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# Editorial: Women in science: seismology 2022

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## Editorial on the Research Topic Women in science: seismology 2022

Seismology is the study of earthquakes and of the propagation of seismic waves within the Earth. Seismologists study the Earth's—and other planets' interiors; provide detailed information on the shallow subsurface composition, where they help find resources (e.g., oil, gas, and geothermal) or estimate the ground stability, an information that is nowadays widely used in building codes. Seismology is a relatively young science that profited enormously from the technological and computational improvements of the past 2 decades. The first analogue seismographs, weighing several tons, appeared in the late 19th century. It was not before the mid 20th century that seismometers were fully digital and of portable sizes, which resulted in much denser deployments and recordings and an explosion in research of various aspects of our Earth (Agnew, 1989; Shearer, 2019).

Among some of the first remarkable discoveries is the one of Inge Lehmann. Inge Lehmann, a female Danish seismologist, discovered in 1936 using seismic waves that Earth has a (solid) inner core (Lehmann, 1930; Lehmann, 1936). Almost a century later, most Earth Scientists are able to cite her name, however, naming a second, similarly remarkable female seismologist poses a challenge. Unfortunately and despite the large and multidisciplinary groups composed of Earth scientists and technicians that work on many different branches of seismology, women still remain a minority.

And this is true for all academics: at present, less than 30% of researchers worldwide are women. Long-standing biases and gender stereotypes discourage girls and women from science-related fields, particularly in STEM (Science, Technology, Engineering, Mathematics) research. For example, in the EU, in STEM disciplines, women represent only 31% of enrolled students despite good employment opportunities: Sweden, Romania, Italy and Poland are the only Member States where female enrolment shares in STEM disciplines exceed 35% (2023 Report on Gender Equality in the EU).

The under-representation of female researchers and women in the highest level of Academia (equivalent to full professorship) can be understood through the “leaky pipeline” phenomenon, the effect of women leaving the career pipeline at different stages (Goulden et al., 2009): progressively lower proportions of females reach each step, visible in the famous scissor-shaped curve (Figure 1A).

As a result, an increase in the share of women among graduates (or at later stages in the career ladder) does not automatically lead to a proportional increase among researchers or grade A academic staff (She Figures 2021, EU, \*). The data suggest

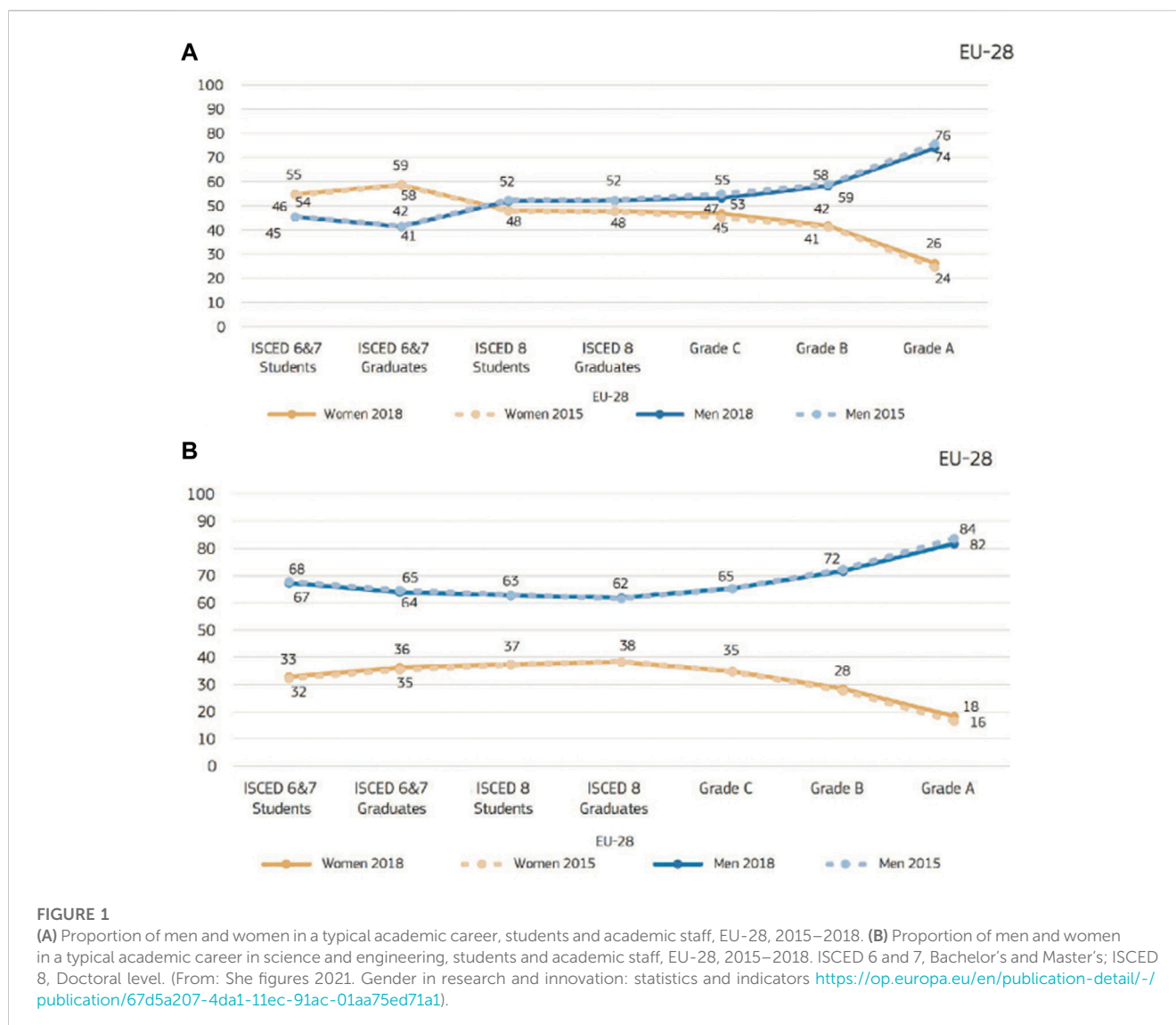


FIGURE 1

(A) Proportion of men and women in a typical academic career, students and academic staff, EU-28, 2015–2018. (B) Proportion of men and women in a typical academic career in science and engineering, students and academic staff, EU-28, 2015–2018. ISCED 6 and 7, Bachelor's and Master's; ISCED 8, Doctoral level. (From: She figures 2021. Gender in research and innovation: statistics and indicators <https://op.europa.eu/en/publication-detail/-/publication/67d5a207-4da1-11ec-91ac-01aa75ed71a1>).

that the extent of vertical segregation in career paths for women in academics is more pronounced in the STEM field (Figure 1B).

\* “The academic staff grades are based on national mappings according to the following definitions: 1) The single highest grade/post at which research is normally conducted within the institutional or corporate system; 2) All researchers working in positions that are not as senior as the top position (A) but definitely more senior than the newly qualified PhD holders (C) (i.e., below A and above C); 3) The first grade/post into which a newly qualified PhD (ISCED 8) graduate would normally be recruited within the institutional or corporate system; 4) Either postgraduate students not yet holding a PhD (ISCED 8) degree who are engaged as researchers (on the payroll) or researchers working in posts that do not normally require a PhD.”

Since significant gender gaps in study choices also persist, challenging outdated gender stereotypes and biased expectations from girls and boys is still an issue to be addressed by education and training systems.

Women have faced a very difficult historical path in the world of science. The attitude towards female scientists has changed only very recently, while their contributions to science have been, over the centuries, many and essential (Kolbl-Ebert and Turner, 2017).

Much has been done in defense of women's rights and gender equality, the process is by no means finished and it is important to create opportunities to reflect on this.

As a tribute to the female scientists of all-time, it is important not to forget the difficulties that some of us still face today and to remember the contributions of the female researchers in the past, thus joining with an invisible but solid thread their discoveries with works thanks to which today's female scientists enrich Geophysics. This Research Topic should also be intended as an acknowledgement to them for creating the fertile conditions allowing us to dedicate ourselves with passion to the research in this field.

To highlight the diversity of research performed by women across the entire breadth of Seismology, and the variety of personal academic experience in developing such research, we requested

contributions whose first author identifies as a woman, and chose to include in the Editorial a short bio of the first authors of the accepted manuscripts.

Given the quite general subject selected for this Research Topic, the five original contributions collected here cover a large range of key topics in Earth sciences: from purely seismological research papers to reports of data collected through operational interventions during a seismic crisis and up to opinions and reviews on science communication and how it is affected by gender.

[Obermann et al.](#) conducted an analysis on the seismicity and 3-D body-wave velocity models across a geothermal area in Iceland. Accurate hypocenter locations achieved by a joint inversion of P and S travel times allowed to provide an interpretation of the tomographic results in terms of migration of the crustal accretion and volcanic activity between volcanic centers.

[Pischiutta et al.](#) used ambient noise measurements performed on Ischia island to retrieve the directional amplification and ground motion polarization) after the 21 August 2017 Md 4.0 earthquake. Three analysis techniques in time and frequency domains agreed that both directional amplification pattern and polarization were mainly controlled by recent fault activity and hydrothermal fluid circulation.

[Moretti et al.](#) presented a data report on the possibilities offered by SISMICO: the INGV operational task force for rapid deployment of a seismic network during earthquake crises. The paper traces the history of the INGV emergency mobile network, the evolution over the years of the coordination group, and of the composition of the team in terms of male and female presence. The details of the real-time acquisition and transmission of seismic data are described, underlining the great importance that this type of data assumes in detailed seismotectonic analyses.

[Rubbia](#) proposed a thorough exploration of the multiple effects of gender in Earth Sciences, from those inherent in the lives of scientists and citizens to the science-society interactions. The widespread use of the term “gender vulnerability” largely about the vulnerability of women contributes to a partial narrative which promotes stereotypical notions of women as “victims”, while neglecting the role of women as agents of resilience and risk reduction. The take home message is that gender issues must not be considered just women’s issues and rather understood in a broader sense, including more sociodemographic factors and overlapping or intersecting categories, such as gender, ethnicity, age, socio-economic status.

[Musacchio et al.](#) starting from the assumption that risk communication is a key tool for building resilient communities and for increasing awareness, explored the evolution that risk communication itself has undergone in the last 2 decades. The authors described the transition from a predominantly “one-way” and top-down communication model, to the promotion of new models in which people, their needs and their participation in disaster risk management are central elements.

These works illustrate the scientific achievements of many different female researchers and want to highlight the significant and potentially impacting role that ideas and studies coming from women or woman-lead teams have on geoscience. We hope that the results presented in

this thematic Research Topic will provide an excellent source of inspiration especially for female students and future scientists.

As a conclusive remark, we would like to point out that the intention of publishing contributions from the widest and most diverse audience of female scientists was not fully achieved, given that most of the authors are employed/affiliated in a few universities or institutions of wealthy countries. This may be due to a couple of reasons: first, it is possible that researchers from less known scientific communities did not receive the announcement of this Research Topic, since they are more difficult to identify (detect?) compared to the most highly regarded or “mainstream” scientists; second, scientists from developing countries with lower research budgets might have found it too onerous and required further support to publish a contribution. Finally, we cannot ignore that a significant proportion of female scientists do not recognize the existence of gender-based discrimination in academia.

Unfortunately, prejudices, although they have decreased over the years, still exist ([ILO, 2019](#)), and there are many difficulties that women often have to face more than their male colleagues and which, inevitably, slow them down (in the best of cases) or stop their career. Forgetting this is the real danger.

The short biographies of the first authors follow:

Anne Obermann is a senior scientist at the Swiss Seismological Service at ETH Zurich. Her main research interests are in the field of seismic interferometry, to shed light on the shallow subsurface and monitor aseismic deformation processes. In this context, she extensively worked on numerical wavefield modeling in multiple scattered media to better understand the coda wave sensitivity. Over the past years, she also worked on induced seismicity at various scales. She is actively advocating for gender equality in her department and network.

Marta Pischiutta is a researcher at INGV, Italy, expert in geophysics and seismology. With 13 years of experience and a record of collaborative international research, her work spans from the study of non-conventional seismic site amplification effects to geophysical prospecting for archeological and geological exploration, and from numerical modeling to the involvement in seismic emergency task forces. She got her degree at Roma Tre University, conciliating her study with maternal duties and work with determination and positiveness, and PhD in Geophysics in 2010 at the University of Bologna, afterwards accepting the challenge of job insecurity that scientific research experiences in Italy.

Giuliana Rubbia, physicist, is Senior Technologist at INGV. She co-developed the first online seismology database in the Italian area and has been responsible for institutional web portals. She served as Past President and current member of the Committee for Wellbeing of Workers and Non-Discrimination and collaborated with Central Administration offices, contributing to personnel regulations and codes of conduct. HR Excellence in Research Award expert assessor, she fosters gender equality and gender dimensions in research and innovation, as a gender expert in the projects’ advisory boards, Gender and Talent Observatory at the National Research Council of Italy, and women scientists networks.

Milena Moretti works at the National Earthquakes Observatory of the National Institute of Geophysics and Volcanology since 2004. She graduated with a degree in Geology at the University of Camerino and then she went to Bologna University to do a PhD in Geophysics. She participated in numerous seismic field campaigns and all seismic emergencies in Italy over the last 20

years, following the earthquakes of L'Aquila (2009), of Emilia (2012) and of Central Italy (2016). She has thus gained a lot of experience in emergency preparedness and management. She is the author of more than 35 papers published in International Journals.

Gemma Musacchio is a scientist, seismologist, at INGV, Italy, since 2011, leading projects and being author of almost 100 papers. In 1991 she was the youngest summa cum laude graduate student in Geology at the University of Milan, when women geologists, and even she, were suggested to “raise children rather than work”. She got her PhD and left Italy, following her interest in Lithosphere studies. She was a scientist at academic centers in Germany, United States and Canada. Her interest shifted to science communication and in 2016 she got a Master degree on it. She focused on youths as being our best chance for a more resilient society.

## Author contributions

MC: Conceptualization, Writing–original draft. GS: Conceptualization, Writing–original draft. AO: Conceptualization, Writing–original draft.

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