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Disproportionate impacts of the COVID-19 pandemic on early career researchers and disabled researchers in volcanology

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The COVID-19 pandemic has brought unprecedented challenges to researchers worldwide, and extensive studies have demonstrated that its impacts since March 2020 have been unequal, including across research discipline, gender, and career status. In 2023, as we navigate the post-pandemic times, questions persist regarding potential disparities and enduring effects faced by volcanology researchers, whose activities range from field work in remote areas to laboratory experiments and numerical modelling. In this study, we explore the multifaceted impacts of the pandemic on volcanology researchers through an online survey distributed globally from January to March 2023. Our survey findings reveal that a considerable fraction of volcanology researchers (44%–62%) face longer-term challenges from the pandemic that continue to impact their research, with a notably higher proportion among early career researchers (62%) and researchers with disabilities (76%). In addition, over half (52%) of all surveyed researchers indicated that they had left or considered leaving academia due to pandemic-related factors. A significantly higher proportion of disabled researchers (56%–70%) had left or considered leaving academia compared to researchers without disabilities (42%). Our findings underscore the pandemic's long-lasting and disproportionate impacts on early career and disabled volcanology researchers. We emphasis the need for concerted efforts by research organisations and funding bodies to mitigate the pandemic's enduring impacts, and stress the importance of making conferences accessible to support disabled researchers' participation. As the pandemic's long-lasting impacts ripple across the broader scientific community, the insights from this research can be used for fostering equitable practices and shaping policies beyond volcanology to other research disciplines.

KEYWORDS

COVID-19, post-pandemic, volcanology, disproportionate, gender, disability, EDI, ECR

1 Introduction

The COVID-19 pandemic emerged as an unprecedented global challenge, profoundly impacting scientific research since March 2020. While the pandemic necessarily prompted intense research efforts across the medical and life sciences (Riccaboni and Verginer, 2022), other research disciplines, such as physical, Earth, and environmental sciences, encountered considerable setbacks. For instance, disciplines that rely heavily on physical laboratories reported the largest decline in research time, in the range of 30%–40% below pre-pandemic levels (Myers et al., 2020). Scientists relying on research activities in the natural environment, such as *in situ* sampling, measurements, surveying and monitoring, faced significant obstacles in planning and conducting fieldwork due to travel restrictions for more than 2 years (Geib, 2020). Both laboratory closures and fieldwork disruptions impeded research progress in volcanology, a discipline inherently reliant on laboratory- and field-based observation and analysis, hindering understanding of volcanic processes and related hazards.

The pandemic has brought to light significant disparities in various research disciplines and among scientists of different demographics or backgrounds. The pandemic disproportionately affected women researchers (Cui et al., 2022; Myers et al., 2020; Korbel and Stegle, 2020; Squazzoni et al., 2020; Johnson et al., 2021; Liggett et al., 2023), under-represented racial minorities (Staniscuaski et al., 2021; Douglas et al., 2022), researchers with childcare responsibilities (Myers et al., 2020; Johnson et al., 2021; Krukowski et al., 2021), early career researchers (Fosci et al., 2020; Jackman et al., 2022; Liggett et al., 2023), and researchers with physical or mental health disabilities (Armitage and Nellums, 2020; Sarju, 2021; Douglas et al., 2022). The pronounced disruption experienced by these groups raises concerns as the impacts could potentially be long-lasting and the extent of such impacts remains uncertain (Johnson et al., 2021; Gao et al., 2021), with the possibility of exacerbating existing inequalities within the research community (Heo et al., 2022).

Gender and racial biases are prevalent within the field of volcanology. According to statistics provided by international and regional volcanology organisations such as the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), American Geophysical Union (AGU) Volcanology, Geochemistry and Petrology Section, and European Geosciences Union (EGU) Geochemistry-Mineralogy-Petrology-Volcanology Division, female researchers make up 31%–39% of the total membership while male researchers constitute 61%–67% (Kavanagh et al., 2022). Biases are particularly evident in the scarcity of women and researchers from the Global South in leadership positions within IAVCEI (Cas, 2022), as well as the under-representation of women, early career researchers, and non-native English speakers in the editorial boards of volcanology journals (Kavanagh et al., 2022). Women and under-represented minorities are given fewer opportunities to deliver talks and keynote lectures at conferences (Ford et al., 2019; Kavanagh et al., 2022), further limiting their visibility and impact in the field. Additionally, despite producing work of comparable quality to men, women's contributions are often less recognised through awards (Kavanagh et al., 2022). There is concern that the disproportionate impacts of the pandemic, especially affecting women and early career researchers, may exacerbate existing inequalities within the volcanology research community. While it will take time for volcanology research to fully recover to pre-pandemic levels, uncertainty lingers about potential long-term impacts of the pandemic, as there is a dearth of research investigating its specific challenges to volcanology researchers.

In our study, we explore the multifaceted impacts of the pandemic on volcanology researchers based on an online survey conducted from 25 January to 8 March 2023. The survey was distributed through volcanology research associations, inviting participation from past and present volcanology researchers worldwide, with the goal of documenting their experiences spanning 3 years from the onset of the pandemic. Our investigation probed various demographics and intersectionality of the pandemic's impacts on volcanology researchers. Due to limited sample sizes in certain categories, however, the focus of our study is on career stages, gender identities, and researchers with disabilities.

2 Methods

We designed an online survey in the English language to examine the positive and negative impacts of the COVID-19 pandemic on the research experience of volcanology researchers (self-identified). The survey was targeted towards researchers at any career stage from any country, working within academic or non-academic settings. The online survey was distributed on 25 January 2023 via email invitations through volcanology research associations and mailing lists, including the international Volcano Listserv, the Volcanic and Magmatic Studies Group (United Kingdom), and the Network for African Volcanologists.

The survey consisted of 33 questions including sections on academic background, demographic information, caring responsibilities, and the effects of the COVID-19 pandemic on the participants' research experience (Supplementary Material S1). We asked the respondents to report their career status both at the start of the pandemic and at the time of completing the survey, to compare responses across career stages. We designed a set of numerical rating questions on 22 different research-related aspects to explore the impacts of the pandemic using a scale of 0–10 (where 0 refers to no impact and 10 refers to high impact, discussed in Section 3.2). We also asked six open-ended questions to explore participants' opinions and experiences. Two questions were about the benefits and greatest challenges experienced by participants in their research due to the COVID-19 pandemic (discussed in Section 3.3). If participants indicated facing longer-term challenges affecting their research work, we prompted them to describe the longer-term challenges in one open-ended question (discussed in Section 3.4). Subsequent to the rating questions regarding the support they received during the pandemic, we presented two open-ended questions to solicit descriptions of the support received. We did not discuss the results regarding the support received considering the diverse background in career stages and workplace settings. However, the participants' responses regarding this aspect have been included in Supplementary Material S3. If participants indicated that they

have considered leaving or have left academia, we asked them to describe in the sixth open-ended question how the pandemic affected their career plans (discussed in Section 3.4).

We utilised the Qualtrics software to develop the survey and collect responses. We set up data collection settings in Qualtrics that automatically anonymised participants to ensure the confidentiality of their responses. Prior to commencing the research, we obtained ethical approval from the University of Cambridge Department of Geography Ethics Review Group (see Ethics Declaration in Supplementary Material S1).

We used descriptive statistics to present the findings of the survey. To compare survey responses across different categories, we employed the non-parametric Mann-Whitney U test and reported significant test findings with a p-value < 0.05. Additionally, we conducted a thematic analysis of the free-text responses using Atlas.ti Mac (version 23.1.0) to gain a deeper understanding of the recurring themes of researchers' experiences during the pandemic. Thematic analysis has been a widely recognised and established method in the literature (Braun and Clarke, 2006; Kiger and Varpio, 2020), which provides a concise summary of the prevalent themes among the survey participants. The analysis process started with a familiarisation stage to thoroughly read and re-read the collected data to become immersed in its content. Following this immersion, we conducted an initial coding phase systematically across the entire dataset, which generated initial codes to identify data segments that are relevant to the study's focus. Subsequently, these codes were categorised and refined, allowing for the emergence of potential themes. The identification of themes was an iterative process, conducted through discussions among the research team to evaluate and re-evaluate the data to ensure coherence and accuracy in theme development. To ascertain the relevance of these identified themes to our research objectives, we continually referred to the original data, verifying the consistency and resonance of the themes within the broader context of the study. Our goal is to ensure that the themes accurately represent the dataset and effectively address the research questions.

3 Results

3.1 Overview of survey participants

We received a total of 160 responses, of which 131 signed the consent form. Cross-referencing this with the membership data of IAVCEI, which had 937 members as of 2021, reveals a survey response rate of approximately 14%. In this study, we analysed only the survey responses with signed consent, and those responses without consent were discarded. We collected demographic data from the participants to identify possible impacts of the pandemic on particular demographic groups (Supplementary Figure S1). The majority of our study participants consist of early career researchers (ECRs, with <10 years of research experience since terminal degree, 69%), followed by mid career researchers (MCRs, 10–15 years of research experience since terminal degree, 24%), and advanced career researchers (ACRs, >15 years of experience since terminal degree, 7%). When the pandemic started, approximately 84% of the participants worked in university/research institutes, 5% in industry, 8% in civil service and 2% in other settings. At the time of the survey, approximately 78% of the participants worked in university/research institutes, 8% in industry, 8% in civil service and 6% in other settings. Geographically, the sample size of this survey is primarily composed of participants working or studying in Europe (48%) and North America (31%). Other participants are from Australia and New Zealand (9%), Asia (3%), Central and South America (2%), Africa (2%), and 5% did not mention. Approximately 42% of the survey participants identify as cisgender male, 47% as cisgender female, 2% as non-binary, 1% as gender fluid/queer, and 4% prefer not to say. Due to the limited sample size within the non-binary and gender minority groups, our gender-related analysis is restricted to the cisgender groups of male and female. About 8% and 15% of the participants reported having a physical or mental health disability, respectively.

3.2 Disparities of the pandemic's impact across volcanology researchers

We categorise the responses to the 22 research-related aspects into three areas: 1) Research Methods and Processes, 2) Research Management and Other Categories, and 3) Research Communication.

Our findings suggest that the pandemic has had a disproportionate impact on volcanology researchers with disabilities (Figure 1A, Supplementary Figure S2). Researchers with physical or mental health disabilities reported, with statistical significance, at least 2 ratings higher of impact experienced compared to researchers without disabilities for various aspects including research progress, research direction, and hiring of students or staff.

In addition, the impacts of the pandemic across different career stages are unequal (Figure 1B, Supplementary Figure S3). Notably, ECRs and MCRs described a much greater impact on paper publication, with a median rating 2 to 3 times higher than that of ACRs. ECRs also reported a more significant impact on job and study applications, as well as research training, compared to MCRs and ACRs. We attribute this to the fact that many ECRs do not hold permanent positions, which makes them more vulnerable during periods of funding uncertainty and reduced job opportunities. On the contrary, MCRs and ACRs reported significantly greater ratings than ECRs (2–2.5 on the absolute scale) of the pandemic's impact on the time available for research due to teaching responsibilities. This aspect received one of the highest median ratings by MCRs and ACRs among all the aspects considered.

Women researchers with caring responsibilities reported a substantially higher impact (6.61, $n = 18$) on their research capacity compared to male researchers with caring responsibilities (5.85, $n = 27$) (Supplementary Table S2); however, we did not find any statistical significance between the gender subgroups of researchers with and without caring responsibilities. Researchers caring for young dependents [e.g., pre-school or primary school child(ren)] reported a higher impact on their capacity to work (7.45 for women and 6.71 for men) than those caring for secondary school/college children or other adult dependents (6.75 for women and 4 for men), but this difference is not statistically significant. A comparison of all

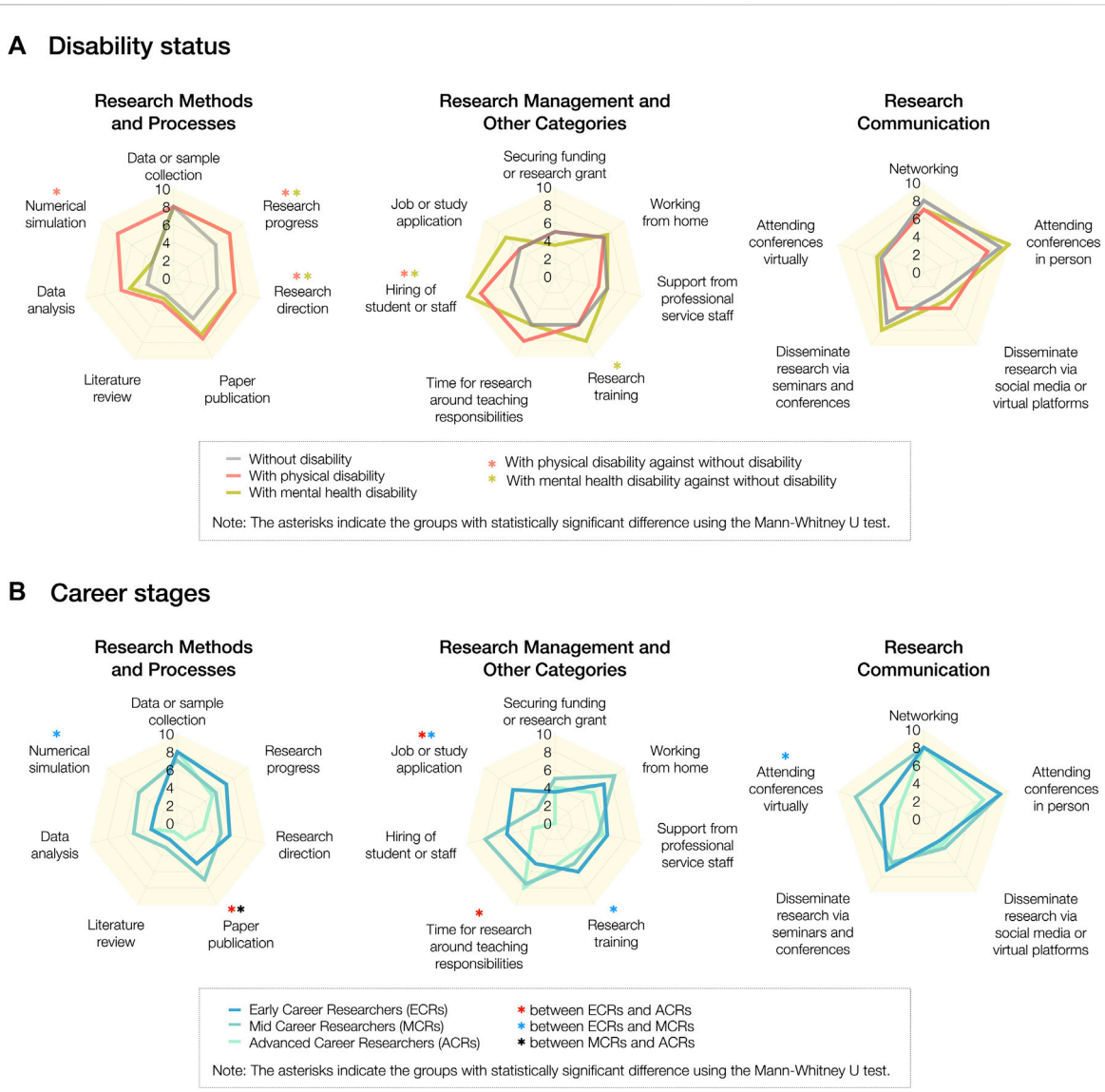

FIGURE 1
Radar plots showing the impact of the COVID-19 pandemic on different aspects of research as rated by volcanology researchers, categorised by **(A)** disability status and **(B)** career stages. The radar plots display the median ratings on a scale of 0–10, where 0 denotes "not impacted" and 10 represents "highly impacted." The asterisks denote the groups that are statistically different at the 95% confidence level using a two-sided Mann-Whitney U test.

research-related aspects as rated by participants categorised by gender (Supplementary Figure S4) shows that there is no statistical significance observed in the majority of research aspects. Our results reveal differences in reported impact between male and female researchers, suggesting that gender may be a moderating factor. However, the restricted sample size in this study might have limited our ability to draw statistically significant results.

3.3 Benefits and challenges encountered by volcanology researchers

To gain insights into the impact of the COVID-19 pandemic on volcanology researchers, we asked the participants two open-ended questions about the benefits and greatest challenges in their research due to the pandemic. Figure 2 shows the prominent themes emerging from the reported benefits and challenges. Our analysis revealed a higher prevalence of reported challenges (102 responses, 26 aspects) compared to reported benefits (87 responses, 13 aspects). Notably, a number of participants (10 mentions) explicitly conveyed that they had not experienced any positive impact on their research.

The most frequently mentioned challenges included reduced networking and connection with people (35 mentions), the inability to conduct fieldwork (28 mentions), and the closure of laboratories and offices leading to a backlog of experiments (27 mentions). Other challenges encompassed delays in research progress (14 mentions), the inability to attend conferences (11 mentions), feelings of isolation (10 mentions), mental health concerns (10 mentions), and childcare responsibilities (8 mentions), among others.

On the other hand, work from home emerged as a prevalent benefit (29 mentions), providing researchers with increased

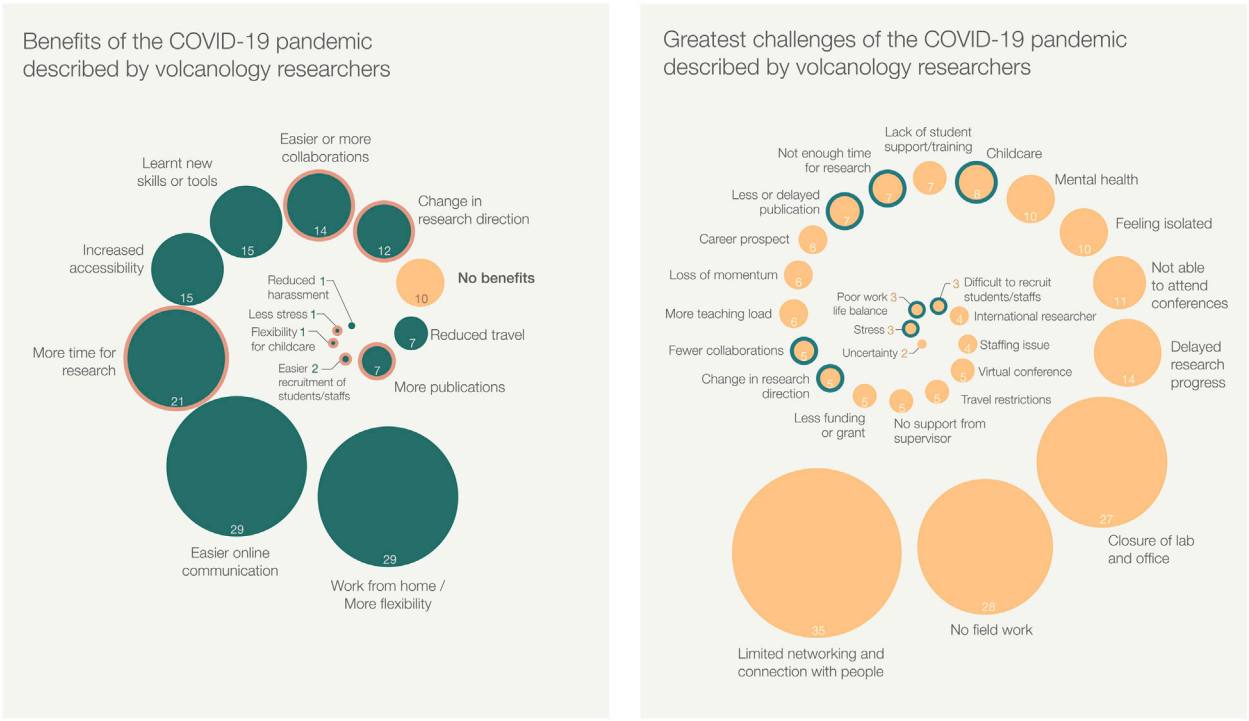

FIGURE 2
The benefits (green) and greatest challenges (orange) of the COVID-19 pandemic described by volcanology researchers, ranked by the frequency of mentions (annotated in or beside the circles) as represented by the size of the circles. The recurring aspects mentioned in both benefits and challenges are highlighted by the bordered circles.

flexibility and the opportunity to allocate more time for research activities. The absence of commuting and the ability to tailor their work schedule to their personal needs were perceived as positive aspects.

> "Working from home saved time on commuting that could be spent on research." (ECR, United States)

> "It is now acceptable to work from home so we do not have to find afterwork child care." (ECR, United Kingdom)

However, the blurring of boundaries between work and personal life (2 mentions), coupled with the challenges of creating a productive work environment at home, were also mentioned as potential drawbacks, especially for researchers with childcare responsibilities (8 mentions). In fact, time for research was described in both benefits and challenges. A large fraction of those who perceived it as a benefit are ECRs (13 mentions), as compared to MCRs (5 mentions) and ACRs (3 mentions). The responses suggested that maintaining a healthy work-life balance and setting clear boundaries became crucial in navigating the new remote work landscape, but that this was almost impossible to achieve for many researchers during the pandemic.

> "Trying (usually unsuccessfully) to do research from home while also teaching and caring for school-aged kids. Research was basically impossible." (MCR, United States)

Easier online communication and virtual events (29 mentions) were perceived as positive outcomes of the pandemic by researchers across all career stages. Researchers appreciated the convenience of attending events remotely, which increased accessibility (15 mentions, of which 8 are ECRs) and reduced the need for extensive travel (7 mentions, of which 5 are MCRs). The virtual format allowed for broader participation, enhancing accessibility and enabling researchers from different countries to engage in conferences and workshops that they might not have been able to attend in person, and fostering international collaboration.

> "Northern hemisphere workshops and lecture series are now much more accessible via online platforms." (ECR, Japan)

> "Larger access to online events (conferences, courses and seminars) that otherwise would not have been streamed on the web, reducing also the necessity of travelling even in post pandemic times." (ECR, Germany)

> "...some collaborations with non-local colleagues has become easier" (MCR, United States).

However, some researchers also highlighted certain drawbacks associated with virtual conferences, expressing concerns about the lack of interactions and informal conversations compared to in-person conferences and workshops (5 mentions).

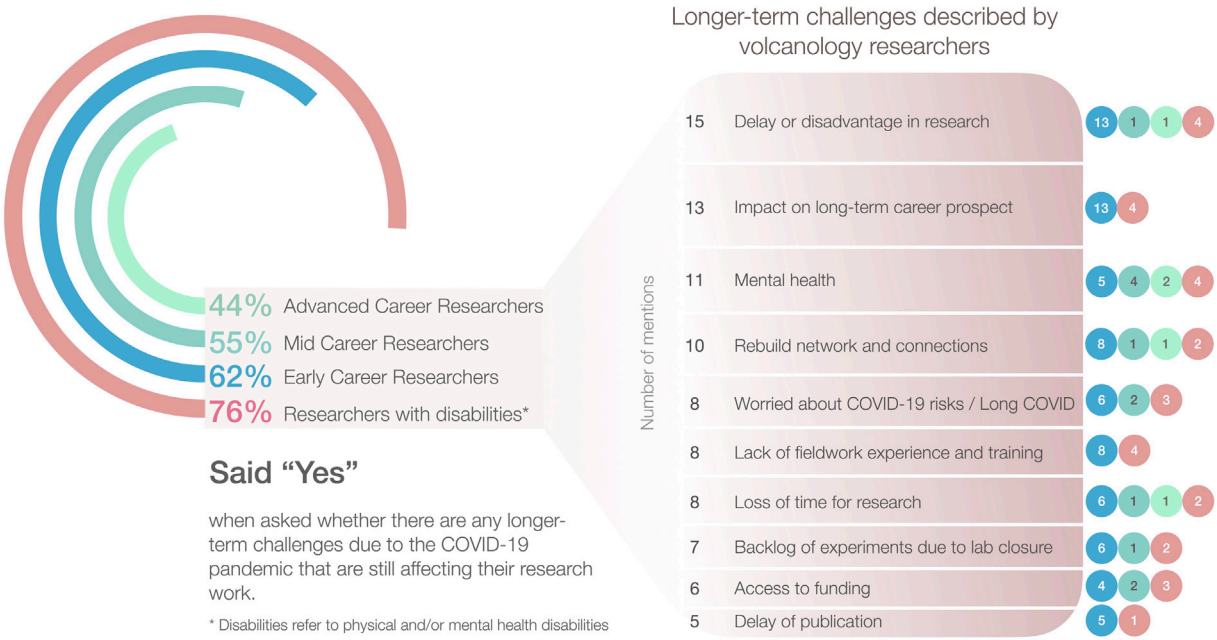

FIGURE 3
Summary of the percentages of researchers (left), categorised by career stage and disability status, who reported that they are still facing longer-term challenges due to the COVID-19 pandemic. The aspects of longer-term challenges described by the participants (right) are ranked by the number of mentions. The circles to the right of each aspect corresponds to the breakdown of the number of mentions by each participant group. Note: We did not provide a definition of longer-term challenges in the survey; instead, we allowed the participants to describe what this concept means to them.

> "...participation in conferences was largely negatively affected in that the socialisation or networking aspect of virtual conferences was significantly diminished." (ECR, United States)

These informal exchanges often play a vital role in fostering collaborations, exchanging ideas, and building professional networks. The absence of these interactions in virtual settings was seen as a limitation, as researchers missed the spontaneous discussions and networking opportunities that physical conferences provide. The findings underscore the complex nature of the impacts of the pandemic. While they offered advantages such as increased accessibility and time for research, researchers also acknowledged the importance of interpersonal connections and informal discussions that may be compromised in virtual settings.

3.4 Longer-term challenges of the pandemic on volcanology researchers

We broadly define longer-term challenges as the enduring impacts of the pandemic that persist even after the restrictions were lifted, and work and social life returned to pre-pandemic levels. A significant percentage of volcanology researchers, spanning all career stages, continue to struggle with longer-term challenges stemming from the pandemic in relation to their research (Figure 3). Of particular concern is the higher prevalence of these challenges among researchers with disabilities (76%) and ECRs (62%), in contrast to researchers without disabilities (53%), MCRs (55%), and ACRs (44%). We identified and ranked the most mentioned longer-term challenges described by researchers in Figure 3. Among these challenges, the most frequently cited is delay or disadvantage in research. Respondents attributed this to the restrictions on fieldwork travel imposed by the pandemic, as well as the closure of laboratories and offices, resulting in a backlog of fieldwork and experiments awaiting completion. There are several challenges that are unique to ECRs wishing to progress while remaining in volcanology research, including long-term career prospects, lack of fieldwork experience and training, and delay in publications. Childcare emerges as a long-term challenge due to increased childcare responsibilities during the pandemic, resulting in reduced and delayed research progress. We speculate that this may be attributed to the limited availability and affordability of childcare services throughout the pandemic.

We find that nearly half of the volcanology researchers surveyed (48%) have either left academia or considered leaving academia due to the COVID-19 pandemic, with 80% of them being ECRs (Figure 4). More notably, when examining the population of researchers with physical or mental health disabilities, 56%–70% of them have considered leaving or left academia. This percentage range is significantly higher compared to researchers without disabilities (42%). When asked how the pandemic has influenced their career plans, researchers mentioned that the pandemic has prompted them to consider alternative careers due to lack of stability, delays and challenges in research, and loss of motivation. Among the surveyed volcanology researchers who have either left academia or considered doing so, 5% mentioned that they had considered leaving academia before the pandemic, but the pandemic made

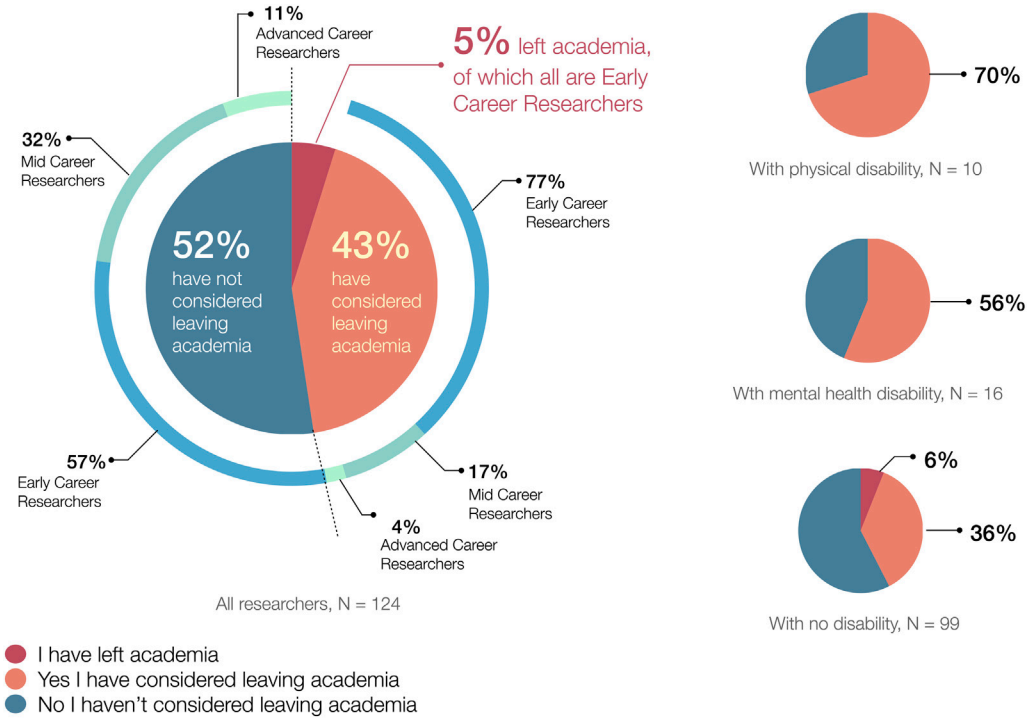

FIGURE 4
Pie charts showing the percentages of survey participants who have left or considered leaving academia, categorised by career stage and disability status.

the downsides of academia more pronounced and accelerated their decision. Researchers working in foreign institutes expressed concern over travel restrictions and a desire to relocate back to their home country to be closer to their families.

4 Discussion

4.1 Longer-term impacts of the pandemic on volcanology researchers are unequal

A core objective of our study is to provide insights into the longer-term challenges that have surfaced because of the pandemic. Our findings indicate that a substantial portion of the surveyed volcanology researchers continue to contend with longer-term consequences of the pandemic (Figure 3). ECRs have faced significant challenges with their career prospects, experiencing delays in research and publication (Figures 1, 3). Despite the loss of research time and research delay during the pandemic, there is an increase in publication pressure in academia following the pandemic (Mat Rifin and Danaee, 2022; Suart et al., 2022; Armond and Kakuk, 2023). Postgraduate students have encountered setbacks in their research careers due to the lack of training and research opportunities in fieldwork and laboratory settings, which are vital for advancing knowledge and continuing a research career in volcanology. Research groups heavily reliant on fieldwork and laboratory experiments are still dealing with a backlog of experiments, and the cancellation of fieldwork has resulted in delay in research progress. In addition, we have observed long-term mental health concerns among researchers across all career stages. These findings highlight the persistent impact of the pandemic on the wellbeing and research trajectories of volcanology researchers.

Our findings reveal a concerning trend, with a significant proportion of ECRs and disabled researchers considering leaving academia due to the challenges posed by the pandemic. This signals a potential loss from academia of talented individuals within these groups. The disproportionate impacts of the pandemic identified through our survey align with other studies, such as ECRs in Antarctic research (Liggett et al., 2023) and disabled researchers in science, technology, engineering, and mathematics (Douglas et al., 2022). We postulate that disabled researchers encounter various barriers that could exacerbate longer-term challenges posed by the pandemic. Such barriers may include physical and digital accessibility issues, alongside limited support and accommodations, affecting these researchers' ability to work effectively. Furthermore, for researchers with disabilities, exacerbation of physical or mental health issues during the pandemic, due to COVID-19 itself and/or to measures aimed at reducing coronavirus infection and transmission, may have impacted their productivity and overall research progress. Considering the pre-existing gender and racial inequalities within volcanology (Ford et al., 2019; Kavanagh et al., 2022), we speculate that the pandemic may have deepened the divides experienced by ECRs and disabled researchers who identify as women or belong to under-represented racial minorities. This could potentially intensify the longer-term challenges they encountered before the pandemic and continue to face in post-pandemic times.

The pandemic has also prompted researchers to re-evaluate their preference for working locations. As a consequence, we anticipate a potential decrease in the number of researchers willing to pursue academic positions outside of their home country in the foreseeable future, aligning with the prediction made by Myers et al. (2020). This shift in career aspirations highlights the profound and enduring influence of the pandemic on the geographical considerations of volcanology researchers.

4.2 Recommendations

By shedding light on the unique challenges and disparities faced by volcanology researchers, our goal is to inform effective practices and evidence-based strategies for international and regional volcanology organisations, as well as funding bodies and academic institutions, to promote resilience, equity, inclusivity and accessibility within the field of volcanology and beyond. We make four recommendations focused on financial support, career support, flexible working, and conference and workshop events.

4.2.1 Financial support

In light of the long-lasting nature of the pandemic's impacts, funding bodies should consider allocating hardship funds for the next 5 years to assist researchers of affected groups to overcome costs arising from the longer-term challenges of COVID-19, such as additional expenses related to cancelled fieldwork and backlogged laboratory experiments, and travel grants for attending conferences and academic visits. The volcanology research community would also benefit from an internationally collaborative community-based online repository/database which collates information on funding available from different sources. This could improve awareness of funding opportunities and potentially foster greater equity in the distribution of funds by increasing the diversity of applicants.

4.2.2 Career support

Career prospects represent a persistent challenge for ECRs (Figure 3). The enduring impacts of the pandemic on the career and research output of individual researchers should be recognised in the form of a COVID impact statement during processes such as study, grant or job applications, award selections and promotions. In addition, integrating equity and bias training for supervisors and executive committee members within volcanology organisations is recommended to ensure fair assessment and support of researchers across diverse work environments and backgrounds. To support ECRs in their careers, international and regional volcanology organisations should extend comprehensive career support initiatives and mentoring schemes for ECRs. A good example is the conference buddy scheme in the Volcanic and Magmatic Studies Group (United Kingdom) Annual Meeting, which pairs first-time attendees with more experienced researchers. Given the differential impact of the pandemic across different demographics, volcanology organisations should organise workshops involving various stakeholders (e.g., researchers, funding body representatives, academic/research institution directors) for open dialogue to identify strategies to mitigate specific challenges faced by researchers. These dialogues can be conducted through virtual platforms, or hosted within workshops integrated into volcanology conferences such as the IAVCEI General Assembly, providing a platform for diverse voices of volcanologists from universities, research organisations, and observatories. Furthermore, integrating mental health resources, counselling services, and stress management programs in academic environments (e.g., doctoral training programmes, research structures from individual research groups to department or university-wide structures) is essential, considering the mental health challenges exacerbated by the pandemic and the broader need for prioritising researchers' wellbeing. For instance, the fieldwork guideline developed by the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) offers a comprehensive framework dedicated to ensuring inclusivity, including considerations for mental wellbeing during fieldwork (COMET, 2023).

4.2.3 Flexible working arrangements

The COVID-19 pandemic has prompted researchers to re-evaluate their work-life balance and led to an increased acceptance of working from home, a practice that many researchers hope to maintain even in the post-pandemic times (Figure 2). Working from home is not equally beneficial to all researchers, in particular to those with childcare responsibilities (Figure 2), but Aczel et al., 2021 showed that a majority of researchers would prefer having the flexibility of remote working in post-pandemic times. This flexibility is an inclusive practice for researchers with disabilities and those concerned about contracting COVID and/or its long-term effects. On the other hand, ECRs with disabilities expressed concern that not being able to physically return to work may increase the risk of discrimination in hiring and funding (European Council of Doctoral Candidates and Junior Researchers, 2020). Another survey study showed that disabled people were more productive and have better wellbeing when working from home as they have more flexibility and are able to take short breaks (UNISON, 2020). To establish an inclusive working environment, institutions should accommodate flexible working arrangements in the post-pandemic times and offer equitable opportunities to those working in person and/or remotely (Taylor et al., 2022).

4.2.4 Conference and workshop events

Another good practice that has emerged during the pandemic is the adoption of hybrid (virtual and in-person) event formats (Figure 2). We strongly advocate for organisers of future conferences and workshops to offer hybrid events to contribute to equitable opportunities for individuals who may face challenges in travelling or prefer virtual attendance, such as under-represented researchers from low-income countries, disabled researchers, those with childcare responsibilities and those conscious about the climate impacts of travelling (Biggin, 2007).

Additionally, we emphasise the importance of measures in conferences and workshops to promote inclusion of researchers with disabilities, including those who suffer from long COVID. Researchers with physical disabilities encounter more obstacles when they are unable to travel, especially when the event is not hybrid. Allowing researchers with disabilities to deliver their presentations virtually or with accommodations should be a standard inclusive practice in future events. Events with in-

person components should comply with common accessibility standards (e.g., Special Interest Group on Accessible Computing, 2021; Joo et al., 2022). Organisers should involve equity, diversity and inclusion representatives in planning the event to ensure consideration of diverse needs and promotion of equitable access for all participants.

Furthermore, we recommend that event organisers prioritise the participation of ECRs to foster a supportive learning and networking environment and contribute to their career development. This can be achieved through practices such as offering invited or keynote presentations specifically dedicated to ECRs, diversifying keynote speakers to avoid recurrent invitations to the same individuals, and including at least one ECR to co-convene conference sessions. This has been demonstrated by the inclusion of the ECR Plenary in the IAVCEI General Assembly 2023, the involvement of student convenors in the AGU Fall Meeting 2023, and application of the Equity, Diversity and Inclusivity (EDI) session logo at the EGU General Assembly. The logo is added to sessions in the EGU listed programme to acknowledge diversity when the session convenors meet the three criteria emphasising diversity in gender, career stage, and geographic affiliation.

4.3 Limitations

We acknowledge that the impacts of the COVID-19 pandemic varied significantly across different countries, influenced by factors such as varying commencement times, severity levels, government responses, and social security systems. These contextual differences likely contributed to the observed variations in its effects on volcanology researchers. We acknowledge that there are no equivalent statistics prior to the pandemic context for comparison. In addition, our study used English as the sole language for both the distribution and administration of the survey. This limitation restricted our capacity to gather the experiences and viewpoints of volcanology researchers who primarily communicate in languages other than English. Consequently, valuable insights from non-English speaking communities within the field of volcanology, who also felt the impacts of the pandemic, might not have been adequately represented in our study. Moving forward, it is advisable to share and conduct surveys in other languages too to ensure a more comprehensive and inclusive understanding of diverse perspectives within the field.

Despite our efforts to gather data from a diverse pool of participants, we recognise that the sample size of this study limits the generalisability of our findings to the entire population of volcanology researchers. We also acknowledge that our survey design limits further investigation of the barriers faced by disabled researchers and researchers with childcare responsibilities. Future survey studies should include questions to investigate the barriers faced by specific groups of researchers, whether and how particular barriers were introduced, exacerbated or reduced during the pandemic, and the extent to which they persist in the post-pandemic times. Additionally, the lack of diversity in certain demographic data, such as gender, ethnicity, and country of residence, restricts a comprehensive analysis of potential contributing variables. Future studies with more extensive and diverse participant groups are essential to gain a deeper understanding of the pandemic's impacts within our rich community of volcanology researchers worldwide.

4.4 Conclusion

The pandemic's long-lasting and disproportionate impacts on ECRs and researchers with disabilities in volcanology necessitate targeted efforts to retain their talent and promote their success in and outside of academia. It is incumbent upon authorities and established researchers in privileged positions within the research community to proactively discuss and address the continuing challenges of the pandemic to create an inclusive and supportive environment for all volcanology researchers. Addressing these persistent challenges is essential in preventing the longer-term effects of the pandemic from exacerbating existing inequalities within the research community, ensuring that researchers in the field of volcanology and beyond are better equipped to navigate similar disruptions in the future.

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.

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

MC: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Visualization, Writing–original draft, Writing–review and editing. EM: Conceptualization, Data curation, Methodology, Writing–review and editing. JM: Data curation, Methodology, Resources, Writing–review and editing. JK: Methodology, Project administration, Writing–review and editing. AD: Data curation, Methodology, Resources, Writing–review and editing. TA: Conceptualization, Supervision, Writing–review and editing. AS: Conceptualization, Supervision, Writing–review and editing.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feart.2023.1291975/full#supplementary-material

SUPPLEMENTARY MATERIAL S1
Provides the ethics declarations, information sheet and sample survey used in this study.

SUPPLEMENTARY MATERIAL S2
Includes supplementary figures and tables of the survey results.

SUPPLEMENTARY MATERIAL S3
Includes the free-text responses of the survey participants. To ensure the anonymity of the survey participants, we only provided the career stages and region of residence for work or study for each free-text response.

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