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GEOSTANDARDS and GEOANALYTICAL RESEARCH

Geostandards and Geoanalytical Research Bibliographic Review 2018

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The GGR bibliographic review is specifically designed to give an overview of publications of the past year (in this case 2018) and presents analytical data for established and widely used reference materials (RMs) and certified RMs (CRMs), and highlights recently developed and characterised RMs. This research involves the careful examination of about 8400 publications from twenty scientific journals in the fields of analytical chemistry, geochemistry, palaeoclimate research and environmental research. About 630 of these publications contain analytical data for RMs (Table 1, Figure 1). These analytical values are included in the GeoReM database (Jochum *et al.* 2005; http://georem.mpch-mainz.gwdg.de). GeoReM is freely accessible to the scientific community and provides published analytical, compiled and certified values of RMs, which are important in geoanalysis and related scientific fields. All publications of 2018 included in GeoReM are listed in Appendix S1. The reference citation is preceded by a key code: the first two digits stand for the year of publication (here: 18) followed by the serial number for the specific year and the GeoReM-ID, which allows easy access to the GeoReM database. Every entry is followed by a concise summary of the elements/isotopes for which measurement results are published, as well as the relevant reference materials and their producers. An overview of the names and abbreviations of reference material providers is given in Appendix S2.

More than 50% of the publications provide data on radiogenic or stable isotopes, whereas less than 10% present data sets for major elements and 16% substantial data sets for trace elements (Figure 1). Some 25% of the papers publish data just for a very few selected elements. Additional to the classical isotopic systems such as Sr, Pb or Nd, various isotopic systems have become more important and measurement results for them have been enabled by progress in analytical techniques (Linge *et al.* 2017).

A comparison of the surveyed journals shows the high impact of GGR, which has, as in former years (Weis *et al.* 2018), at 71% the highest proportion of publications containing analytical data for RMs, followed by Lithos with 27% and Journal of Analytical Atomic Spectrometry with 23% (Figure 2). In absolute numbers, Lithos and Chemical Geology deliver the main contributions to this review with 100 and 85 publications in 2018, respectively (Figure 3, Table 1). Figure 4 shows the number of papers in 2018, which contain data for RMs of the most common providers. The largest numbers of published data in

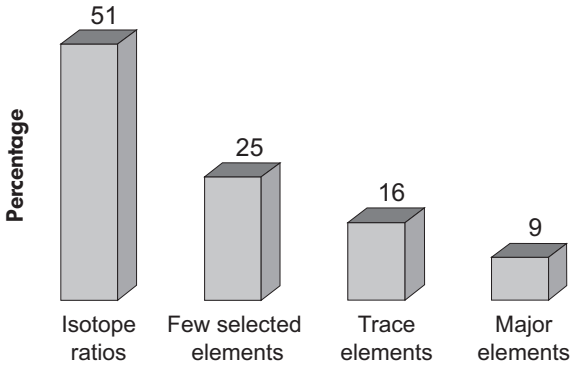

Figure 1. Percentage of papers which present analytical data of special geochemical categories such as isotope ratios, major element sets (MJs), substantial trace element sets (TEs) and few selected elements.

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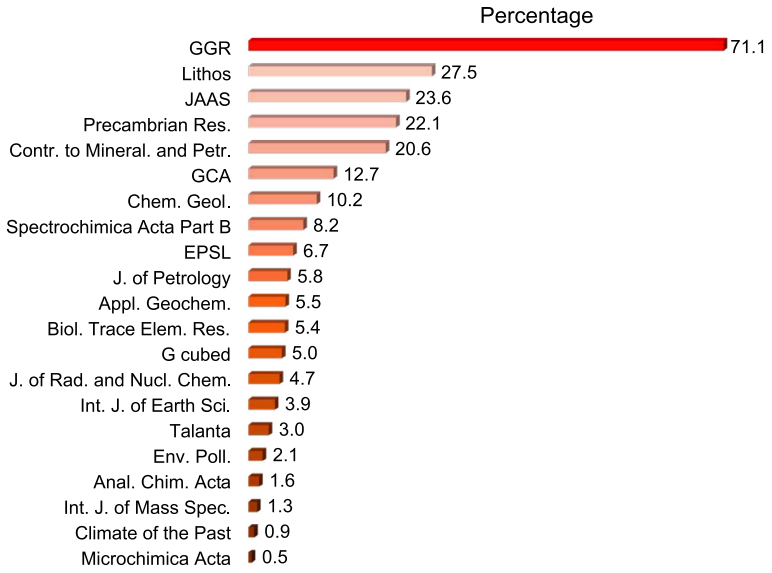

Figure 2. Bar chart illustrating the ratio (in per cent) of articles containing analytical data for RMs compared with the total number of articles published in specified journals in 2018. [Colour figure can be viewed at wileyonlinelibrary.com]

2018 are available for RMs and CRMs distributed by the National Institute of Standards and Technology (NIST), the United States Geological Survey (USGS) and the Geological Survey of Japan (GSJ) with a widespread assortment of RMs of various types. Additionally, there are also providers of a small number of very specific RMs, for which many new analytical data are available.

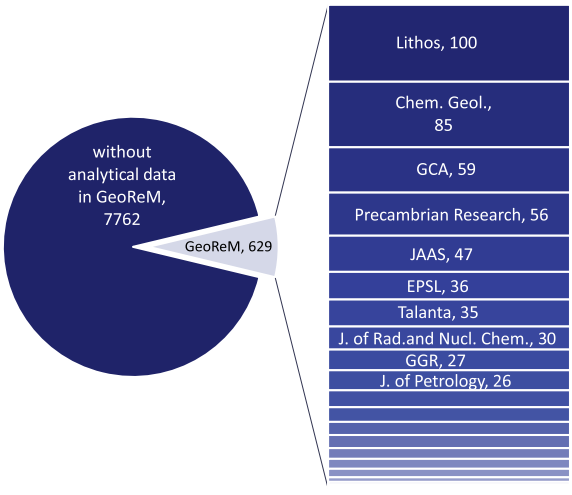

Figure 3. Number of publications of specific journals in 2018 containing analytical data for RMs, which are included in GeoReM, compared with the total number of researched publications. [Colour figure can be viewed at wileyonlinelibrary.com]

The importance of isotopic systems in geochemistry and related fields is confirmed by the introduction of new isotopic RMs as well as by substantial isotopic studies on numerous RMs, which are presented in 2018. In the following paragraphs, some examples are shown.

Richter *et al.* (2018) prepared and certified with IRMM-2019-2029 a set of uranium nitrate solutions. The JMC 3-0749L Zn solution for Zn isotopes is nearly exhausted. Therefore, a new RM as a replacement is urgently needed. A zinc metal reference material from NIST – NIST SRM 683 – was analysed for its isotopic composition and calibrated as a new reference material for Zn isotope analysis by Yang *et al.* (2018). Also, there is a lack of data sets for Se isotopes, which is why Yierpan *et al.* (2018) determined Se and Te with isotope dilution ICP-MS (ID-ICP-MS) and double-spike MC-ICP-MS in several RMs. ID-(MC)-ICP-MS was also used for the determination of In and Sn in sixteen geological RMs by Kirchenbaur *et al.* (2018).

As there is a need of molybdenum RMs, Liu *et al.* (2018) performed a preparation and characterisation of CRMs of three molybdenum ores (GBW07141 to GBW07143, abbreviated as GMo-1 to GMo-3) and one molybdenum concentrate (GBW07144, abbreviated as GMo-4) with certified values for up to twenty-six elements.

A large number of papers publish data for zircon reference materials such as zircon 91500 from HMM (Harvard Mineralogical Museum, USA; Wiedenbeck *et al.*

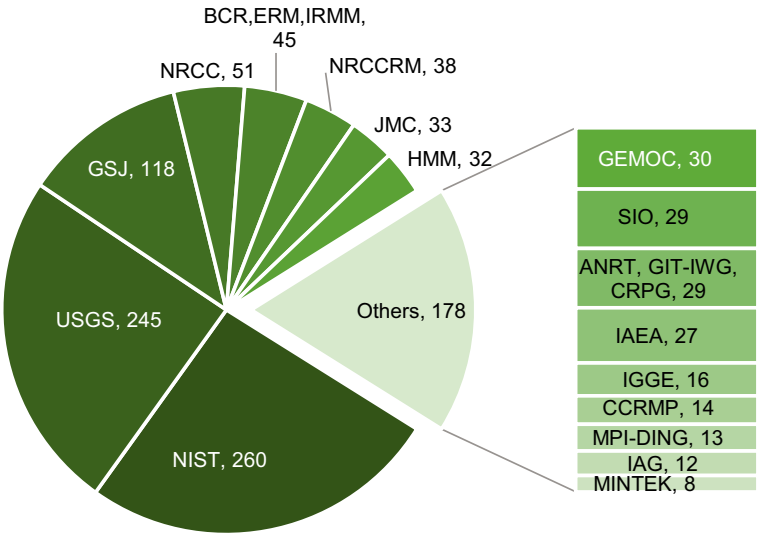

Figure 4. Number of publications containing analytical data for RMs of specific providers. [Colour figure can be viewed at wileyonlinelibrary.com]

1995; thirty-five publications) and GJ-1 from GEMOC (National Key Centre for *Geochemical Evolution* and *Metallogeny* of *Continents, Macquarie University, Australia*; thirty values). Also, the Plešovice zircon (Sláma *et al.* 2008) with nineteen published values in 2018 plays an important role. In 2018, several new natural zircon RMs were characterised: MAD 559, a zircon from Madagascar, was introduced as a new microanalytical reference material for calibrating trace element mass fractions in zircon measured by SIMS (Coble *et al.* 2018). GZ7 and GZ8, two zircons from Sri Lanka, were characterised as microanalytical RMs for SIMS U-Pb geochronology by Nasdala *et al.* (2018). A new natural rutile reference material R632 was presented, suitable for U-Pb dating by microanalytical methods (Axelsson *et al.* 2018).

Laser ablation MC-ICP-MS was used by Xu *et al.* (2018) for the determination of Sm-Nd isotopic compositions in several RMs. Shalev *et al.* (2018) realised an interlaboratory comparison to obtain reliable Mg isotope values for eight RMs. In the field of microanalytical techniques, Evans and Müller (2018) present a considerable laser ablation ICP-MS study with analytical results for various microanalytical RMs, including carbonates such as MACS-3 (USGS), phosphates and the MPI-DING-glasses (Jochum *et al.* 2006, 2012, Klemme *et al.* 2008). Weber *et al.* (2018) tested the suitability of carbonate and phosphate RMs for microanalysis by LA-MC-ICP-MS and provide Sr isotopic data for these materials derived by LA-MC-ICP-MS and solution ICP-MS.

De Hoog (2018) proposes a calibration strategy to correct for matrix effects during SIMS measurements and presents new preferred values for Li for several reference materials from MPI-DING, USGS, Smithsonian and NIST. Wu *et al.* (2018) optimised and compared sample preparation techniques for LA-ICP-MS bulk analysis (ultrafine powder pellet and flux-free fusion glass) and applied them to granitoid RMs from different providers such as USGS, GSJ and NRCCRM.

Table 1.
Scientific journals from which relevant articles were reviewed

Journal	No. of papers
Analytica Chimica Acta	11
Applied Geochemistry	14
Biological Trace Element Research	17
Chemical Geology	85
Climate of the Past	1
Contributions to Mineralogy and Petrology	22
Earth and Planetary Science Letters	36
Environmental Pollution	19
Geochemistry, Geophysics, Geosystems	13
Geochimica et Cosmochimica Acta	59
Geostandards and Geoanalytical Research	27
International Journal of Earth Sciences	6
International Journal of Mass Spectrometry	2
Journal of Analytical Atomic Spectrometry	47
Journal of Petrology	26
Journal of Radioanalytical and Nuclear Chemistry	30
Lithos	100
Marine Pollution Bulletin	1
Microchimica Acta	3
New Phytologist	1
Precambrian Research	56
Quaternary Science Reviews	1
Spectrochimica Acta Part B	17
Talanta	35

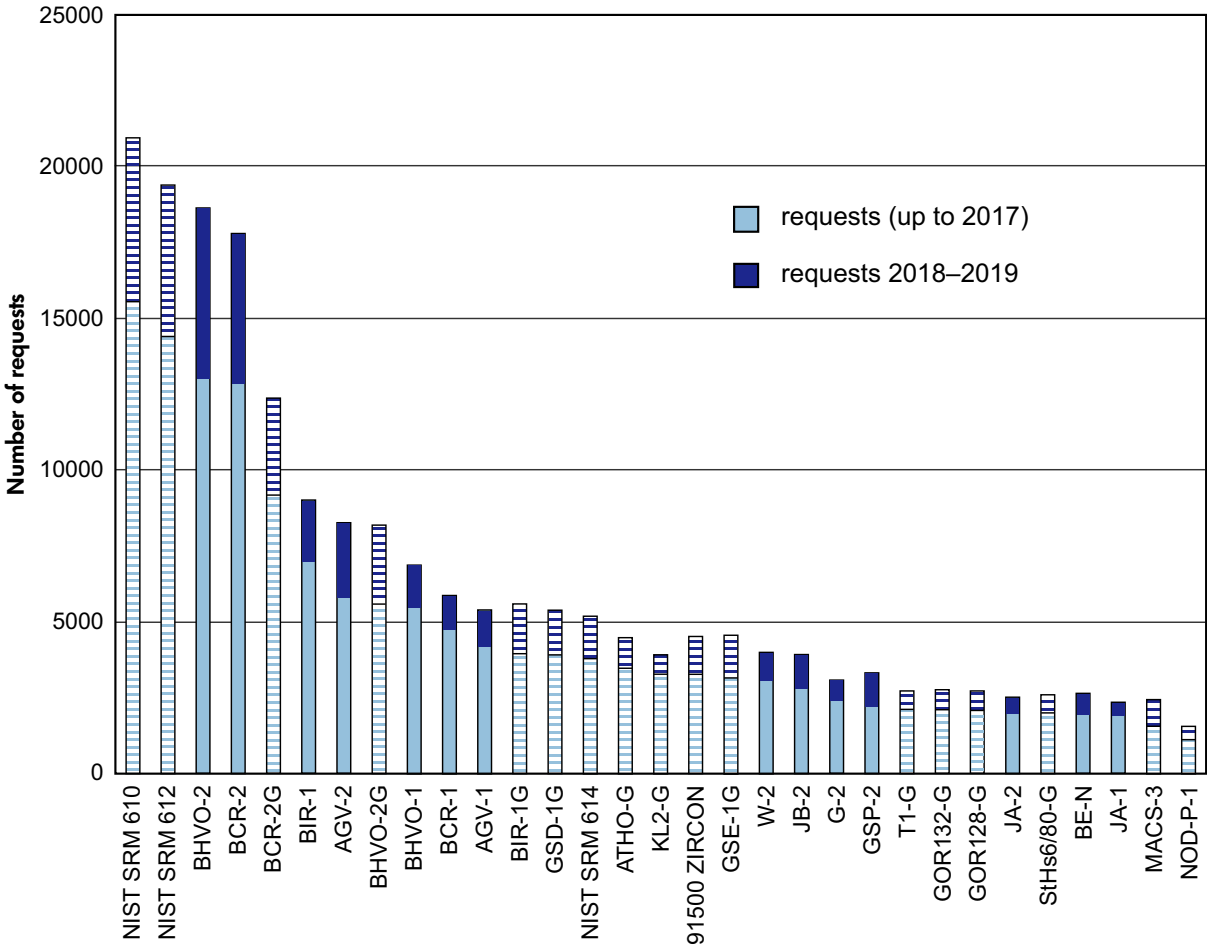

Figure 5. Number of accesses to the GeoReM database in 2018 for thirty-one different RMs, in decreasing order. [Colour figure can be viewed at wileyonlinelibrary.com]

In many 2018 publications, the applications for widely used RMs are increased by characterising new parameters, especially stable isotopic compositions. Brett *et al.* (2018) publish precise thallium isotopic compositions for sixteen geological RMs from different providers such as the USGS, CRPG, NIST and others. High-precision cadmium isotope ratios for a series of standard solutions and geological RMs from various providers such as BAM, IGGE and others are reported by Li *et al* (2018).

For the accurate determination of nitrogen mass fractions and $\delta^{15}N$ of silicate rocks with a low nitrogen mass fraction of < 200 μg g^{-1}, a method using a high-temperature sealed-tube combustion technique coupled with a continuous-flow isotope-ratio mass spectrometer (CF-IRMS) was developed and used for the analysis of USGS BHVO-2 and BCR-2 (Feng *et al.* 2018).

There are few analytical data available for halogens, and only some RMs are well characterised for halogens. Recently, there have been studies to fill this gap (e.g., Marks *et al.* 2017). In 2018, there are two substantial publications providing data for halogens: Kendrick *et al.* (2018) publish data for F, Cl, Br and I in thirteen RMs mainly from the USGS, NIST and GSJ, whereas He *et al.* (2018) present Br and I values for fifty-three Chinese RMs.

In order to measure radionuclides in various materials such as environmental samples and food samples after the accident at the Fukushima nuclear power plant, the development of appropriate RMs became necessary. Miura *et al.* (2018) introduce two recently prepared and certified fish meat and bone ash RMs for anthropogenic nuclides and the results of an interlaboratory comparison.

Appendix S3 presents a list of the 100 most requested RMs within the GeoReM database in 2018 (Jochum *et al.* 2005). Figure 5 shows the number of requests for the thirty-one most searched for RMs in GeoReM. The most frequent searched RMs are the NIST SRM 6x series glasses and BHVO-2 and BCR-2 from the USGS. Seventeen of the most requested

RMs are microanalytical RMs, which also confirm the increasing relevance of microanalytical techniques such as LA-ICP-MS and SIMS.

Acknowledgements

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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Supporting information

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

Appendix S1. Details of researched papers published in 2018.

Appendix S2. Abbreviations for reference material providers.

Appendix S3. List of the hundred most requested RMs from the GeoReM database.

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