



Diversity, equity, and inclusion: Tackling under-representation and recognition of talents in geochemistry and cosmochemistry

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Abstract

Diversity, at every step along the scientific path, drives innovative research. Scientific societies, like the Geochemical Society (GS) and the European Association of Geochemistry (EAG), have a significant influence over which discoveries and innovators are celebrated. Such choices impact the future of research, and therefore influence the evolution of our discipline and its relationship to the global community. Our professional societies are well positioned to define and promote the success of all scientists, including those from under-represented groups, through proactive advocacy, inclusive mentorship, awards, and leadership. At present, only binary gender data are available to examine the distribution of under-represented groups among memberships, awardees, and leadership positions. To assess gender diversity in the geochemistry and cosmochemistry community, we have reviewed available records of GS and EAG membership through Goldschmidt Conference attendees, and compared these to awardees and leadership data.

Awards have in the past been disproportionately given to white men, though this is changing. The GS and EAG have taken positive steps to increase both diversity of awardees (e.g., broadened definition of Fellows criteria) and inclusion (e.g., mentoring efforts aimed at early career and underrepresented minority scientists). This work identifies strategies to continue to improve professional societies' recognition of excellent science resulting in a more diverse representation of awardees. The strategies (e.g., revisions to award criteria and procedures to enlarge and diversify nomination pools) will require ongoing

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analysis and modifications. Future work is needed to address historically under-represented groups. We must work together to create a legacy of inclusion.

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1. INTRODUCTION

Geochemistry and cosmochemistry apply principles of chemistry to address a diverse set of scientific questions about major societal concerns as well as our habitable planet's operation, secular evolution, and origin. Geochemical concepts and principles govern many Earth, planetary, and environmental processes that are part of global-scale biogeochemical cycles over geological time. These processes concern present-day human interaction with our planet's land, oceans, atmosphere and biosphere, as well as fundamental research into the chemistry and dynamical evolution of the Solar System. The origins of life, and its co-evolution with planetary surface environments, are additional areas to which our community contributes scientific knowledge. The science that we do also covers themes ranging from the impacts of climate change through paleoclimate reconstructions and understanding past Earth System processes, understanding the mechanisms of groundwater contamination, sustainable use of resources, as well as their sometimes direct relationships to policy and to public health, the management of ocean ecologies, and the sustainability and strength of world economies (e.g., United Nations Sustainable Development Goals and the European Green Deal). The breadth of our research themes concern major present-day global challenges with important societal implications, and can also guide humanity's aspirations on and off-Earth. For the disciplines of geochemistry and cosmochemistry to prosper and reach full potential, we must attract, develop and nurture a diverse community of talented people (Cooperdock et al., 2020).

The Geochemical Society (GS) and the European Association of Geochemistry (EAG) have a long history of promoting diversity and inclusion, especially during their joint meeting, the annual Goldschmidt Conference (e.g., Wood and Gunter, 2005). However, it was not until 2020 (following the murder of George Floyd and Black Lives Matter

protests) that both GS and EAG created Diversity, Equity and Inclusion (DEI) committees (<https://www.geochemsoc.org/about/committeesandpersonnel/diversity-equity-and-inclusion> and <https://www.eag.eu.com/about/dei/>). These committees are composed of diverse members with the collective goals of improving two-way dialogue with the community, addressing challenges to inclusion within geochemistry, and promoting DEI (e.g., Riches et al., 2021). The work of the two DEI committees also helps to examine and find solutions to problems such as the lack of equitable opportunities for career development and bias in society awards.

We have a responsibility as professional societies, and as key voices for the geochemical and cosmochemical communities, to encourage, inspire and support change. Recently, both the GS and the EAG have modified their governance, policies and activities to promote inclusion and diversity (e.g., by creating DEI committees). The work of both GS and EAG DEI committees has been influenced not only by our need to advance excellence and reflect the values expressed by members and elected leaders, but also by the policy and practice of other leading geoscience societies (e.g., American Geophysical Union: White and Bell, 2019; European Geosciences Union: Holmes et al., 2020), governmental organizations and funding agencies. Over recent decades, studies have shown - albeit centred on workforce data for the USA - that changes have resulted in increased numbers of white women in the profession, while the proportion of scientists from historically excluded ethnic and racial groups, and under-represented countries, have remained consistently low for ~ 40 years (e.g., Mukasa, 2009; Bernard and Cooperdock, 2018; Morris, 2021). The GS and EAG DEI committees seek to gather data to inform initiatives aimed at establishing best practices for removing barriers while promoting diversity and inclusion. Here we present a three-year dataset (2018–2020) of the

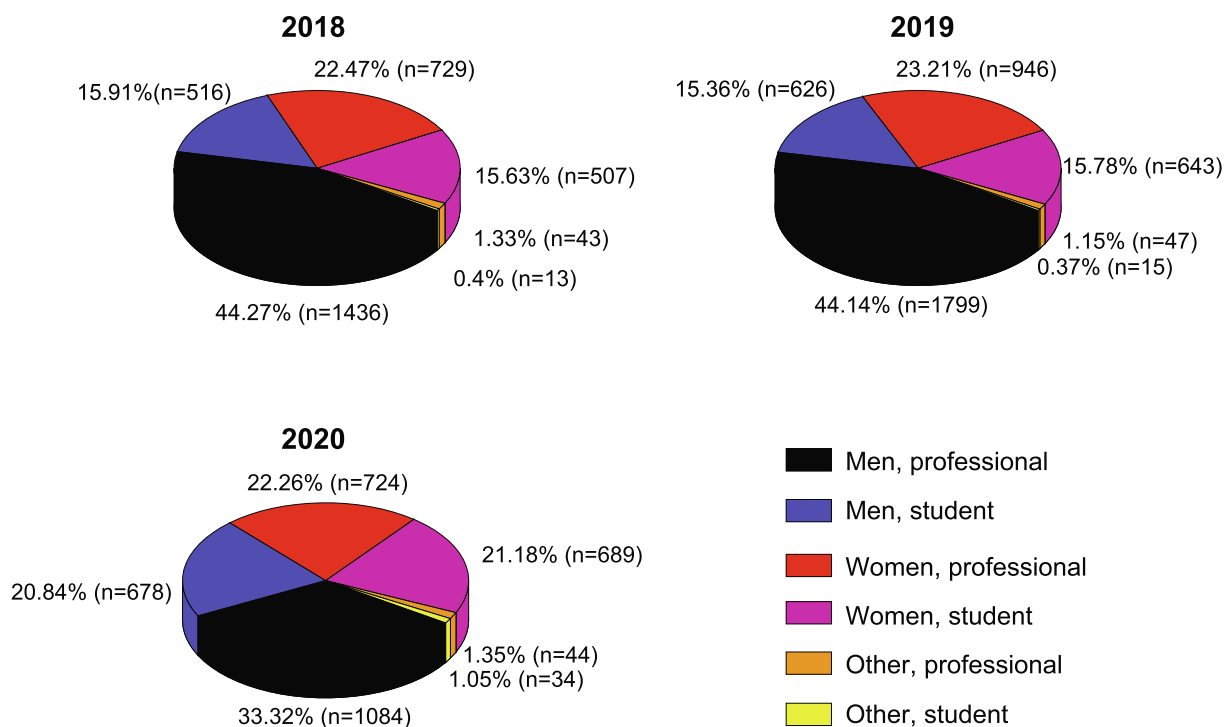


Fig. 1. Gender and career stage distribution of Goldschmidt Conference attendees between 2018 and 2020.

gender demographic make-up of Goldschmidt conference attendees, which provides an (imperfect) view of the demographics of our discipline. We also evaluate the gender breakdown of GS-EAG awardees as gender data is more complete than information for other historically under-represented groups. Analyses of these data allow us to make recommendations regarding future demographic data collection and suggest new approaches to reduce inequities in award allocations.

2. ASSESSING MEMBERSHIP TRENDS THROUGH GOLDSCHMIDT CONFERENCE ATTENDANCE

Professional society membership data are limited to broadly defined status (job title, institution...), whereas data on gender, gender identity, race, ethnicity, LGBTQ + identity, and disability status are not presently collected when a person joins either society. Therefore, to assess gender diversity in the geochemistry and cosmochemistry community, we have examined Goldschmidt attendee data over the period 2018–2020 (Fig. 1), the only period for which gender data were collected, in line with international data protection protocols that ensure the security of data. We know that geochemistry and cosmochemistry research is conducted by more people than are current members of the GS (about 4000 members) or EAG (about 3000 members), and of those members, only a fraction attend a given Goldschmidt conference. The selection is not random, and is based on factors such as access to financial resources or caring of others (e.g. children). Thus, using these data as a proxy for the demographics of global geochemists introduces a bias and filters out a large body of people,

including many that the DEI efforts should be directed to. Nevertheless, these are the only demographic data presently available, so we will use them as an imperfect proxy for the global geochemical and cosmochemical community.

In this three-year period (Fig. 1), 58% of attendees are men (70% professional, 30% students), 40% women (57% professional, 43% students) and 2% others; 65% of attendees are professionals (63% men, 35% women and 2% other) and 35% students (49% men, 49% women and 2% others). It is notable that while there is gender parity amongst student attendees, participation tilts heavily towards men in the professional category as previously documented throughout the Earth Sciences at professional levels (Bernard and Cooperdock, 2018; Piccoli and Guidobaldi, 2021). This result reflects the larger proportion of men in the profession, which has been attributed to lack of research time, gendered differences among funding outcomes, and/or tendencies for greater family/caring responsibilities among women. Interestingly, 2020 saw a higher attendance by students (both male and female) compared to professionals, and women compared to men. The 2020 conference was held online, as a result of the COVID-19 pandemic, while in previous years, Goldschmidt conferences were held in person (Boston, MA, USA in 2018; Barcelona, Spain in 2019). These data may reflect more equitable access to online conferences (Niner et al., 2020) because they do not require travel, are less costly, and are therefore more accessible to students, researchers from developing nations and women. In the latter case, women are, on average, in earlier career stages than men (e.g., Sonnert and Holton, 1996).

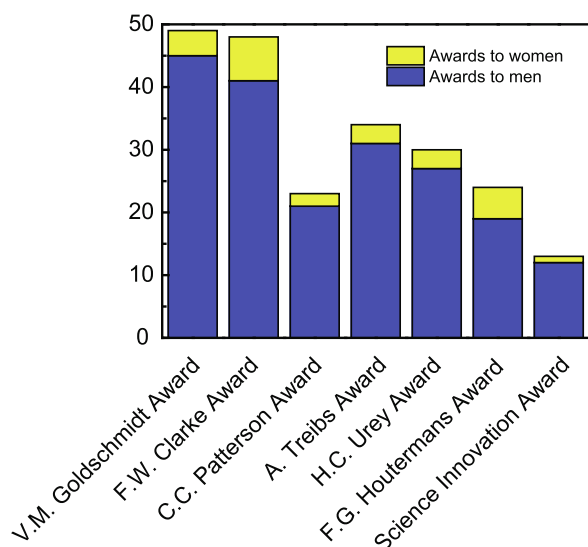
The Goldschmidt Conference delegate gender data echo a wealth of documented evidence in Science, Technology, Engineering and Mathematics, that the proportion of women in academia progressively decreases with advancing career stages. For example, the Royal Society of Chemistry finds that female chemists tend to leave academia at early-career stages — and that those who remain do not ascend to senior ranks in the same proportion as their male counterparts (Gewin, 2019). Women comprise just 9% of UK chemistry professors, and 18% of Natural Sciences and Mathematics in the European Union (Picoli and Guidobaldi, 2021) implying that after graduation, the relative proportion of female natural scientists drops by 32%. This phenomenon of differential attrition, known as the “leaky pipeline” (Alper, 1993), affects all research fields and all minorities (including LGBTQ+: Hughes, 2018; racial: Dowey et al., 2021) but is particularly accentuated

in geosciences (Bernard and Cooperdock, 2018). These stark and deeply concerning failures with respect to the retention of diverse scholars are a problem for the entire community as this stifles scientific excellence and innovation.

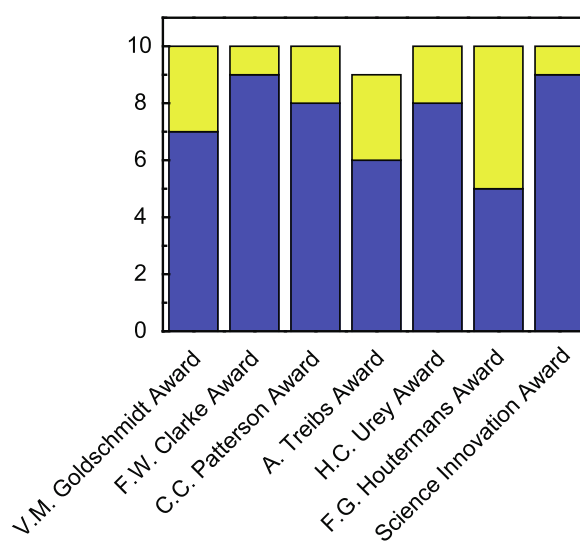
3. DATA FOR SOCIETY AWARDS

The GS and EAG award several prominent honors annually: the V.M. Goldschmidt, F.W. Clarke, C.C. Patterson, A. Treibs, H.C. Urey, F.G. Houtermans medals and Science Innovation Award (see award descriptors below). The two societies also award Fellowships to outstanding scientists who have made major contributions to geochemistry (note that recipients of the V.M. Goldschmidt, C.C. Patterson, A. Treibs, H.C. Urey and Science Innovation Awards become Fellows automatically).

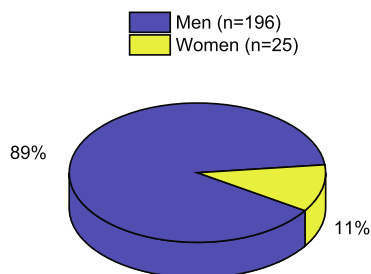
(a) All-time awards



(b) Recent awards (2011-2020)



(c) All-time awards



(d) Recent awards (2011-2020)

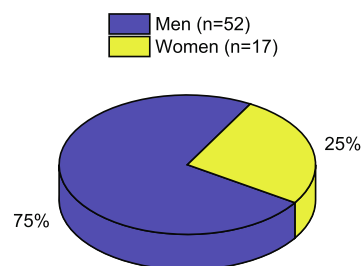


Fig. 2. Gender breakdown among selected award recipients, including (a) all-time award categories, (b) award categories from the last ten years, (c) all-time awards, and (d) awards for the past ten years (data accessed on 04/29/2021). While we recognize that gender is not binary, we could not include non-binary people in our analysis due to lack of available information. Awardees were assigned a binary gender using first names and in some cases, based upon the authors’ own perceptions and knowledge.

Award Descriptors up to 2021:

V.M. Goldschmidt Award, the GS's highest honor, presented annually for major achievements in geochemistry or cosmochemistry, consisting of either a single outstanding contribution, or a series of publications that have had great influence on the field.

F.W. Clarke Award, presented annually by GS to an early-career scientist for a single outstanding contribution to geochemistry or cosmochemistry, published either as a single paper or a series of papers on a single topic.

C.C. Patterson Award, awarded annually by GS for a recent innovative breakthrough in environmental geochemistry of fundamental significance, published in a peer-reviewed journal.

A. Treibs Award, given by GS for major achievements, over a period of years, in organic geochemistry.

H.C. Urey Award, the EAG's highest honor, recognizing outstanding contributions advancing geochemistry over a career.

F.G. Houtermans Award, recognizing exceptional contributions to geochemistry made by scientists within 12 years from the start of PhD by EAG.

Science Innovation Award, recognizing scientists who have recently made a particularly important and innovative breakthrough in geochemistry by EAG, subject area differs from year to year, according to the following five-year cycle:

Alfred Edward "Ted" Ringwood Medal honoring his work in petrology and mineral physics; **Heinz Lowenstam Medal** honoring his work in biogeochemistry; **Nicholas Shackleton Medal** honoring his work in climatology; **Samuel Epstein Medal** honoring his work in isotope geochemistry; **Werner Stumm Medal** honoring his work in low temperature and surface geochemistry.

Geochemistry Fellows Honor, given to outstanding scientists who have made major contributions to geochemistry and recognising the broad spectrum of scientific achievements that advance geochemistry.

Of 221 awards in the above categories, 196 (89%) were bestowed upon men and 25 (11%) were awarded to women (Fig. 2 a and c). It is the same for fellowships (316 awardees, with 274 men and 42 women; 87/13 ratio). Gender ratios of awards in the last decade (2011–2020) have improved slightly (Fig. 2 b and d). Of 69 awards and 132 fellowships, 52 (75%) awards went to men and 17 (25%) went to women whereas 104 (79%) fellows were men and 28 (21%) were women. Two-thirds of all awards to women were bestowed in the last ten years (68%). The F.G. Houtermans award is the only category with equal gender representation in the last decade, perhaps because it targets relatively early career researchers, before the “leaky pipeline” takes effect in earnest. Though efforts to enlarge nomination pools and improve diversity are being undertaken by GS and EAG, the awards and fellowships bestowed by the societies have been imbalanced with respect to gender. In particular, we need to reward not just narrowly-defined research excellence among individuals but also community contributions, and must better take into account a diversity of career paths. The EAG have started to do this for all of their awards in 2020, the GS award criteria (other than Fellowships and Urey award) have yet to refine and broaden their criteria, but that is in process. In 2020, the Fellows honor criteria were revised by the two

societies to recognize the broad spectrum of scientific achievements that advance geochemistry (<https://www.geochemsoc.org/honors/awards/geochemistryfellows>). Combined with society efforts to generate a larger nomination pool, this resulted in a much improved and diverse 2021 Fellows class, with for example, 43% female (6 out of 14) and based in four continents. Indeed, reforming awards is critical to the health, appeal, reputation and competitiveness of our discipline because awardees serve as prominent and inspiring role models as well as ambassadors. Thus, we need to ensure that these role models reflect the global societies that we serve and are relatable for all kinds of talented people whose aspirations may rise in consequence.

4. REPRESENTATION IN SOCIETY LEADERSHIP

Gender equity in committee representation has been a challenge for decades; however, the GS and EAG have taken some encouraging steps forward in this space over recent years. Gender ratios of GS board of directors and EAG council in the last decade (2011–2020) have improved slightly (women to men: 43 to 57 and 46 to 54, respectively). As of 2021, the GS board of directors is composed of ten women and seven men, in comparison to four women and 12 men in 2010. The current EAG council also comprises ten women and six men, in comparison to 3 women and 12 men in 2010. Leadership positions in the GS and EAG also reflect improvements in gender equity: the last four GS Presidents have been women (although only one for the EAG). However, we note that there is a trend in societies to have women undertaking greater proportions of the leadership work without commensurate increases in awards and recognition. Other categories such as ethnicity, race, sexual orientation, (non-binary) gender identity, career path, neurodiversity, and physical ability have not yet been addressed to the same extent as binary gender has. This is primarily because there is currently a lack of data and data collection can be limited by national privacy laws. Nevertheless, the improvement in gender balance in leadership positions within the two societies is important, as it will promote long-term systemic change (Mukasa, 2009).

As already highlighted by Mukasa in 2009, gender equity remains a significant problem for geochemistry and cosmochemistry. It is evident from our results (see section 2 and Figs. 1 and 2) that there persists absence among women in geochemical science leadership roles. As an example, the relatively modest proportion of women professionals attending the Goldschmidt Conference may have a direct link with inequality in awards; since conferences are places where networking occurs and this cultural factor could also affect nominations. To test this hypothesis, and any bias in nomination, there is a need for a sociological study that investigates the intellectual process of award nomination.

Specific challenges exacerbated by the low number of women receiving awards include: women's progression and retention; the leaky pipeline of women in higher education; gender pay/promotion/strategic influence/infrastructure allocation inequities; and lower publication rates on

average, especially as first author (Pico et al., 2020). Indeed, publication rates can be lower between women and men while some regional factors and institutional promotion criteria may currently emphasize such flawed publication metrics. Publication rate alone is not a measure of the novelty, difficulty, innovation, interdisciplinary nature or scientific impact of published works that should be considered as primary markers of excellence. We are mindful that this does not take account of differences in access or career path, contributions to excellent edited volumes or books, training and mentoring of superb personnel, curation of major collections, instrument and/or laboratory development and construction. Further, leadership of complex international initiatives or space missions, important new advances in curricula, leadership of scientific meetings, engagement with the public and policy makers, and wider contributions to build capacity and advance the field are undervalued when publication metrics are over-emphasized.

5. RECOMMENDATIONS

The results of our preliminary investigation of gender demographics lead to a series of recommendations to improve practices and inclusion:

(i) Collection of voluntary anonymous demographic data for the GS and EAG membership should be prioritized because such data are foundational to evaluating the present make-up of our community. We are aware that a whole host of privacy laws in multiple countries necessitates careful planning for their collection and the navigation of such legislation requires specialist guidance. These data will also provide a basis for identifying target areas to make a concerted effort in promoting diversity and inclusion, hence shaping the ongoing development of the GS and EAG DEI Strategic Plans. The number of scientists from under-represented minoritized groups who are joining, remaining with, or leaving GS and EAG are currently unknown. Career stages (early / junior, mid, and senior) of professional members, not currently reported through society records, could provide much needed insights into membership trends and the composition of community leaders. Increased availability of demographic information, provided anonymously and voluntarily by participants, that is commensurate with international privacy laws and community practices, would help to evaluate the health of the societies (where we understand that the results will require strong community engagement and high participation rates to be meaningful);

(ii) Strong and visible diverse leadership free of academic misconduct and/or bullying (which has not been documented within the leadership of GS and EAG, but has been within our community; Anonymous, 2016; Dalton, 2001; Xin, 2011). We suggest that past awardees (and current nominees) who have been proven guilty of misconduct relating to discrimination, harassment, bullying or criminal activities will lose their honors (or be omitted from consideration). Such an action will align with that recently proposed by other professional societies (e.g., National Academy of Sciences and Royal Society of Chemistry);

(iii) The names chosen for awards should evolve, with consideration to how current names reflect privileges in

terms of access to opportunity, socioeconomic setting, and circumstances. Hence, potentially perpetuating unconscious cognitive bias, as well as subtleties of their aspiration and appeal among minoritized people. We are well aware that current names have existed for a long time and mean something to the community members in terms of recognition. As a first step, we might be able to add a neutral or female name to the Science and Innovation awards and to consult with the community to gather perspectives to inform the evolution of awards' naming conventions. As AGU and EGU did when choosing the name of their new awards, a greater diversity in award names would contribute to changing the perception that the successful scientist is a white male (Karacam, 2016), in consequence inspiring all genders and ethnicities to a career in science;

(iv) Increased two-way dialogue providing opportunities or platforms through which marginalized and minoritized groups can share their views with the societies. These exchanges can include friendly and critical discussion at conferences and during online Town Halls, via email contact points, and also through social media and publications in journals, magazines and blogs (e.g., parents caring for children with disabilities; Pourret, 2020). Embedding better ways to reach and engage with geochemists and cosmochemists across the world is a key target. Networking and Open Science are part of the solution (Irawan et al., 2020);

(v) Revision of current nomination processes to enlarge and diversify nomination pools, account for inequity and reduce bias in award nomination, and better align with wider diversity, equity, and inclusion principles. Nominations for awards have historically come from a small number of people who are not representative of the society memberships and our depth of deserving talent. This discrepancy could be addressed by publishing materials that improve clarity for nomination procedures, possibly providing feedback to nominators to help them improve nomination packages (as modelled by AGU), and by polling or canvassing members on nominations. If 1000 GS members were polled, this would represent ~25% of the current total memberships. Such polling could be facilitated by recruiting volunteers. Polled members would be encouraged to nominate people across genders and ethnicities. Eventually, a more radical idea might be to say that no award will be given unless a minimum of five or ten nominations are submitted (or 30 for fellowships).

(vi) Evaluation and reform of award criteria and assessment procedures (i.e. work in progress by the joint GS-EAG Awards Task Force). Such reforms will help to recognize teams while lessening emphasis on troublesome metrics such as number of citations or journal impact factors. These revisions will also provide recognition of varied contributions to raise the image of the discipline as well as broadening impact and engagement so as to increase (e.g., geographic) diversity. The lack of equity in career development should also be addressed in award attribution. Women, people of racial minorities, and those identifying as non-binary may not have the same career opportunities as men and have to work against conscious and unconscious bias. Plus, scientists in developing nations or small institutions do not have access to the same facilities as col-

leagues, for instance, based in large employers in Europe and North America. In addition, minoritized people could face greater scientific cultural obstacles that are targeted by ongoing - but not completed - community practice and structural reforms. If these issues are to be addressed, we need to be able to identify ways to quantitatively define and level the playing field among measures of research success. This is a complex goal to tackle, but it could benefit from externally-funded collaborations involving experts in social and behavioral science; discussions regarding this approach are ongoing. Nevertheless, a more level playing field might be achieved by collecting data on research metrics of past awardees. Although one's research success should not be reduced to a number, a more balanced quantitative measure of research achievement would remove biases and allow for scaling to opportunity (e.g., when scaling to opportunity, a European male scientist with 1000 citations could be as deserving as a European female scientist with 500 citations, or an African male scientist with 200 citations). We are well aware that citation metrics are flawed because they may favor whatever the dominant demographic may be in a particular field. But they are also flawed in that they only reflect the science that is popular, and many times, some of the most interesting work actually takes some time to become widely recognized and cited.

(vi) Increasing recognition of effective working partnerships and value of collaborative research groups to include technical staff and laboratory managers. This approach may reduce potential fuel for “toxic academic environments” or over-pressured internal competition. Indeed, we have a responsibility to identify in our award systems that research excellence is driven by collaboration, and so must recognize research teams. While individual recognitions are important, scientific discoveries are more often a team effort. This has been identified by awards such as the Nobel Prize (itself with its own DEI challenges) where a team of researchers are acknowledged for their scientific discovery. Collaborative working is the foundation of geochemical and cosmochemical research and it has led to numerous discoveries and innovations (e.g., clumped isotope interlaboratory calibration, [Petersen et al., 2019](#)) as well as scientific advances underpinned by sample collection involving international and diverse groups of researchers (e.g., International Ocean Discovery Program, space missions such as Stardust and Hayabusa2). Yet, while space agencies such as NASA and ESA do give group achievement awards, these collaborative efforts are currently overlooked by GS's and EAG's award systems in geochemistry and cosmochemistry. In addition, by recognizing team efforts and cooperative research cultures, divisive issues arising from competition within the community, institutional pressures, and exploitation/bullying of early career and/or under-represented groups, could potentially be reduced. A new award serving this purpose should be created by GS and EAG, and we advise that the name for this is generated through consultation with the wider membership.

(vii) More targeted research and statistical analysis to characterize the workforce in geochemistry and cosmochemistry globally. Such efforts will gain from new partnerships with practitioners of social and behavioral sciences

and will benefit from meaningful financial support from funders across all nations and regions.

We must take more genuine action to build, promote, and retain a diverse student population, work on curricula and fieldwork requirements that are inclusive and provide opportunities for disadvantaged groups so as to unite in promoting equity (e.g., [Anadu et al., 2020](#); [Chiarella and Vurro, 2020](#); [Kingsbury et al., 2020](#)). Such efforts will enable us to build an increasingly diverse community in which a wide spectrum of people feel that they belong, thereby supporting scholars through student journey to early career to mid- and senior scientist stages while enriching our scientific excellence through the retention of diversity of thought and talent.

To increase the speed of transition, we propose new commitments aimed at reforming our policies and practices:

- (i) Examining how we collaborate and value teams within our community, both those within and those that cross traditional subject matter, geographic, and institutional boundaries;
- (ii) Encouraging community engagement with publications of this type and also with GS's and EAG's forthcoming strategic plans to advance diversity, equity, and inclusion;
- (iii) Collecting DEI data, observations, and gathering expertise available wherever possible to inform centralized initiatives that seek to transform scientific workplaces and ecosystems for the better of all (e.g., via government/funder focused studies and programs).
- (iv) Reports and publications derived from DEI data could help beyond the scope of improving inclusivity and equity in GS and EAG award procedures. These openly accessible studies could inform and influence the protocols of other international bodies while also encouraging the community in cooperative efforts to improve the representation in geochemistry and cosmochemistry among other international awards.

The entire community should help to build momentum and inspire more reform. We need to lift the bar in higher education, and among private and non-profit employers, for diversity and inclusion. Institutions should better recognize the inherent value and the full range of contributions made to their organization by colleagues among diverse workforces, and must make greater commitments to developing the best environments and policies for change. The geochemical and cosmochemical community needs to overcome institutional disadvantages and encourage as many individuals to contribute to scientific discovery and innovation as possible. We must accelerate the pace of change and broaden the discussion beyond gender.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Olivier Pourret: Conceptualization, Data curation, Formal analysis, Visualization, Writing - original draft,

Writing - review & editing. **Pallavi Anand:** Writing - original draft, Writing - review & editing. **Sandra Arndt:** Writing - original draft, Writing - review & editing. **Pieter Bots:** Writing - original draft, Writing - review & editing. **Anthony Dosseto:** Writing - original draft, Writing - review & editing. **Zimin Li:** Writing - original draft, Writing - review & editing. **Johanna Marin Carbonne:** Writing - original draft, Writing - review & editing. **Jennifer Middleton:** Writing - original draft, Writing - review & editing. **Bryne Ngwenya:** Writing - original draft, Writing - review & editing. **Amy J.V. Riches:** Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: OP is a member of the Editorial Board of Chemical Geology and the DEI Committees of both EAG and GS. PA, SA, PB, ZL, ECM and JMC are members of the DEI Committee of EAG. AD is a member of the Editorial Board of Chemical Geology and the DEI Committee of GS. JM is a member of the DEI Committee of GS. BN is a member of the Editorial Board of Chemical Geology and the DEI Committee of EAG. AR is Co-Chair of the DEI Committee of EAG and has previously served as Guest Managing Editor in leading a Special Issue of *Geochimica et Cosmochimica Acta*.

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