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...
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.

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 Mineralological Museum, USA; Wiedenbeck et al. 1995).
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            |
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 δ¹⁵N 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

![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)](image-url)
RMAs are microanalytical RMs, which also confirm the increasing relevance of microanalytical techniques such as LA-ICP-MS and SIMS.

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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.

References

Axelsson E., Pope J., Berndt J., Corfu F., Mezger K. and Raith M.M. (2018)
Rutile R632 – A new natural reference material for U-Pb and Zr determination. Geostandards and Geoanalytical Research, 42, 319–338.

Brett A., Prytulak J., Hammond S.J. and Rehkämper M. (2018)
Thallium mass fraction and stable isotope ratios of sixteen geological reference materials. Geostandards and Geoanalytical Research, 42, 339–360.

Coble M.A., Vazquez J.A., Barth A.P., Wooden J., Bums D., Kylander-Clark A., Jackson S. and Vennari C.E. (2018)
Trace element characterisation of MAD-559 zircon reference material for ion microprobe analysis. Geostandards and Geoanalytical Research, 42, 481–497.

De Hoog J.C.M. (2018)
Matrix effects during SIMS measurement of the lithium mass fractions of silicate glasses: Correction procedures and updated preferred values of reference materials. Geostandards and Geoanalytical Research, 42, 513–522.

Evans D. and Müller W. (2018)
Automated extraction of a five-year LA-ICP-MS trace element data set of ten common glass and carbonate reference materials: Long-term data quality, optimisation and laser cell homogeneity. Geostandards and Geoanalytical Research, 42, 159–188.

Feng L., Li H. and Liu W. (2018)
Nitrogen mass fraction and isotope determinations in geological reference materials using sealed-tube combustion coupled with continuous-flow isotope-ratio mass spectrometry. Geostandards and Geoanalytical Research, 42, 539–548.

He T., Xie J., Hu Z., Liu T., Zhang W., Chen H., Liu Y., Zong K. and Li M. (2018)
A rapid acid digestion technique for the simultaneous determination of bromine and iodine in fifty-three Chinese soils and sediments by ICP-MS. Geostandards and Geoanalytical Research, 42, 309–318.

Jochum K.P., Nohl U., Herwig K., Lammel E., Stoll B. and Hofmann A.W. (2005)
GeoReM: A new geochemical database for reference materials and isotopic standards. Geostandards and Geoanalytical Research, 29, 333–338.

Jochum K.P., Stoll B., Herwig K., Wildboord M., Hofmann A.W., Amini M., Aarburg S., Abouchami W., Hellebrand E., Mocek B., Raczek I., Stracke A., Alard O., Bouman C., Becker S., Ducking M., Bratz H., Klemd R., de Bruin D., Carll D., Cornell D., de Hoog C.-J., Dalpe C., Danyushevsky L., Eisenhauer A., Gao Y., Snow J.E., Groschopf H., Gunther D., Latkoczy C., Guillong M., Hauti E.H., Hofer H.E., Lahaye Y., Horz K., Jacob D.E., Kasemann S.A., Kent A.J.R., Ludwig T., Zack T., Mason P.R.D., Meixner A., Rosner M., Misawa K., Nash B.P., Pfander J., Premo W.R., Sun W.D., Tiepolo M., Vannucci R., Vennemann T., Wayne D. and Woodhead J.D. (2006)
MPLDING reference glasses for in situ microanalysis: New reference values for element concentrations and isotope ratios. Geochemistry, Geophysics, Geosystems, 7, 1–44.

Jochum K.P., Schols D., Stoll B., Weis U., Wilson S.A., Yang Q., Schwab A., Börner N., Jacob D.E. and Andreae M.O. (2012)
Accurate trace element analysis of speleothems and biogenic calcium carbonates by LA-ICP-MS. Chemical Geology, 318–319, 31–44.

Kendrick M.A., D’Andres J., Holden P. and Ireland T. (2018)
Hologens (F, Cl, Br, I) in thirteen USGS, GSJ and NIST international rock and glass reference materials. Geostandards and Geoanalytical Research, 42, 499–511.

Kirchenbaur M., Heuser A., Bragagni A. and Wonbacher F. (2018)
Determination of In and Sn mass fractions in sixteen geological reference materials by isotope dilution MC-ICP-MS. Geostandards and Geoanalytical Research, 42, 361–377.

Klemme S., Prawatke S., Munker C., Magee C.W., Lahaye Y., Zack T., Kasemann S.A., Cabato E.J.A. and Kaeser B. (2008)
Synthesis and preliminary characterisation of new silicate, phosphate and titanite reference glasses. Geostandards and Geoanalytical Research, 32, 39–54.

Li D., Li M.-L., Liu W.-R., Qin Z.-Z. and Liu S.-A. (2018)
Cadmium isotope ratios of standard solutions and 87Sr/86Sr in soils and sediments by ICP-MS. Geostandards and Geoanalytical Research, 42, 593–605.

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Linge KL, Bedard LP, Bugai R, Enzweiler J, Jochum KP, Killian R, Liu J, Marin-Carbonne J, Merchel S, Munnik F, Morales L.F.G, Rollan-Bard C, Sauders A.K., Sylvester P.J. and Weis U. (2017) Geostandards and Geoanalytical Research, 41, 493–562.

Liu M, Cheng Z, Huang H, Gu T, Yan W, Wang L and Bai J. (2018) Certified reference materials of molybdenum ore and molybdenum concentrate (GBW07141, GBW07142, GBW07143 and GBW07144). Geostandards and Geoanalytical Research, 42, 549–557.

Marks M.A.W, Kendrick MA, Eby G.N, Zack T and Wenzel T. (2017)Preparation and certification of certified reference materials of fish meat and ashed bone for determination of 90Sr and 89Sr. Geostandards and Geoanalytical Research, 41, 107–122.

Miura T, Minai Y, Yonezawa C, Kakita K, Kojima L, Okada Y, Uematsu Y, Okada A and Hiri S. (2018)Preparation and certification of certified reference materials of fish meat and ashed bone for determination of 90Sr and 89Sr. Geostandards and Geoanalytical Research, 41, 107–122.

Nasdala L, Goro F, Schoene B, Topper S.R, Wall C.J, Schmitz M.D, Ovtcharova M, Schaltegger U, Kennedy A.K, Kronz A, Reiners P.W, Yang Y-H, Wu F-Y, Gain S.E.M, Griffin W.L, Szymanoski D, Chanmuang N.C, Ende M, Vallely J.W, Spicuzza M.J, Wathanachaisaeng B and Giester G. (2018)Two zircon reference materials for SIMS U-Pb geochronology. Geostandards and Geoanalytical Research, 42, 431–457.

Richter S, Venchiariutti C, Hennessy C, Jacobsson U, Bujak R, Truyens J and Aregbe Y. (2018)Preparation and certification of the uranium nitrate solution reference material series IRMM-2019 to IRMM-2029 for the isotopic composition. Journal of Radioanalytical and Nuclear Chemistry, 318, 347–352.

Shalev N, Farkas J, Fietzke J, Novak M, Schuessler J.A, Hogge von Strandmann P.A.E and Torber P.B. (2018)Mg isotope interlaboratory comparison of reference materials from earth-surface low-temperature environments. Geostandards and Geoanalytical Research, 42, 205–221.

Slama J, Kosler J, Condon D.J, Crowley J.L, Gerdes A, Hanchar J.M, Horstwood M.S.A, Morris G.A, Nasdala L, Norberg N, Schaltegger U, Schoene B, Tubrett M.N. and Whitehouse M.J. (2008)Piezoacive zircon – A new natural reference material for U-Pb and Hf isotopic microanalysis. Chemical Geology, 249, 1–35.

Weber M, Lugli F, Jochum K.P, Cipriani A and Scholz D. (2018)Calcium carbonate and phosphate reference materials for monitoring bulk and microanalytical determination of Sr isotopes. Geostandards and Geoanalytical Research, 42, 77–89.

Weis U, Kaiser V, Leisgang I, Nohl U, Reichstein A, Schwager B, Stoll B, Zwillich F. and Jochum K.P. (2018)Geostandards and Geoanalytical Research bibliographic review 2017. Geostandards and Geoanalytical Research, 42, 425–430.

Wiedenbeck M, Allé P, Corfu F, Griffin W.L, Meier M, Oberti F, von Quadt A, Roddick J.C and Spiegel W. (1995)Three natural zircon standards for U-Th-Pb, Lu-Hf, trace element and REE analyses. Geostandards Newsletter, 19, 1–23.

Wu S, Karius V, Schmidt B.C, Simon K and Womer G. (2018)Comparison of ultraline powder pellet and flux-free fusion glass for bulk analysis of granitoids by laser ablation-inductively coupled plasma-mass spectrometry. Geostandards and Geoanalytical Research, 42, 575–591.

Xu L, Yang J, Ni Q, Yang Y, Hu Z, Liu Y, Wu Y, Luo T and Hu S. (2018)Determination of Sm-Nd isotopic compositions in fifteen geological materials using laser ablation-MC-ICP-MS and application to monazite geochronology of metasedimentary rock in the North China Craton. Geostandards and Geoanalytical Research, 42, 379–394.

Yang Y, Zhang X, Liu S-A, Zhou T, Fan H, Yu H, Cheng W and Huang F. (2018)Calibrating NIST SRM 683 as a new international reference standard for Zn isotopes. Journal of Analytical Atomic Spectrometry, 33, 1777–1783.

Yierpan A, Konig S, Labidi J, Kurzawa T, Babechuk M.G and Schoenberg R. (2018)Chemical sample processing for combined selenium isotope and selenium-tellurium elemental investigation of the Earth’s igneous reservoirs. Geochimica, Geophysics, Geosystems, 19, 516–533.