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On the potential of preprints in geochemistry: the good, the bad and the ugly

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In recent years, the pace of the dissemination of scientific information has greatly increased [1]. In this context, the possibility and value of sharing open access (OA) online manuscripts in their preprint form seem to be growing in many scientific fields [2]. More and more platforms are especially dedicated to free preprint sharing. Preprints? What? Also sometimes referred to as e-prints, they are digitally-shared, non-peer-reviewed scholarly articles that typically precede publication in a peer-reviewed journal [3]. They have been a part of science since at least the 1960s [4]. In 1990, Tim Berners-Lee created the World Wide Web to help researchers share knowledge easily. A few months later, in August 1991, as a centralized web-based network, arXiv (https://arxiv.org/, pronounced ˈär kīv like the word archive; from the Greek letter 'chi') was created. arXiv is arguably the most influential preprint platform and has supported the fields of physics, mathematics and computer science for over 30 years. Since then, and after about a 15 year hiatus, preprint platforms have become popular in many disciplines (*e.g.*, bioRxiv for biological sciences) due to the increasing drive towards OA publishing, and can be publisher- or community-driven, profit or not for profit, and based on proprietary or free and open source software. A range of discipline-specific or cross-domain platforms now exist (*e.g.*, [5]), with exponential growth these last five years as highlighted on Figure 1. While preprints as a whole still represent only a small proportion of scholarly publishing (*e.g.*, 2% of the biomedical literature published every month ; [6]), a strong and diverse community of early adopters is already beginning to experiment with integrated value-enhancing tools in many more disciplines than before (*e.g.*, peer review overlay platforms). In general, the Earth Science community, and its subcommunities, have perhaps been a little slow in adopting the use of preprints. Several dedicated servers now exist, including EarthArXiv, ESSOAr, and paleorXiv, as well as InarXiv, which researchers use to share some earth scientific research in Indonesian language.

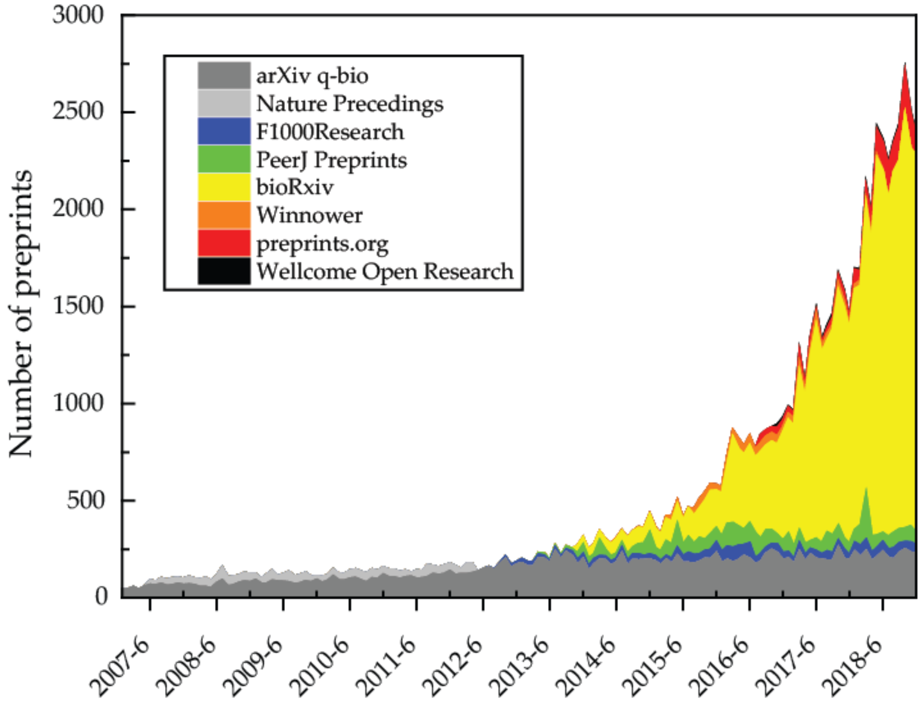

Figure 1. Preprints evolution per month in biological sciences (source http://www.prepubmed.org/monthly_stats/; accessed on 03/03/2020).

The reasons for this general growing importance, popularity, and acceptance of preprints are numerous. One of the reasons is the delay in the peer-review process and the eventual subsequent publication (Figure 2), which can also impact the career progress of researchers. This is a generic problem in scholarly publishing, and affects the geochemistry community as much as other disciplines. Some research has shown that preprints tend to be of similar quality to their final published versions in journals [7]. This raises major issues around the "added-value" of both the publishing and peer-review processes, which continue to cost 10s of billions of dollars in public and private money each year [8]. In geochemistry, we know that around US$ 7,000,000 each year is spent on Open Access in journals [9], with virtually none of this being reinvested or reimbursed into the community itself. Given the immense value of preprints, it seems that there is a great potential to reinvest this into more sustainable community-led non-profit ventures, such as EarthArXiv.

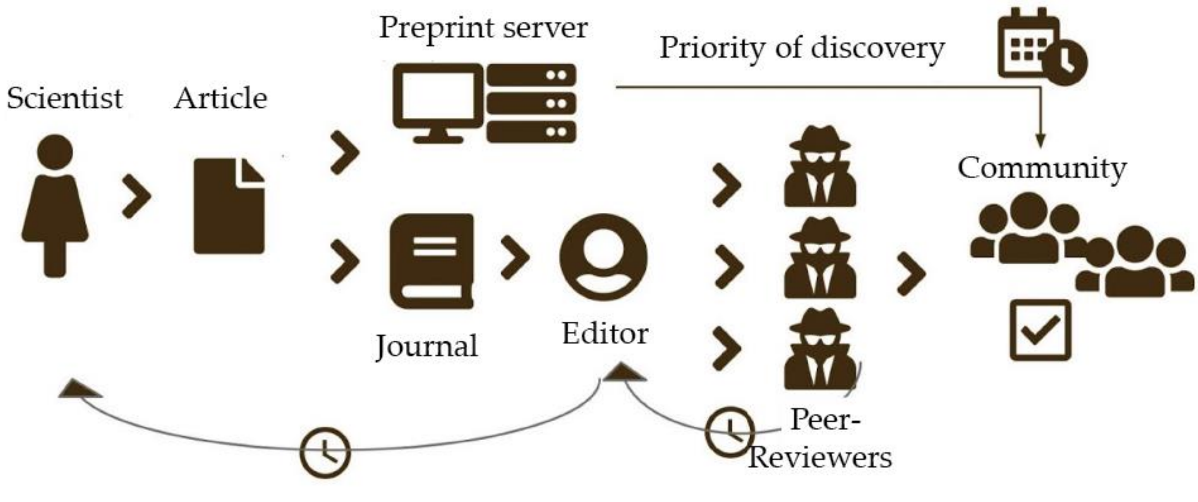

Figure 2. Preprint submission workflow establishing priority of discovery (modified after Tennant et al. [2]).

There are a number of general benefits but also potential drawbacks of preprint sharing. Many of the possible benefits of preprint sharing for geochemists include:

- rapid sharing of research results, particularly during outbreaks (*e.g.*, COVID-19), where there remains a clear role for the wider geoscience community [10];
- visibility and accessibility (*i.e.* not placed behind a paywall);
- sharing diverse types of outputs such as data, research code, or methods;
- extra feedback and peer-review;
- small or even non-existent costs for authors;
- assignment of a digital object identifier (DOI) so that the paper is known and stored in the digital world;
- possibility of setting research precedents (preventing scooping);
- work can be reported on internationally, and then be improved (*i.e.* overall quality, integrity, and reproducibility of research outputs) and released later;
- incentivizes collaboration;
- authors retain full copyright on their article;
- less labour-intensive to use than many journal submission portals (*e.g.*, it takes about five minutes to upload a preprint to the Open Science Framework).
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However, the preprint model still has some possible drawbacks. For example, the increased dissemination effect has the potential to be used to promote poor-quality scholarship or fake news, and adds an extra potential burden on journalists reporting on new research [11], as well as preprint platform moderators. According to Altmetric, the most-shared research article ever at the time of writing is a bioRxiv preprint about the COVID-19 virus [12]. This article has since been withdrawn due to flaws in the research. However, retractions are common even in peer-reviewed scholarly journals, so this is not necessarily a trait exclusively for preprints; in fact, preprints actually tend to make the process of correcting the scholarly record far simpler. The preprint model also increases the scientific community's responsibility by not legitimizing preprint publications that lack scientific rigour. Thus, the burden is on researchers, and indeed everyone, to think critically about the research they read, share, and re-use, whether it has been peer-reviewed or not.

Despite this development, there is still some apparent resistance to preprints among geochemists and the wider geoscience community. One major hurdle is the question of their citation. Some researchers have argued that preprints are no different from other grey literature due to their preliminary existence. It is a direct consequence of our academic culture where typically only work that has been explicitly peer-reviewed and published in a scholarly journal is usually cited. Another argument is that a preprint might bring confusion in citation when it has been published formally in a journal. Moreover, some authors report that manuscripts are rejected because similarity-check software shows high similarity between submitted and preprint version. The extent of these issues remains poorly understood, but should be clarified in journal policies and on preprint platforms. However, we believe that it is our duty as scholars, and readers in general, to think critically of anything that we are reading, irrespective of whether it has been 'peer-reviewed' or not.

"It should be noted that reference 15 is a non-peer reviewed version. I suggest referring to a peer-reviewed publication from another source."

Reviewer #2

Sustainability of geoscience preprint systems is always questionable, as we can see through popular, not-for profit, community driven preprint servers (*e.g.,* INA-Rxiv) that currently face closure because of financial troubles [13] or are moving towards other economic options (*e.g.,* EarthArXiv). This highlights the issue with sustainability of these services, which should perhaps not be an issue considering how much money is currently being spent on less-efficient and less-sustainable for-profit systems (*i.e.* commercial publishing activities; around US$ 7,000,000 per year these last years) [9]. Governments and funders desperately need to reconsider their focus on where they allocate funds during decisions related to scholarly communication [14]. Learned societies might also have a role to play in supporting preprints more in the future. For example, the Geological Society of America and Geological Society of London both indirectly support preprints, but have not yet financially or formally supported any of the community-led initiatives around them. Part of the issue here is that there seems to be a general fear that preprints might threaten the sustainability of traditional journals, which geoscientific learned societies still derive a substantial portion of their revenue from.

In the Earth Sciences only a few articles are submitted as preprints every month [15-16], so we cannot really provide much insight into their specific use at the present. But what about preprints in Geochemistry? As stated by Pourret et al. [17] and Pourret [18], the preprint model is unfortunately still perhaps little-known and is not routinely used by geochemists. A small overview of preprints available in geochemistry using the keywords Earth Science category and Geochemistry, Geochemistry and Petrology, Biogeochemistry and Cosmochemistry sub-categories, and Geochemistry category (depending on servers) show that less than 250 articles have used this model in total in the last three years (Table 1). This number is very low compared to the 9,326 and 9,196 articles published in the field of geochemistry in 2018 and 2019, respectively [9].

Table 1 Number of preprints by servers (data accessed on 03/03/2020)

Servers	Homepage	Number
EarthArXiv	https://eartharxiv.org/	146
Preprints	http://www.preprints.org	25
OSF Preprints	https://osf.io/preprints/	17
ESSOAr	https://www.essoar.org/	15
PeerJ preprints[#]	https://peerj.com/preprints-search/	8
INA-Rxiv	https://osf.io/preprints/inarxiv	7
arXiv*	https://arxiv.org	4
AgriXiv	https://agrixiv.org/	3
Zenodo	https://zenodo.org/	>2

[#] discontinued

* via Hyper Articles en Ligne (HAL : https://hal.archives-ouvertes.fr/)

However, as stated by Pourret [18], a majority of the journals in geochemistry also have a green colour according to the SHERPA/RoMEO grading system, indicating that preprint (and the peer reviewed postprint version) articles submitted to these journals can be freely shared on a preprint server, without compromising authors' abilities to publish in parallel in those journals. Moreover, Pourret et al. [17] highlighted that the majority of journals in geochemistry allow authors to share preprints of their articles (47/56; 84%). Therefore, the relatively low uptake of using preprints in geochemistry is not because the opportunity is not there. More likely, similar to other small research communities, it is likely that a complex network of sociocultural factors is responsible for their low use (*e.g.*, a similar pattern is observed in palaeontology), even if open data sharing has been acknowledged by the community for more than 15 years [19]. The two main options for geochemists are EarthArXiv, a free preprint service for the Earth sciences initially powered by OSF Preprints, and ESSOAr, developed in a joint initiative by the American Geophysical Union with financial support from Wiley. Moreover, geochemists who published in the many journals of the European Geosciences Union have already become accustomed to such openness and are posting their work prior to peer-review as a discussion on the Copernicus platform [20].

Attempts to close this gap between the inherent benefits of preprints and their relatively low uptake by research communities have concentrated primarily on making preprints more citable, for instance by having improved metadata, permanent identifiers (DOIs), and even the look and feel of a conventional and historical journal article (*e.g.*, Preprints.org). There are good preprints and bad preprints, just like there are with journal articles. Overall, don't be afraid to be scooped or plagiarized! Preprints also actually protect against scooping [21-22]. Preprints establish the priority of discovery as a formally published item. Therefore, a preprint acts as proof of provenance for research ideas, data, code, models, and results - all outputs and discoveries. The fact that most preprints come with a permanent identifier (*e.g.*, DOI) also makes them easier to cite, index and track; and articles that are published as preprints appear to gain more citations at a faster rate [23]. Although arXiv was established almost thirty years ago, we're only just at the start and there's a long way to go still for preprints. The Earth Sciences are extremely complex, with many subdisciplines like geochemistry – each with its own norms. It is reasonable that a "one size fits all" model for preprints would never work across the entire scientific community and that geochemists need to develop and sustain their own model. The community should really be developing this, along with new standards for linking their datasets in the spirit of FAIR model [24], and the usage of open standards, licensing, and free and open source Software.

In the near future, given the increase in the use and profile of preprint servers, and alternative publishing platforms such as F1000 Research, it will be necessary to identify how many relevant platforms exist, to describe their scientific scope (*i.e.* covered disciplines), and similar to the way that researchers evaluate the aims and scope of journals, to compare their characteristics and policies. In the vast usage of public software sharing platforms (e.g., Github, http://github.com and Gitlab, http://gitlab.com), there is also strong encouragement to make code re-usable, shareable, and citable, via DOI or other persistent link systems. For example, GitHub projects can be connected with Zenodo for indexing, archiving, and making them easier to cite alongside the principles of software citation [25]. This all comes as part of a wider global shift towards more ‘open research practices’, and the geochemistry community needs to make sure it is engaging widely with these, as well as connected issues like research integrity and reproducibility, if it is to maintain its relevance in the modern research age.

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