206 (1-2), 1–14. doi:10.1016/j.jvolgeores.2011.06.007

Joseph, E. P., Fournier, N., Lindsay, J. M., Robertson, R., and Beckles, D. M. (2013). Chemical and isotopic characteristics of geothermal fluids from Sulphur Springs, Saint Lucia. *J. Volcanol. Geotherm. Res.* 254, 23–36. doi:10.1016/j.jvolgeores.2012.12.013

Kanakiya, S., Adam, L., Rowe, M. C., Esteban, L., Lerner, G. A., and Lindsay, J. M. (2022). Petrophysical and elastic properties of altered lavas from Mt. Taranaki: implications for dome stability. *J. Volcanol. Geotherm. Res.* 432, 107693. doi:10.1016/j.jvolgeores.2022.107693

Kanakiya, S., Adam, L., Rowe, M. C., Lindsay, J. M., and Esteban, L. (2021a). The role of tuffs in sealing volcanic conduits. *Geophys. Res. Lett.* 48, e2021GL095175. doi:10.1029/2021GL095175

Kanakiya, S., Turner, G. M., Rowe, M. C., Adam, L., and Lindsay, J. M. (2021b). High remanent magnetization measured in hydrothermally altered lavas. *Geophys. Res. Lett.* 48, e2021GL095732. doi:10.1029/2021GL095732

Kereszturi, G., Németh, K., Cronin, S. J., Agustín-Flores, J., Smith, I. E. M., and Lindsay, J. (2013). A model for calculating eruptive volumes for monogenetic volcanoes - implication for the Quaternary Auckland Volcanic Field, New Zealand. *J. Volcanol. Geotherm. Res.* 266, 16–33. doi:10.1016/j.jvolgeores.2013.09.003

Kereszturi, G., Procter, J., Cronin, S. J., Nemeth, K., Bebbington, M., and Lindsay, J. (2012). LiDAR-based quantification of lava flow susceptibility in the City of Auckland (New Zealand). *Remote Sens. Environ.* 125, 198–213. doi:10.1016/j.rse.2012.07.015

Le Corvec, N., Bebbington, M. S., Lindsay, J. M., and McGee, L. E. (2013c). Age, distance, and geochemical evolution within a monogenetic volcanic field: analyzing patterns in the Auckland Volcanic Field eruption sequence. *Geochem. Geophys. Geosyst.* 14 (9), 3648–3665. doi:10.1002/ggge.20223

Le Corvec, N., Menand, T., and Lindsay, J. (2013b). Interaction of ascending magma with pre-existing crustal fractures in monogenetic basaltic volcanism: an experimental approach. *J. Geophys. Research: Solid Earth* 118 (3), 968–984. doi:10.1002/jgrb.50142

Le Corvec, N., Spörli, K. B., Rowland, J., and Lindsay, J. (2013a). Spatial distribution and alignments of volcanic centers: clues to the formation of monogenetic volcanic fields. *Earth-Science Rev.* 124, 96–114. doi:10.1016/j.earscirev.2013.05.005

Lindsay, J. M., Charlton, D., Clive, M. A., Bertin, D., Ogburn, S., Wright, H., et al. (2023a). The diversity of volcanic hazard maps around the world: insights from map makers. *J. Appl. Volcanol.* 12, 8. doi:10.1186/s13617-023-00134-5

Lindsay, J. M., de Silva, S., Trumbull, R., Emmermann, R., and Wemmer, K. (2001a). La Pacana caldera, N. Chile: a re-evaluation of the stratigraphy and volcanology of one of the world's largest resurgent calderas. *J. Volcanol. Geotherm. Res.* 106 (1-2), 145–173. doi:10.1016/S0377-0273(00)00270-5

Lindsay, J. M., Robertson, R., Shepherd, J., and Ali, S. (2005c). *Volcanic Hazard Atlas of the Lesser Antilles*. Trinidad and Tobago: The Seismic Research Unit, University of the West Indies, 279.

Lindsay, J. M., and Robertson, R. E. A. (2018). Integrating volcanic hazard data in a systematic approach to develop volcanic hazard maps in the lesser Antilles. *Front. Earth Sci.* 6. doi:10.3389/feart.2018.00042

Lindsay, J. M., Shepherd, J. B., and Wilson, D. (2005b). Volcanic and scientific activity at kick'em jenny submarine volcano 2001-2002: implications for volcanic hazard in the southern grenadines, lesser Antilles. *Nat. Hazards* 34 (1), 1–24. doi:10.1007/s11069-004-1566-2

Lindsay, J. M., Smid, E. R., Balfour, N., Deligne, N., Doherty, A., Hall, A., et al. (2023b). *The Determining Volcanic Risk in Auckland (DEVORA) Research Programme: a transdisciplinary approach to address the challenge of distributed volcanism in an urban environment*. Under review for the USGS Professional Paper on Distributed Volcanism.

Lindsay, J. M., Stasiuk, M. V., and Shepherd, J. B. (2003). Geological history and potential hazards of the late-Pleistocene to Recent Plat Pays volcanic complex, Dominica, Lesser Antilles. *Bull. Volcanol.* 65 (2-3), 201–220. doi:10.1007/s00445-002-0253-y

Lindsay, J. M., Trumbull, R. B., Schmitt, A. K., DeSilva, S. L., and Siebel, W. (2001b). Magmatic evolution of the La Pacana Caldera system, Central Andes, Chile: compositional variation of two cogenetic, large volume felsic ignimbrites. *J. Petrology* 42 (3), 459–486. doi:10.1093/petrology/42.3.459

Lindsay, J. M., Trumbull, R. B., Schmitt, A. K., Stockli, D. F., Shane, P. A., and Howe, T. M. (2013). Volcanic stratigraphy and geochemistry of the Soufriere Volcanic Centre, Saint Lucia with implications for volcanic hazards. *J. Volcanol. Geotherm. Res.* 258, 126–142. doi:10.1016/j.jvolgeores.2013.04.011

Lindsay, J. M., Trumbull, R. B., and Siebel, W. (2005a). Geochemistry and petrogenesis of late pleistocene to recent volcanism in southern Dominica, lesser Antilles. *J. Volcanol. Geotherm. Res.* 148 (3-4), 253–294. doi:10.1016/j.jvolgeores.2005.04.018

Lindsay, J. M., Worthington, T. J., Smith, I. E. M., and Black, P. M. (1999). Geology, petrology, and petrogenesis of Little barrier island, hauraki gulf, New Zealand. *N. Z. J. Geol. Geophys.* 42 (2), 155–168. doi:10.1080/00288306.1999.9514837

McGee, L. E., Millet, M.-A., Beier, C., Smith, I. E. M., and Lindsay, J. M. (2015a). Mantle heterogeneity controls on small-volume basaltic volcanism. *Geology* 43 (6), 551–554. doi:10.1130/G36590.1

McGee, L. E., Millet, M.-A., Beier, C., Smith, I. E. M., and Lindsay, J. M. (2015b). *Reply to: 'Mantle heterogeneity controls on small-volume basaltic volcanism - comment'*. Geology FORUM. doi:10.1130/G37100Y.1

McGee, L. E., Millet, M.-A., Smith, I. E. M., Nemeth, K., and Lindsay, J. M. (2012). The inception and progression of melting in a monogenetic eruption: motukorea Volcano, the Auckland Volcanic Field, New Zealand. *Lithos* 155, 360–374. doi:10.1016/j.lithos.2012.09.012

McGee, L. E., Smith, I. E. M., Millet, M. A., Handley, H. K., and Lindsay, J. M. (2013). Asthenospheric control of melting processes in a monogenetic basaltic system: a case study of the Auckland volcanic field, New Zealand. *J. Petrology* 54 (10), 2125–2153. doi:10.1093/petrology/egt043

Murcia, H., Lindsay, J. M., Németh, K., Smith, I. E. M., Cronin, S. J., Moufti, M. R. H., et al. (2017). Geology and geochemistry of Late Quaternary volcanism in northern Harrat Rahat, Kingdom of Saudi Arabia: implications for eruption dynamics, regional stratigraphy and magma evolution. *Geol. Soc. Lond. Spec. Publ.* 446 (1), 173–204. doi:10.1144/SP446.2

Murcia, H., Németh, K., El-Masry, N. N., Lindsay, J. M., Moufti, M. R. H., Wameyo, P., et al. (2015). The Al-Du'aythah volcanic cones, Al-Madinah City: implications for volcanic hazards in northern Harrat Rahat, Kingdom of Saudi Arabia. *Bull. Volcanol.* 77 (6), 54. doi:10.1007/s00445-015-0936-9

Murcia, H., Németh, K., Moufti, M. R., Lindsay, J. M., El-Masry, N., Cronin, S. J., et al. (2014). Late Holocene lava flow morphotypes of northern Harrat Rahat, Kingdom of Saudi Arabia: implications for the description of continental lava fields. *J. Asian Earth Sci.* 84, 131–145. doi:10.1016/j.jseaes.2013.10.002

Ogburn, S. E., Charlton, D., Norgaard, D., Wright, H. M., Calder, E. S., Lindsay, J., et al. (2023). The volcanic hazard maps database: an initiative of the IAVCEI commission on volcanic hazards and risk. *J. Appl. Volcanol.* 12, 2. doi:10.1186/s13617-022-00128-9

Runge, M. G., Bebbington, M. S., Cronin, S. J., Lindsay, J. M., Kenedi, C. L., and Moufti, M. R. H. (2014). Vents to events: Determining an eruption event record from volcanic vent structures for the Harrat Rahat, Saudi Arabia. *Bull. Volcanol.* 76 (3), 804–816. doi:10.1007/s00445-014-0804-z

Runge, M. G., Bebbington, M. S., Cronin, S. J., Lindsay, J. M., and Moufti, M. R. (2015). Sensitivity to volcanic field boundary. *J. Appl. Volcanol.* 4, 22. doi:10.1186/s13617-015-0040-z

Runge, M. G., Bebbington, M. S., Cronin, S. J., Lindsay, J. M., and Moufti, M. R. (2016). Integrating geological and geophysical data to improve probabilistic hazard forecasting of Arabian Shield volcanism. *J. Volcanol. Geotherm. Res.* 311, 41–59. doi:10.1016/j.jvolgeores.2016.01.007

Sivarajan, S. P., Lindsay, J. M., Cronin, S. J., and Wilson, T. M. (2020). New Zealand farmer perceptions on pasture remediation and recovery following major tephra fall. *Australas. J. Disaster Trauma Stud.* 24 (2).

Storm, S., Schmitt, A. K., Shane, P., and Lindsay, J. M. (2014). Zircon trace element chemistry at sub-micrometer resolution for Tarawera volcano, New Zealand, and implications for rhyolite magma evolution. *Contributions Mineralogy Petrology* 167 (4), 1000. doi:10.1007/s00410-014-1000-z

Storm, S., Shane, P., Schmitt, A. K., and Lindsay, J. M. (2011). Contrasting punctuated zircon growth in two syn-erupted rhyolite magmas from Tarawera volcano: insights to crystal diversity in magmatic systems. *Earth Planet. Sci. Lett.* 301 (3-4), 511–520. doi:10.1016/j.epsl.2010.11.034

Storm, S., Shane, P., Schmitt, A. K., and Lindsay, J. M. (2012). Decoupled crystallization and eruption histories of the rhyolite magmatic system at Tarawera volcano revealed by zircon ages and growth rates. *Contrib. to Mineral. Petrol.* 163 (3), 505–519. doi:10.1007/s00410-011-0682-8

Thompson, M., Lindsay, J. M., and Gaillard, J. C. (2015b). The influence of probabilistic volcanic hazard map properties on hazard communication. *J. Appl. Volcanol.* 4 (1), 6. doi:10.1186/s13617-015-0023-0

Thompson, M. A., Lindsay, J. M., Sandri, L., Biass, S., Bonadonna, C., Jolly, G., et al. (2015a). Exploring the influence of vent location and eruption style on tephra fall hazard from the Okataina Volcanic Centre, New Zealand. *Bull. Volcanol.* 77 (5), 38. doi:10.1007/s00445-015-0926-y

Thompson, M. A., Lindsay, J. M., Wilson, T. M., Biass, S., and Sandri, L. (2017). Quantifying risk to agriculture from volcanic ashfall: a case study from the Bay of Plenty, New Zealand. *Nat. Hazards* 86 (1), 31–56. doi:10.1007/s11069-016-2672-7

Tsang, S. W. R., and Lindsay, J. M. (2020c). Lava flow crises in inhabited areas part I: lessons learned and research gaps related to effusive, basaltic eruptions. *J. Appl. Volcanol.* 9 (1), 9. doi:10.1186/s13617-020-00096-y

Tsang, S. W. R., Lindsay, J. M., Coco, G., and Deligne, N. I. (2020b). The influence of surficial features in lava flow modelling. *J. Appl. Volcanol.* 9, 6. doi:10.1186/s13617-020-00095-z

Tsang, S. W. R., Lindsay, J. M., Coco, G., Wysocki, R., Lerner, G. A., Rader, E., et al. (2019). The heating of substrates beneath basaltic lava flows. *Bull. Volcanol.* 81 (11), 68. doi:10.1007/s00445-019-1320-y

Tsang, S. W. R., Lindsay, J. M., Kennedy, B., and Deligne, N. (2020a). Thermal impacts of basaltic lava flows to buried infrastructure: workflow to determine the hazard. *J. Appl. Volcanol.* 9, 8. doi:10.1186/s13617-020-00098-w

Wild, A., Bebbington, M., Lindsay, J., and Charlton, D. (2021). Modelling spatial population exposure and evacuation clearance time for the Auckland Volcanic Field, New Zealand. *J. Volcanol. Geotherm. Res.* 416, 107282. doi:10.1016/j.jvolgeores.2021.107282

Wild, A. J., Bebbington, M. S., and Lindsay, J. M. (2022). Short-term eruption forecasting for crisis decision-support in the auckland volcanic field, New Zealand. *Front. Earth Sci.* 10, 893882. doi:10.3389/feart.2022.893882

Wild, A. J., Bebbington, M. S., Lindsay, J. M., and Deligne, N. (2023). Cost-benefit analysis for evacuation decision-support: challenges and possible solutions for applications in areas of distributed volcanism. *J. Appl. Volcanol.* 12, 7. doi:10.1186/s13617-023-00133-6

Zawalna-Geer, A., Lindsay, J. M., Davies, S., Augustinus, P., and Davies, S. (2016). Extracting a primary Holocene crytoptephra record from Pupuke maar sediments, Auckland, New Zealand. *J. Quat. Sci.* 31 (5), 442–457. doi:10.1002/jqs.2866