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The growth of open access publishing in geochemistry

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Abstract

In this communication, we look at Open Access (OA) publishing practices in geochemistry. We examine a list of 56 journals and assess whether Article Processing Charges (APCs) and Journal Impact Factors (JIFs) appear to influence publication or not. More than 40% of articles in 2018-2019 were published OA, and about 70% of that portion in fully OA journals. These had a mean APC of US$ 900, whereas the remaining were published in hybrid journals with a higher mean APC of more than $US 1,800. A moderate and positive correlation is found between the number of OA articles published in hybrids journals and their JIF, whereas there is a stronger positive relationship between the number of OA articles published in fully OA journals and the APC. For OA articles published in hybrid journals, it seems that the proportion of OA articles tends to increase in journals with higher JIF.

Keywords: Open Access; Open science; Article Processing Charge; Journal Impact Factor; Scholarly communication

1. Introduction

Throughout history, the scholarly community has increasingly made various cases for wider and easier public access to published research, which in the early 2000s became known broadly as Open Access (OA) [1]. Over the last two decades, scholarly publishing has undergone a major and global transformation, with the move to system-wide OA marking a radical shift in the financial models of major publishers away from journal subscriptions [2]. This has now opened up an enormous diversity in publishing paths for authors and research institutes, raising further issues around publishing ethics. For example, a key element of this transition is that virtually all stakeholders have recognized the importance of ensuring that researchers and their institutes should not have to pay even more to read articles than they already do [3]. With total revenue across the English language Scientific, Technical and Medical publishing sectors estimated to be around US$ 10 billion in 2017 [4].

As recently outlined by Pourret et al. [5], OA publication is often conflated with the author-facing business model of Article Processing Charges (APCs), whereby authors (or their institutions) pay a pre-specified fee to cover the publication cost. However, OA publishing was already widespread many years before the advent of APCs, which became popular as OA publishing became increasingly commercialized. When publishers such as BioMed Central and PLOS demonstrated the feasibility of APC-based business models, the larger and traditionally subscription-based publishing houses began to recognize OA publishing as complimentary to rather than a threat to their business model, and began to adopt it through APC-driven 'transitional' hybrid journals. However, in their overview of OA practices in geochemistry, Pourret et al. [6] highlighted some discrepancies within this seemingly dominant perspective. Critically, the majority of these journals also have self-archiving policies that allow authors to share their peer reviewed work in parallel via 'green' OA routes and without charge (*i.e.* APC-free options). The journals with the highest APCs are typically those of the major commercial publishers, rather than journals from geochemical societies [6]. Together, these observations indicate that, in our view, significant control on how we communicate and evaluate our research as a global research community has been ceded to third-party commercial vendors.

To our knowledge, no report has been presented on the impact on the geochemical community of differences in Article Processing Charge (APC) and differences between fully-OA and hybrid journals (*i.e.* partial-OA). This work comes at an important time, as supra-national initiatives such as Plan S (supported by cOAlition S, an international consortium of research funders: https://www.coalition-s.org/) are seemingly showing a strong financial preference towards APC-driven ‘gold’ (OA within journal) models, while simultaneously appearing to neglect more equitable and financially sustainable ‘green’ (self-archived OA) and ‘diamond’ (‘gold’, but no-APC) routes [7]. However, while this article was under review, cOAlition S announced that they were looking more into non-commercial forms of OA publishing, following wider consultation [8].

Here, we present an overview of OA practices in geochemistry based on articles published in 2018 and 2019 and whether APC levels seem to correspond with OA publication preferences or not. We expect this analysis to be useful in helping the geochemistry community to make more informed and sustainable choices in their future publishing activities, especially those elements which are publicly-funded and for which the geochemistry community has an increasing responsibility to provide public access to their research.

2. Material and methods

We applied the same method as described in Tennant and Lomax [9] for analyzing paleontology journals. The full dataset from Pourret et al. [6] was updated to include APC and publication rates for OA articles in 2018 and 2019. We only analyze two years because of the dynamic nature of the data (especially for APC). Information for these APCs, rates for OA publication were sourced from the Web of Science, Scopus and journal web pages in January 2020. Key data are available in Table 1 and the full data are available as electronic Supplementary Information and from this online repository (https://zenodo.org/record/3659528).

Table 1 List of journals in geochemistry detailing their impact factor 2018, their APC (in US$) and their status (either fully OA, hybrid or none).

Journal Name	JIF 2018	APC US$	Status
ACS Earth and Space Chemistry	2.243	4000	Hybrid
Acta Geochimica/Chinese Journal of Geochemistry	na	2690	Hybrid
Acta Petrologica Sinica/Yanshi-Xuebao	1.317	na	Not OA
American Mineralogist	2.631	900	Hybrid
Applied Clay Science	3.89	2500	Hybrid
Applied Geochemistry	2.894	2750	Hybrid
Aquatic Geochemistry	1.44	3140	Hybrid
Biogeochemistry	3.406	3140	Hybrid
Biogeosciences	3.951	1000	OA
Canadian Mineralogist	1.398	na	Hybrid
Chemical Geology	3.618	1950	Hybrid
Chemie der Erde/Geochemistry	1.19	1500	Hybrid
Clay Minerals	1.797	3070	Hybrid
Clays and Clay Minerals	1.835	2500	Hybrid
Contributions to Mineralogy and Petrology	3.23	3760	Hybrid
Earth and Planetary Science Letters	4.637	3200	Hybrid
Earth and Space Science	2.152	1800	OA
Economic Geology	3.285	3000	Hybrid
Elements	4.224	4000	Hybrid
Environmental Geochemistry and Health	3.252	3140	Hybrid
European Journal of Mineralogy	1.663	800	Hybrid
Frontiers in Earth Science-Geochemistry	2.892	2490	OA
Geochemical Journal	0.99	1400	Hybrid
Geochemical Perspectives	5.75	0	OA
Geochemical Perspectives Letters	4.032	0	OA
Geochemical Transactions	2.615	1140	OA
Geochemistry Geophysics Geosystems	2.946	3500	Hybrid
Geochemistry International/Geokhimiya	0.835	na	Hybrid
Geochemistry-Exploration Environment Analysis	1.109	3600	Hybrid

Geochimica et Cosmochimica Acta	4.258	3150	Hybrid
Geochronology	na	0	OA
Geofluids	1.437	1600	OA
Geosciences Frontiers	4.16	0	OA
Geosciences-Geochemistry	na	1000	OA
Geostandards and Geoanalytical Research	4.256	3700	Hybrid
Geothermal Energy	1.732	500	OA
Global Biogeochemical Cycles	5.733	3500	Hybrid
Hydrology & Earth System Sciences	4.936	1000	OA
Journal of Chemistry-Geochemistry	1.727	1600	OA
Journal of Geochemical Exploration	3.472	2500	Hybrid
Journal of Geophysical Research-Solid Earth	3.585	3500	Hybrid
Journal of Petrology	3.38	3150	Hybrid
Lithology and Mineral Resources	na	na	Not OA
Lithos	3.913	3500	Hybrid
Mineralium Deposita	3.397	3140	Hybrid
Mineralogical Magazine	2.21	3070	Hybrid
Mineralogy and Petrology	1.573	3140	Hybrid
Minerals	2.25	1400	OA
Neues Jahrbuch für Mineralogie	0.6	na	Not OA
Ore Geology Reviews	3.387	2600	Hybrid
Organic Geochemistry	3.12	2500	Hybrid
Periodico di Mineralogia	1.417	0	Not OA
Precambrian Research	3.834	3300	Hybrid
Results in Geochemistry	na	800	OA
Reviews in Mineralogy & Geochemistry	8.745	na	Not OA
Solid Earth	2.38	1000	OA

na not available

3. Results and discussion

The number of 'gold' OA articles started to increase in the early 2000's and continued rapidly over the last 10 years (Figure 1a). A shift occurred 5 years ago with a decrease of OA articles from hybrid journals (*i.e.* mixed, OA and non OA articles) towards an apparent preference for articles in fully OA journals (*i.e.* journals that publish 100% OA articles). Indeed, the first fully OA journal in Geochemistry was launched in 2000 (*Geochemical Transactions* [9]) and since then this number has regularly increased each year (Figure 1b), with the last title launched in Autumn 2019 (*Results in Geochemistry*). Among the 56 journals considered here, 16 are fully OA, 35 are hybrids and 5 do not yet offer an OA option (Table 1). In 2018, out of 9,603 articles, 4,043 (42.1%) were published as 'gold' OA, and in 2019, out of 9,559 articles, this proportion had increased slightly to 4,192 (43.8%). It must be noted that these numbers are most likely an overestimation as we included the total number of articles for journals which have a Geochemistry section (*e.g.*, journals like *Frontiers Earth Sciences*). Among these articles, 72.5% and 80.7% are published in fully OA journals, in 2018 and 2019, respectively. This overall proportion is comparable with 49% of the annual research publications in France in 2018 being available as OA (including 'green' OA, not considered in our evaluation; https://ministeresuprecherche.github.io/bso/) and 45% of the Danish annual research production being uploaded into university repositories (https://www.oaindikator.dk/en/) [5].

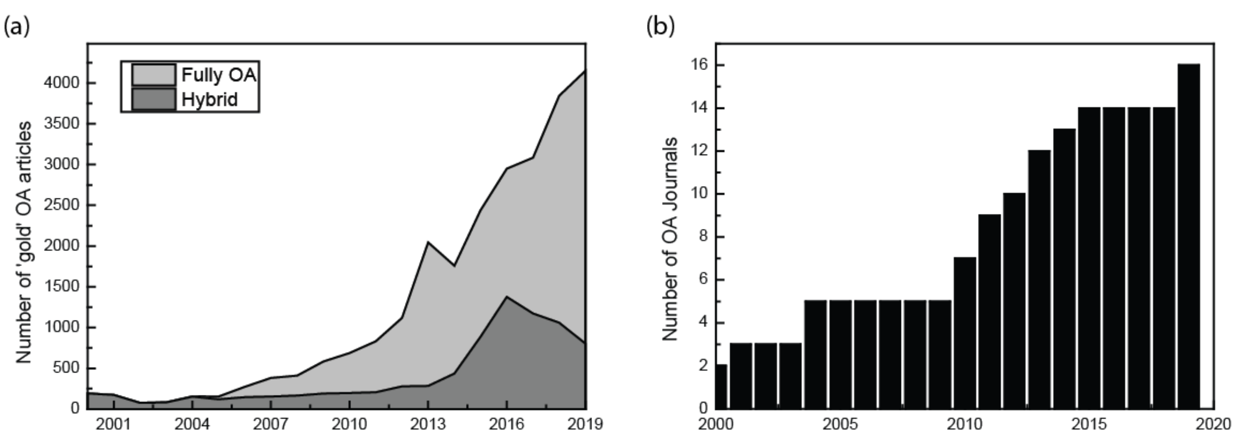

Figure 1 Evolution of the number of (a) 'gold' OA articles and (b) fully OA journals in geochemistry. Data are from Scopus.

During the last two decades, journal publishing has significantly changed, with the earlier dominance by learned societies being largely replaced by several big commercial publishers (*i.e. Elsevier, Springer Nature* and *Wiley*) [11, 12]. Many learned societies now have outsourced their publishing operations to those commercial operations, and derive a significant revenue stream from them which is used to support other activities of the society [13]. This represents a strange form of vendor lock-in, whereby societies become more closely linked to commercial functions of publishing houses, and perhaps cannot transition to OA as fast as they would like without compromising other functions of the society. Nonetheless, major changes are now becoming more mainstream, including the increasingly widespread free access to articles [14], funded not by subscriptions but largely through APCs. While this was previously primarily through a per-article basis, publishers have started offering, what is referred to as, 'transformative' agreements that tend to variably bundle subscriptions and publication fees together at a much larger, often national, scale. This approach tends to increase the revenue-making capacity of the large commercial publishers [11], while simultaneously providing authors, institutes, and nations with relatively fewer financial privileges, as well as concentrating the publishing market in a few established groups and restricting the ability of smaller or more innovative groups to develop [15]. The European Commission themselves have acknowledged that this market dysfunction is a problem that they are monitoring, and one that Plan S could address in the future [16]. In the context of the United Nations Sustainable Development Goals, alternative routes that are more equitable are required for the communication of scholarship with wider society. Such a function has recently been highlighted through the impact of the 2020 coronavirus pandemic, with a clear role for the wider geoscience community to play [17]. This could include exploring alternative publishing models whereby research outputs are more accessible to benefit society rather than as commercial commodities [18].

Regardless of any potential waiver or discount systems being in place (including through negotiations between universities and publishers), the total APC paid by the geochemistry community is estimated at US$ 7,307,260 in 2018 and US$ 7,308,140 in 2019. This is based on a mean value per article of US$ 1,807 in 2018 and US$ 1,743 in 2019 for the 49 journals we selected (with a minimum of US$ 0 and a maximum of US$ 4,000) (Table 2). For fully OA journals, the total APC is estimated at US$ 3,584,100 (*i.e.* 49% of the estimated total) in 2018 and US$ 4,287,280 (*i.e.* 59% of the estimated total) in 2019. This is based on a mean value per article of US$ 1,259 in 2018 and US$ 1,325 in 2019 (with a minimum of US$ 0 and a maximum of US$ 2,490) (Table 2). We note that the dataset is not normally distributed (Table 2). Publishing in a fully OA journal is substantially less-expensive than publishing in a hybrid journal, on average around half the cost for an equivalent output. In this context, *Results in Geochemistry* has proposed an APC of US$ 800. Such an APC is still relatively high when compared with US$ 400 estimated by Grossmann and Brembs [19] for the true costs of article production, and there are journals where the production costs are up to two orders of magnitude lower than this, such as the *Journal of Open Source Software* or *Journal of Machine Learning Research* [20].

Table 2 Descriptive statistics of APCs for all geochemistry journals.

	Fully OA		Hybrid		All	
	2018	2019	2018	2019	2018	2019
articles	2846	3240	1197	952	4043	4192
mean	1259	1328	3111	3183	1779	1727
median	1000	1400	3200	3500	1400	1400
minimum	0	0	800	800	0	0
maximum	2490	2490	4000	4000	4000	4000
quartile 1	1000	1000	3140	3150	1000	1000
quartile 3	1600	1600	3500	3500	2500	2490
IQR	600	600	360	350	1500	1490
2 sigma	1071	1128	1234	1252	2005	1912

At the moment, it is not clear why such big differences exist. This represents billions of dollars annually plus substantial investment from the private and philanthropic sectors. Due to the opacity of the publishing process, it is difficult to know why such disparities exist. According to the Directory of Open Access Journals (DOAJ; https://doaj.org/), around 71% of fully OA journals do not levy APCs; which is proportionally much higher than the case for the geochemistry sector (*i.e.* 4/15, ca. 27%). However, perhaps counter-intuitively, most articles published OA are published in journals with APCs (*e.g.*, for the geochemistry journals considered in our study 96% in 2018 and 95% in 2019), as calculated by Crawford [21]. The highest APCs are typically those leveraged by the large commercial publishers (see Pourret et al. [6] for details relevant to geochemistry), with annual profit margins in excess of 20-30% [20].

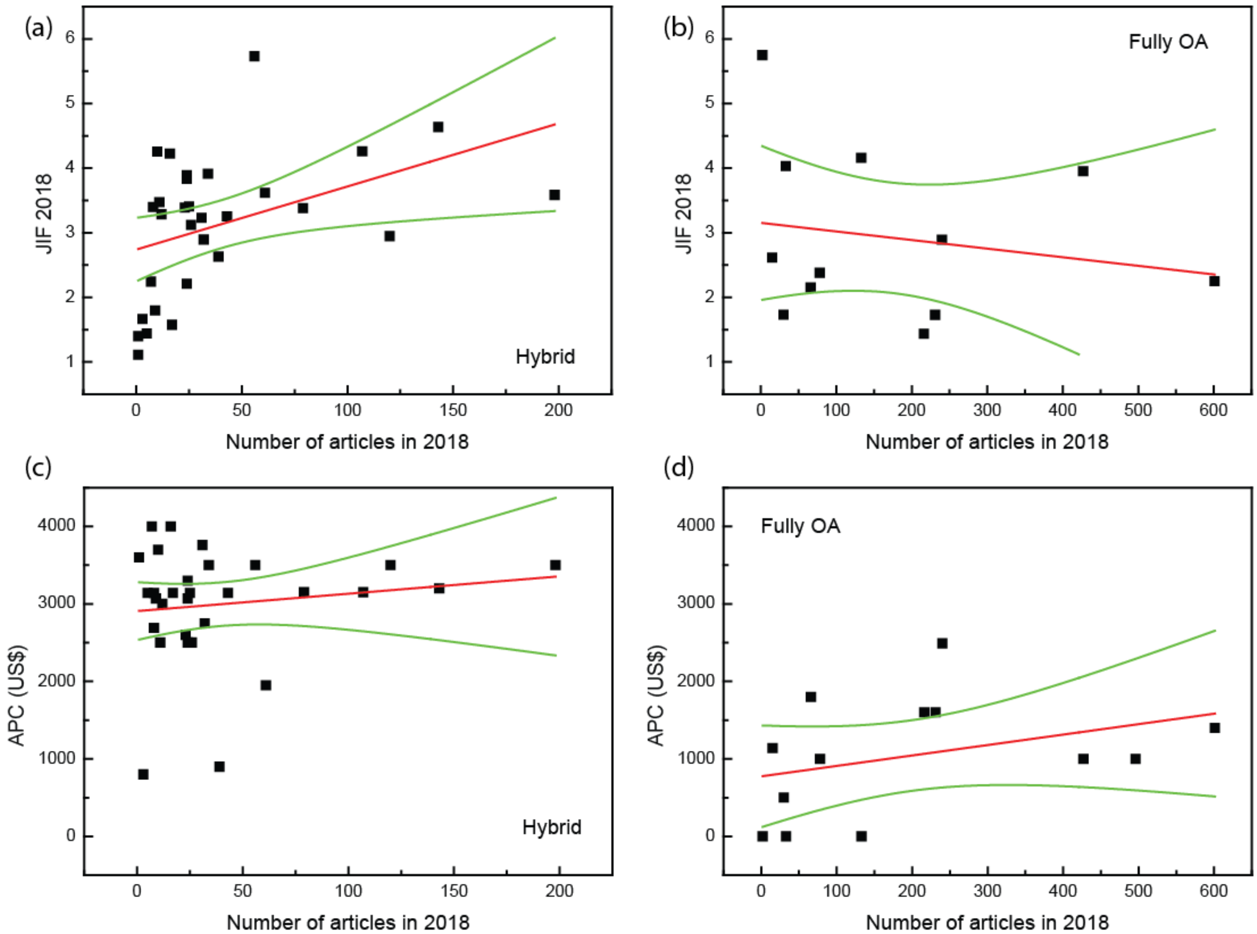

Figure 2 Number of ‘gold’ OA articles in 2018 as a function of JIF 2018 (a) for hybrid (Pearson's r = 0.42226) and (b) fully OA (Pearson's r = -0.19917) journals, and APC (US$) (c) for hybrid (Pearson's r = 0.13932) and (d) fully OA (Pearson's r = 0.34932) journals; red line corresponds to the linear fit, whereas green lines correspond to the 95% intervals.Data are from Scopus, Web of Science and journal webpages.

As illustrated in Figure 2a and 2b, there is a moderate positive relationship (Pearson’s r=0.42226) between the number of OA articles published in hybrids journals and Journal Impact Factor (JIF) whereas this relationship is weak and negative for fully OA journals (Pearson’s r=-0.19917). This indicates that the number of OA articles in hybrid journals was partly driven by the JIF in

2018/2019. The slightly higher number of articles in journals with a higher JIF is because there may be an inherent bias for researchers to prefer to publish in a journal with a higher JIF, while academic assessment systems continue to favor the 'publish or perish' approach [22]. Conversely (Figure 2c and 2d), there is a moderate and positive relationship (Pearson's r=0.34942) between the number of OA articles published in fully OA journals and the APC whereas none exists for hybrid journals (Pearson's r=-0.13932).

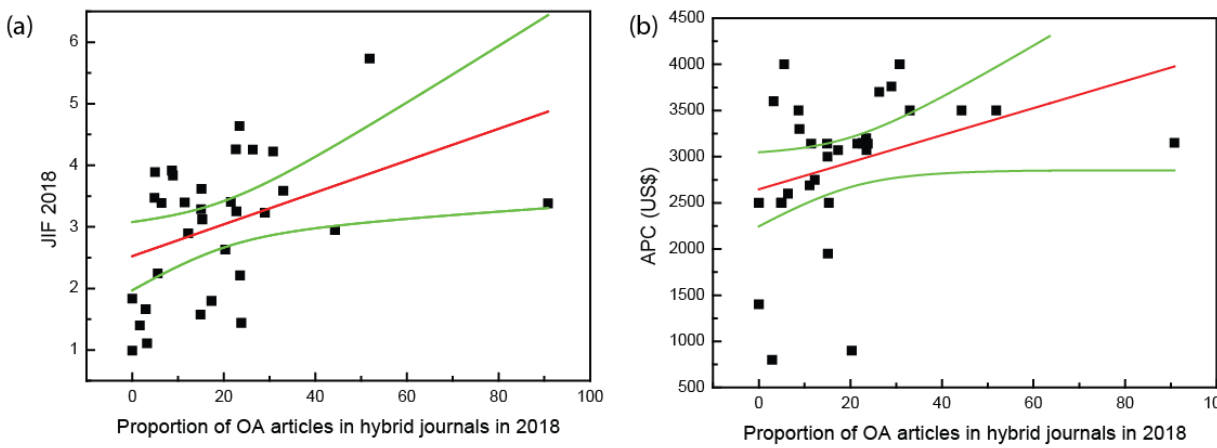

Figure 3 Proportion of 'gold' OA articles in hybrid journals in 2018 as a function of (a) JIF (Pearson's r = 0.4136) and (b) APC (US$) (Pearson's r = 0.3356); red line corresponds to the linear fit, whereas green lines correspond to the 95% intervals. Data are from Scopus, Web of Science and journal webpages.

If we look further at OA articles published in hybrid journals (*i.e.* the majority of historical journals in geochemistry), it seems that the proportion of OA articles tends to increase in journals with a higher JIF (Figure 3a; Pearson's r=0.4136). This relationship is weaker for APCs (Figure 3b; Pearson's r=0.3356).

During the OA transitional phase, publishing can become more difficult when an APC-based system without appropriate and commensurate additional financial support, especially when authors feel that this is the only route available to them. Thus, the APC-driven elements of OA can restrain journal choice for those individuals who want to or have to publish OA, but have restricted funding, and feel this is the only potential pathway to achieving OA publication and meet relevant OA policies. This is further complicated by constraints often indirectly imposed by publication-based evaluation systems, which it could be argued already restrict choice of how to disseminate research. Consequently, where funding is restricted the only option for some researchers to publish in a high impact journal, is to place their paper behind a subscription paywall.

This APC-dominated philosophy has created a complex system and hierarchy of financial privilege around OA publishing [5]. In this situation, those researchers who can afford to publish in OA journals, and in particular those which have a high JIF and charge high APCs are given an advantage over those who do not benefit from such financial security and are restricted in choice imposed by their inability to afford APCs. A third group can also be considered who are more ambivalent about making their work OA, stating that it is not their "job" (https://ministeresuprecherche.github.io/bso/). It would be of interest to also evaluate the demographic context of constraints on APCs on publication choice and the potential impact this can have on the visibility and re-use of geochemical research. Given that we know OA publishing tends to lead to increased 'impact' for researchers [23], the inherent bias of current APC-based OA publishing perpetuates this through the 'Matthew Effect' (*i.e.* the rich get richer and the poor get poorer), ultimately reinforcing the journal-coupled prestige economy that currently governs so much of our global research systems.

As illustrated in Figure 4, 'gold' OA is now mostly funded by institutions through 'Read and Publish' agreements or direct support from research funding agencies, and in some cases through researchers themselves. The non-OA and 'green' self-archiving routes are typically only funded by institutions and funding agencies (*i.e.* because there are no author-facing charges). If a researcher happens to be within an institution that can afford to pay both APC and journal subscriptions, this does not seem to be a big issue; the cost is supported externally, and thus there is no incentive for authors to publish in less-expensive venues which might be seen as having a lower 'value'. However, for other institutions (with lower budgets) and for their individuals, cost certainly remains a problem.

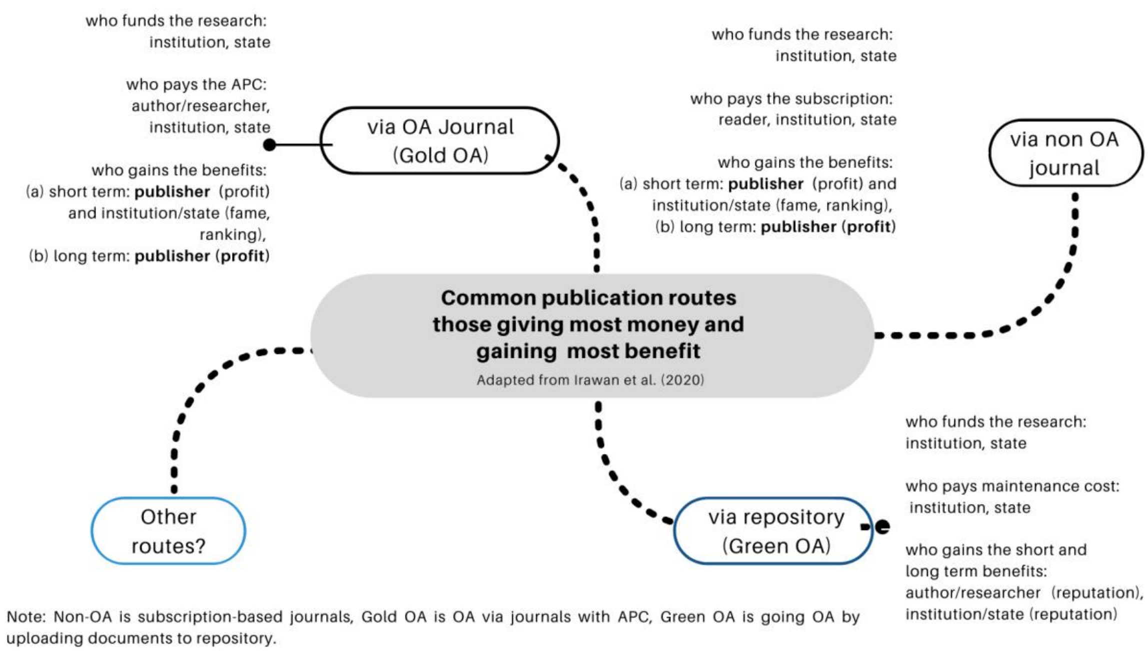

Figure 4 The academic publication route: a schematic representation of OA decision steps highlighting financial burden and benefit/reward for different stakeholders (adapted from Irawan et al. [24]).

To help resolve this inequity, there is a clear role for self-archiving of peer reviewed and accepted manuscripts (*i.e.* postprints), the 'green' way, in parallel to traditional, subscription-based journal publication. The 'green' OA route is cost-free for authors, and in terms of time usually only takes a matter of minutes to share articles online [25]. Often, it seems that awareness and understanding of 'green' OA are among the biggest barriers to more frequently engage with this practice. To pursue 'green' OA, numerous stable, long-term platforms are available such as institutional repositories and collaborative services such as EarthArXiv (https://eartharxiv.org/). It is unfortunate that the latter is infrequently used by the geochemical community relative to the scale of the total research outputs produced [6, 26], and its sustainability remains uncertain. Evidently, the current APC model imposed by many journals used be the geochemical community can have deleterious effects on researchers who have no funding, especially from lower income countries with a temptation to publish in 'predatory journals' that might have lower APC [27].

Overall, the Open Access landscape has become more complicated in the last decade, and not just for the geochemistry community. As highlighted by Mellor et al. [28], there is a "*Conflict between Open Access and Open Science"* and *"APCs are a key part of the problem, preprints are a key part of the solution*". For all of us, getting the right information about optimal practice and available publication options can be time-consuming, and it is our hope is that the geochemical community can move towards a more reliable, equitable, and transparent system of scholarly communication. Key first steps would be to ensure journals clarify their preprint/peer review/postprint policies [29], research datasets need to be FAIR (*i.e.* Findable, Accessible, Interoperable and Reusable) [30], and underlying data mining software should be free and open source, to the greatest extent possible. It is evident that FAIR data is already becoming widely adopted in the Earth Sciences [31] and Geochemistry communities [32], but further engagement is required. We feel that there is a strong connection between geochemical research and protecting our global environment, and we must ensure future research is being performed and subsequently communicated with this in mind.

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CRediT authorship contribution statement

Olivier Pourret: Conceptualization, Data Curation, Formal Analysis, Visualization, Writing Original draft, Writing - review & editing. Dasapta Erwin Irawan: Data Curation, Visualization, Writing - review & editing. Jonathan P. Tennant: Writing Original draft, Writing - review & editing. Andrew Hursthouse, Eric D. van Hullebusch: Writing - review & editing.

Declaration of competing interest

No potential conflicts of interest are reported by the authors.

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