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GEOSTANDARDS and GEOANALYTICAL RESEARCH

Geostandards and Geoanalytical Research Bibliographic Review 2020

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Here, we present the Geostandards and Geoanalytical Research Bibliographic Review 2020—an overview of scientific publications in 2020 that contribute important data for geoanalytical reference materials (RMs).

The use of RMs for calibration and quality control purposes of analytical techniques is essential for geoanalytical research and related scientific fields to obtain reliable results. This review encompasses RMs used in traditional geochemistry as well as for palaeoclimate research or environmental and other related applications. The systematic research comprises more than 7200 individual publications from nineteen scientific (i.e., peer-reviewed) journals. Additionally, some specific publications of further journals are included. A total of 630 of these articles present measurement results for RMs, which represent about 9% of all surveyed publications (Table 1; Figure 1). In 2020, publications included data that were obtained by new analytical developments or improved analytical protocols for established RMs. In addition, this year's survey identified some

Table 1.
Scientific journals from which relevant articles were reviewed

Journal	No. of papers with data for RMs
Analytical Science Advance	1
Analytical Sciences	7
Applied Geochemistry	1
Aquatic Geochemistry	4
Biological Trace Element Research	25
Bulletin of Environmental Contamination and Toxicology	5
Chemical Geology	83
Climate of the Past	1
Contributions to Mineralogy and Petrology	27
Earth and Planetary Science Letters	61
Environmental Geochemistry and Health	11
Environmental Monitoring and Assessment	12
Geochemical Perspectives Letters	2
Geochemistry, Geophysics, Geosystems	13
Geochimica et Cosmochimica Acta	95
Geostandards and Geoanalytical Research	35
Global Biogeochemical Cycle	1
International Journal of Earth Sciences	11
Journal of Analytical Atomic Spectrometry	54
Journal of Petrology	29
Journal of Radioanalytical and Nuclear Chemistry	17
Lithos	103
Mediterranean Archaeology and Archaeometry	1
Microchimica Acta	2
Mycorrhiza	1
Nature Geoscience	1
Spectrochimica Acta Part B	9
Talanta	17
The Holocene	1

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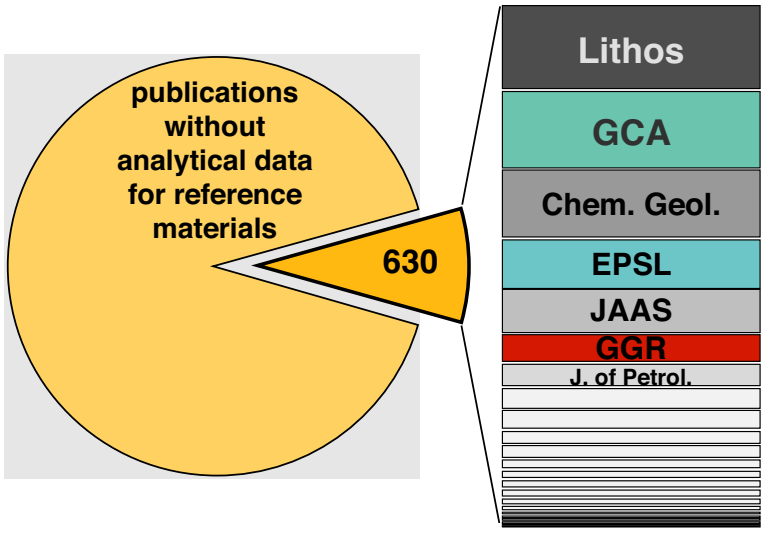

Figure 1. Pie chart showing the fraction of publications of specific journals in 2020 containing analytical data for RMs, which are contained in GeoReM, compared with the total number of reviewed publications.

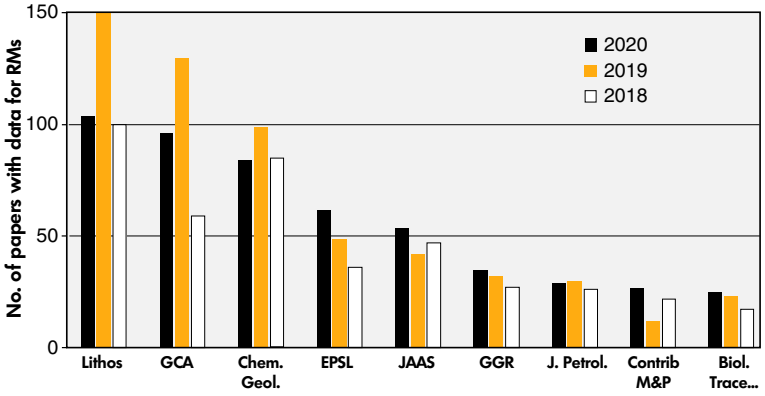

Figure 2. Bar chart showing the number of publications of specific journals containing analytical data for RMs in 2020 in comparison with 2019 and 2018 showing the constant amount of contributions.

recently developed RMs for various scientific topics. All data we refer to in this review have been compiled in the GeoReM database that is freely available online (Jochum *et al.* 2005, http://georem.mpch-mainz.gwdg.de). The recent Application Version 30 of GeoReM (as of January 2021), which includes more than 3800 RMs of numerous providers worldwide, will be replaced by Application Version 31 (March 2022). Appendix S1 contains the full list of publications surveyed for 2020, which are the topic of this review and also are included in the GeoReM database in alphabetical order. The GeoReM reference citation in Appendix S1 is preceded by a key code: at first, there is serial number followed by the GeoReM-ID, which enables fast and easy queries within the database. An overview of the names and abbreviations of RM providers is given in Appendix S2.

Since 2019, the Max Planck Society and many German universities have faced the challenge of limited access to some of the major publishing houses (e.g., Elsevier) as pointed out in the Geostandards and Geoanalytical Research Bibliographic Review 2019 (Weis *et al.* 2021). Therefore, some journals, which have been part of the research for the GGR Bibliographic Review for many years, cannot be accessed and surveyed in this review. For this reason and also to broaden the spectrum of research topics, this review includes for the second time journals from other publishers that present relevant data for RMs such as

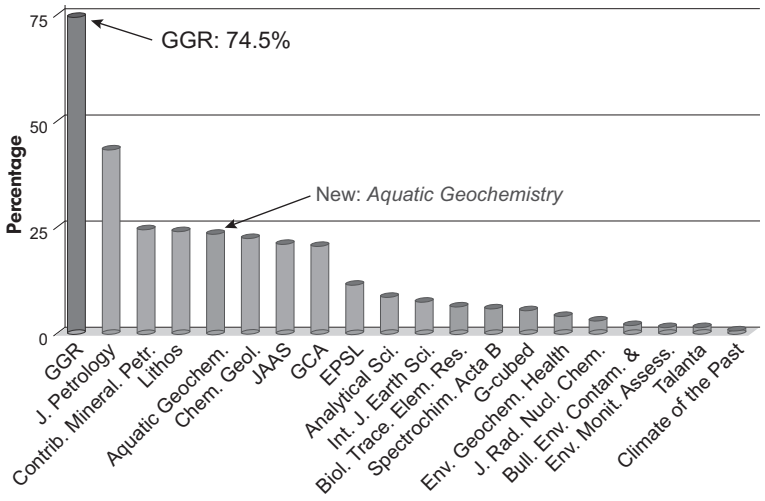

Figure 3. Bar chart illustrating the ratio (in per cent) of articles containing analytical data for RMs compared with the total number of articles published in specified journals in 2020. GGR holds the highest amount with 74.5%. Aquatic Geochemistry, surveyed for the first time, is among the group of journals with relatively high rates (23.5%).

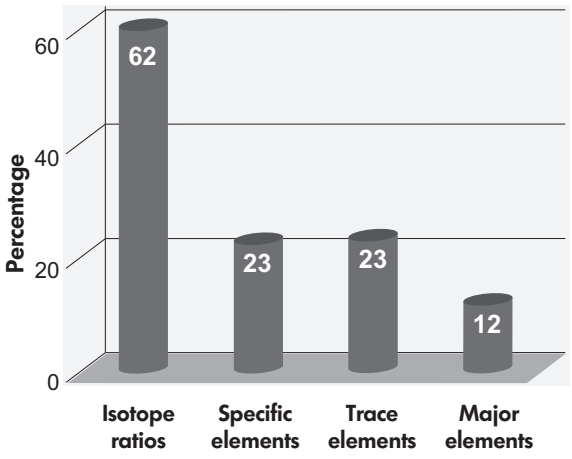

Figure 4. Percentage of papers that present analytical data of special geochemical categories demonstrating the importance of isotopic systems for geochemistry in comparison with several elemental categories.

'Bulletin of Environmental Contamination and Toxicology' (five publications in 2020) or 'Environmental Monitoring and Assessment' (twelve publications in 2020, Table 1; Figure 2). For the first time, we have added the journal 'Aquatic Geochemistry' to our review, which provides four publications that contribute 23.5% of analytical data on RMs relative to their total number of papers published in the issues of 2020 (Figure 3).

As in 2018 and 2019, again, the journals *Lithos*, *Geochimica et Cosmochimica Acta* and *Chemical Geology* provided the largest number of papers to the present study, with about 100 publications each, whereas the absolute number of articles relevant for this review is lower than 2019 (Weis *et al.* 2021; Figure 2). Considering the percentage figure, *Geostandards and Geoanalytical Research* has, as in former years, by far the highest ratio of papers referring to RMs with 74.5% followed by *Journal of Petrology* with 43.3% (Figure 3; Weis *et al.* 2021).

The share of scientific papers providing data for isotopic systems is very high (62%) compared with the number of papers referring to trace elements (23%) or even major elements (12%, Figure 4). The percentage of papers focusing on single or very few specific elements is with 23% relatively high compared with studies on major elements (12%, Figure 4).

Figure 5 shows the distribution of the most important providers of RMs within our study. 28% of the articles publish data for USGS RMs, 25% for NIST RMs and 11% for GSJ RMs. All other distributors have a share lower than 5%. USGS, NIST and GSJ are institutions providing many RMs of various matrices explaining the high amount of published data. GeoReM contains data for 424 RMs from NIST, 138 from USGS, 49 from GSJ, whereas for example there are only eight MPI-DING glasses, provided by the Max Planck Institute for Chemistry (Jochum *et al.* 2006). Currently, the USGS is not distributing its existing RMs due to an internal reorganisation. Nevertheless, the USGS Geological Reference Materials project will be proceeded both with development of new RMs and replacement RMs and also

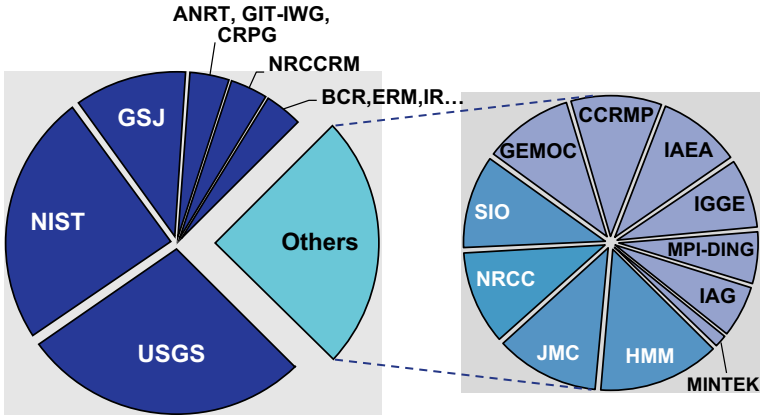

Figure 5. Number of publications containing analytical data for RMs of specific providers.

with updated documentation for the established RMs (https://www.usgs.gov/centers/geology%2C-geophysics%2C-and-geochemistry-science-center/science/development-usgs-geochemical).

The increasing relevance of isotopic systems, regarding both radiogenic and stable isotopes, is also reflected by a number of studies, which provide data sets consisting of values for many different RMS. In the following, we show some examples for thorough studies regarding one or more isotopic systems on a wide range of RMs: An *et al.* (2020) have presented new Ba isotope data for thirty-four geological reference materials of various matrices, such as silicates, carbonates, sediments and soils. These RMs cover a wide range of Ba mass fractions from 6.4 $\mu g\ g^{-1}$ up to 1900 $\mu g\ g^{-1}$. The zinc (Zn) stable isotope system is used to investigate natural and anthropogenic processes in various disciplines like Earth and planetary sciences or biomedical research. For there is a lack of well-characterised matrix-matched RMs, Druce *et al.* (2020) have published Zn isotopic data for eighteen reference materials including many previously uncharacterised RMs. A large study on Cd isotopes with results for rock and soil RMs of different providers covering a range of -0.251 to 0.632‰ relative to NIST SRM 3108 has been conducted by Liu *et al.* using a MC-ICP-MS technique with double spike correction (Liu *et al.* 2020). Isotopic signatures of Pb, Nd, Sr, Zn, Cu and Fe are commonly used as sensitive geochemical tracers. Vanderstraeten *et al.* (2020) developed a chromatographic protocol to separate the six elements of interest, which enables the amount of material required for sample preparation and isotopic analysis to be minimised by combining sequentially several columns. In addition to data for several RMs, they reported the first combined isotopic data for two dust RMs, namely BCR-23 and ATD.

In 2020, several new RMs have been characterised of which we present a few samples here. For many analytical techniques such as microanalysis, it is essential to use matrix-matched RMs for calibration and quality control. A set of four selenium-rich rocks (GBW07397 to GBW07400) has been formalised as CRMs for mass fractions of selenium, arsenic, copper, zinc, molybdenum, cadmium, lead, vanadium and silver by Tang *et al.* (2020). Zhang *et al.* (2020) introduced the RMJG rutile - a new microanalytical RM of natural origin for U-Pb dating and Hf isotopic analysis. Zircon is a mineral widely used in U-Pb geochronology, but also for trace element mass fractions and Li, O and Hf isotopic studies. Many of the established natural zircon RMs are nearly exhausted. Therefore, there is need of additional and replacement RMs. A new natural zircon RM 'SA01' is proposed by Huang *et al.* (2020) on the basis that this zircon megacryst is homogenous and therefore suitable for U-Pb geochronology as well as O and Hf isotope geochemistry by microanalytical techniques. For environmental and biological research, Haraguchi *et al.* (2020) developed the CRM 'NIMD-01' for the analysis of mercury speciation and some trace elements in human hair. Synthetic RMs have the advantage of offering higher homogeneity compared with many natural materials. Therefore, Ke *et al.* (2020) have synthesised and characterised a $CaWO_4$ single crystal (CaW-1) to quantitatively calibrate REE mass fractions in natural scheelite samples by microanalytical techniques such as LA-ICP-MS. The established RMs of Fe and Mg isotopic compositions are almost out of stock, and González de Vega *et al.* (2020) present two new isotopic RMs, 'IRMM-524A and ERM-AE143' as replacements, which can be used for high-precision isotopic measurements of Fe and Mg. Additionally, they published the Fe and Mg isotopic compositions of more than thirty geological and biological RMs. Bao *et al.* (2020) prepared a magnesium standard

solution 'GSB-Mg' as a RM for Mg isotopic measurements. The isotopic composition of GSB-Mg is similar to Mg isotopic compositions of carbonate rocks and marine sediments, and therefore, it is suitable as a RM for samples with these matrices (Bao *et al.* 2020).

These are a few examples for new developments of RMs with different matrices and for various fields of science from traditional geochemistry to biomedicine. This review shows that a substantial number of publications in 2020 focussed on both newly developed RMs and analytical data achieved by improved methods. This reflects the persistent importance of RMs in numerous analytical techniques across geoanalytical and related research.

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Data availability statement

The data that supports the findings of this study are available in the supplementary material of this article and in the GeoReM database (http://georem.mpch-mainz.gwdg.de/).

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Supporting information

The following supporting information may be found in the online version of this article:

Appendix S1. List of reviewed publications from 2020.

Appendix S2. Abbreviations used for reference material providers.

This material is available from: http://onlinelibrary.wiley.com/doi/10.1111/ggr.12421/abstract (This link will take you to the article abstract).