



## PRISMA 2020 Checklist

| Section and Topic    | Item # | Checklist item  | Location where item is reported |
|----------------------|--------|---|---------------------------------|
| <b>TITLE</b>         |        |   |                                 |
| Title                | 1      | <b>Identify the report as a systematic review.</b><br>Application of Raman spectroscopy for the study of shocked zircon from terrestrial and lunar impactites: a systematic literature review.  | Lines: 2-4                      |
| <b>ABSTRACT</b>      |        |   |                                 |
| Abstract             | 2      | <b>See the PRISMA 2020 for Abstracts checklist.</b><br>The author summarized the objective, eligibility criteria, databases searched, methods for selecting studies, synthesis of results, along with the results, for the review:<br>“A highly resistant mineral, zircon is capable of preserving information about impact processes. The present review paper is aimed at determining the extent to which Raman spectroscopy can be applied to studying shocked zircons from impactites to identify issues and gaps in the usage of Raman spectroscopy, both in order to highlight recent achievements, and to identify the most effective applications. Method: Following PRISMA guidelines, the review is based on peer-reviewed papers indexed in Google Scholar, Scopus and Web of Science databases up to 5 April 2022. Inclusion criteria: application of Raman spectroscopy to the study of shocked zircon from terrestrial and lunar impactites. Results: A total of 25 research papers were selected. Of these, 18 publications studied terrestrial impact craters, while 7 publications focused on lunar breccia samples. Nineteen of the studies were focused on the acquisition of new data on geological structures, while six examined zircon microstructures, their textural and spectroscopic features. Conclusions: The application of Raman spectroscopy to impactite zircons is linked with its application to zircon grains of various terrestrial rocks and the progress of the electron backscatter diffraction (EBSD) technique in the early 2000s. Raman spectroscopy was concluded to be most effective when applied to examining the degree of damage, as well as identifying phases and misorientation in zircon | Lines: 9-23                     |
| <b>INTRODUCTION</b>  |        |   |                                 |
| Rationale            | 3      | <b>Describe the rationale for the review in the context of existing knowledge.</b><br>The analysis of the publications shows that in the study of zircons from impact craters, the main method was by electron backscatter diffraction on a scanning electron microscope (EBSD-SEM), and only a small number of publications used the method of Raman spectroscopy. There have been a few attempts to investigate deformed zircon grains with Raman spectroscopy in combination with EBSD [23,29,30]. It was demonstrated that shock deformations also affect the Raman spectra of zircon. On the contrary, in studies of terrestrial zircons of non-impact origin, Raman was quite often used in comparison with EBSD. There is a gap in the experience of the two scientific communities. The underestimation of the information content of Raman spectroscopy, and its capabilities, hinders possible progress in the study of impact zircons.   | Lines: 91-96                    |
| Objectives           | 4      | <b>Provide an explicit statement of the objective(s) or question(s) the review addresses.</b><br>“In reviewing this information three aims are: (1) to determine the extent to which peer-reviewed scientific publications applied Raman spectroscopy for study shocked zircon from terrestrial and lunar impactites over time, (1) to attract attention and encourage specialists to use the Raman spectroscopy method in the study of shocked zircons from impactites, (3) to highlight recent achievements and applications of the Raman spectroscopy.”  | Lines: 102-107                  |
| <b>METHODS</b>       |        |   |                                 |
| Eligibility criteria | 5      | <b>Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.</b><br>Eligibility criteria: “peer-reviewed studies in English language about the application of Raman spectroscopy to investigate shocked zircon obtained from natural terrestrial and lunar impactites”.   | Lines: 131-133                  |



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| Information sources     | 6      | <p><b>Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.</b></p> <p>“The search was based on Google Scholar, Scopus and Web of Science databases.”</p> <p>“The search was carried out 05 April 2022.”</p> <p>“References in papers.”</p>  | <p>Line: 125</p> <p>Line: 144</p> |
| Search strategy         | 7      | <p><b>Present the full search strategies for all databases, registers and websites, including any filters and limits used.</b></p> <p>The keywords chosen were: (1) “Raman”, (2) “shocked zircon”, (3) “impactites”, (4) “lunar breccia”. A set of keywords defines: (1) the method of investigation, (2) the group of minerals, and (3, 4) the geological rocks where they occur. Results or conclusions were not included in the search criteria. The analysis of the results obtained in papers was the subject of the “results” and “discussion” section of this work. To guarantee the eligibility criteria “application of Raman spectroscopy to investigate shocked zircon from natural terrestrial and lunar impactites”, two combinations of keywords were included in the search strategy: A = {(1) and (2) and (3)}, B = {(1) and (2) and (4)} (Table 1, Figure 1). By examining the bibliographies of the remaining papers and other sources, an additional three related studies were identified and scrutinized. The search was carried out on 05 April 2022.</p>  | <p>Lines: 133-144</p>             |
| Selection process       | 8      | <p><b>Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.</b></p> <p>Microsoft Excel software was used to collect data reports and produce the first stage of study selection. The search reports (A and B) from the databases (Scholar Google, Scopus, WoS) were imported into different sheets of an Excel document. The sheet tables were filled by listing the bibliographic citations in alphabetical sequence. The data from each search report were collected by one reviewer without automation tools. To minimize the risk of bias, the database search and data collection from each report were independently performed by the author, twice. To guarantee the robustness of the present review, only peer-reviewed publications in English were taken into consideration: comments and replies, conference abstracts, post-graduate dissertations and theses, and irrelevant book chapters were outside the scope of the review. To decide whether a study met the inclusion criteria, the database page devoted to each study or publisher page was read. The data on publication were checked (peer-review, language, type of publication) and markers were added in the Excel document. The data were combined into one table and duplicates were excluded. At the next step, the studies were exported into free Mendeley desktop software [36] as a reference list and as PDF files; metadata were downloaded automatically from the online Mendeley database. The completeness of each study metadata were checked and corrected by the author. To check the correspondence inclusion criteria “application of Raman spectroscopy to investigate shocked zircon from natural terrestrial and lunar impactites” detailed analysis of the metadata and the full-text of studies were performed on the second stage of the study selection. Only publications on the study of terrestrial and lunar impactites were included for consideration in this review. The full texts were checked for presence of keywords “Raman”, “shocked zircon”, “impactites” and “Lunar breccia”, and studies with keywords in the reference list and in context but without new data were removed. Non-relevant studies of computer modelling, synthetic, experimentally shocked zircon. Studies were marked as “include” or “exclude” in the tag field of the metadata. The included studies were combined in one folder of the Mendeley desktop software to produce the data search.</p> | <p>Lines: 146-171</p>             |
| Data collection process | 9      | <p><b>Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study</b></p>  |                                   |



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|                               |        | <b>investigators, and if applicable, details of automation tools used in the process.</b><br>Mendeley desktop was used to extract data from each study by using words in the Search option. As a result of the search by different combinations of words and detailed investigation of the abstracts and full texts of the studies, Table 2 was created with the data items. A detailed investigation of each study was considered as a method to increase the reliability of the results.   | Lines: 176-178                  |
| Data items                    | 10a    | <b>List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect.</b><br>The table form (Table 2) was designed in accordance with objectives of the review. The data items were presented in Table 2 and ordered in alphabetical sequence. These were extracted from studies based on detailed investigation of the studies: bibliometric parameters to characterize the researchers and level of publication (authors, year, the name of journals and books, quartile), geological objects and zircon microstructures to show how widely the Raman method was applied (crater or lunar breccia, microstructures), the Raman data presented in the studies (spectra, maps, measures band parameters), application of Raman data to recognize what the method was used for (phase identification, radiation damage degree, orientation effects), and EBSD data usage.<br>This design of the data items was appropriate to each study. All results were compatible with each study. Raman spectroscopy was not applied for all microstructures. In some studies, Raman data were presented only in several grains. The author of the review marked "yes" in table data item in the case of data presented in studies in any volume. Supplementary files were used in search. | Lines: 176-184<br>Line: 194     |
|                               | 10b    | <b>List and define all other variables for which data were sought (e.g., participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.</b><br>Other variables for which data were sought were journal quartile in SCImago, specialization of journals and books, types of deformation, methods, pressures and temperatures.  | Lines: 184-186                  |
| Study risk of bias assessment | 11     | <b>Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.</b><br>The method of consistency of scientific ideas and consistency of data in the reviewed studies were used as criteria for absence bias risk in the included studies. Automation tools were not used. Only one author assessed each study.  |                                 |
| Effect measures               | 12     | <b>Specify, for each outcome, the effect measure(s) (e.g., risk ratio, mean difference) used in the synthesis or presentation of results.</b><br>Effect measures were not used in the synthesis or presentation of results due to the qualitative character of these outcomes (Table 2).   |                                 |
| Synthesis methods             | 13a    | <b>Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).</b><br>The analysis was performed by one person (author of review), based on the table of data items. All studies which contained eligible criteria were included in each synthesis.  |                                 |
|                               | 13b    | <b>Describe any methods required to prepare the data for presentation or synthesis, such as handling of</b>  |                                 |



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|                           |        | <b>missing summary statistics, or data conversions.</b><br>The data analysis was based on table data items (Table 2). Combinations of data in columns were used for synthesis.  |                                 |
|                           | 13c    | <b>Describe any methods used to tabulate or visually display results of individual studies and syntheses.</b><br>The data are presented in Table 2. The number of studies per year were calculated and plotted in an Excel file. The plot is presented as Figure 2 and Table 2.   |                                 |
|                           | 13d    | <b>Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.</b><br>The data in the columns of Table 2, and its combinations, were used for synthesis. The synthesis was based on a detailed analysis of the reviewed studies.  |                                 |
|                           | 13e    | <b>Describe any methods used to explore possible causes of heterogeneity among study results (e.g., subgroup analysis, meta-regression).</b><br>Homogeneity of the characteristic value or its monotonous (or stepwise) behavior in columns was controlled.   |                                 |
|                           | 13f    | <b>Describe any sensitivity analyses conducted to assess robustness of the synthesized results.</b><br>The design of the Table 2 and data items were universal for each study. The set of columns characterized each study well, to achieve the review objectives. The robustness of the synthesized results was checked by randomly excluding one study.   |                                 |
| Reporting bias assessment | 14     | <b>Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).</b><br>The risk of bias was assessed by randomly excluding one study of the review.  |                                 |
| Certainty assessment      | 15     | <b>Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.</b><br>The quantitative parameters were not used to assess certainty in the body of the evidence for an outcome.   |                                 |
| <b>RESULTS</b>            |        |   |                                 |
| Study selection           | 16a    | <b>Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.</b><br>The number of finds on keywords, and combination of keywords, in Google Scholar, Scopus, and Web of Science (search: 05 April 2022) are presented on Table 1. The highest number of finds were in Google Scholar, a smaller amount (by several times) was found in Scopus, and significantly fewer were found in WoS. The analysis showed that more than half of the finds in Google Scholar did not comply with the eligibility criteria for the review. In WoS, a significant number of included publications were lost. The closest number of matches was in the Scopus database report. The combination of keywords required the presence of each word in the publications. It follows from the table that the Raman method was very common, but the objects of study were less popular. There were very few studies of shocked zircons. Among the four keywords, the "shocked zircon" was the narrowest criteria. | Lines: 197-209                  |
|                           | 16b    | <b>Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.</b>  |                                 |



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|                               |        | Of interest were publications where the method of Raman spectroscopy was applied to study natural zircon grains from terrestrial and lunar impact structures that experienced the significant shock influence of meteorites. Hence, studies of computer modelling, synthetic, experimentally shocked zircon and other minerals were excluded. In this review, all publications on meteorites were excluded, since the presence of deformations in zircon grains is rare and irregular in meteorites, and it is almost impossible to determine, from them, what impact crater structures they belong to. In addition, a non-systematic primary review of the literature showed that Raman spectroscopy applied to the study of meteorite zircons as well as to impact terrestrial rocks, was even more limited due to the small grain size of zircons. Therefore, it would not practically contribute to the achievement of the aim of this study. Abstracts were individually screened, so that comments and replies, conference abstracts, post-graduate dissertations and theses, and irrelevant book chapters, were excluded.  |                                 |
| Study characteristics         | 17     | <b>Cite each included study and present its characteristics.</b><br>The characteristics are presented in Table 2.   | Lines: 174                      |
| Risk of bias in studies       | 18     | <b>Present assessments of risk of bias for each included study.</b><br>All considered studies form a uniform picture of ideas about Raman data in shocked zircon, and reflect its evolution. No contradictions were identified. Each article presented data in terms of ideas at the time of the investigation conducted, so the latest studies show broader data and more reliable views. For example, in one of the first studies based on experimental data [4], Geisler et al. wrote that "frequency shifts of the 1000 cm <sup>-1</sup> band by a few cm <sup>-1</sup> might be due to strained zircon caused by shock waves or high-pressure-induced deformation or disorder in zircon. Similar frequency shifts were observed in radiation-damaged zircon". This was the starting point of reliable systematic data for further studies, and most of the reviewed studies cite this publication. However, no reliable confirmation was found in subsequent works, since these two effects cannot be separated in natural samples. Additionally, by indirect signs, this effect has not been confirmed, which possibly indicates only the secondary influence of deformations on Raman band shift and width.  | Line: 463-471                   |
| Results of individual studies | 19     | <b>For all outcomes, present for each study: (a) summary statistics for each group (where appropriate), and (b) an effect estimate and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.</b><br><br>Of the 25 studies that were identified, the earliest was [37] which was devoted to the study of single zoned zircon grain in a thin section of a 23 mg lithic fragment, lunar sample 14161, 7069, from an Apollo 14 soil (Table 2). The next publication was a book chapter in <i>Cratering in Marine Environments and on Ice</i> [4] devoted to the investigation of cathodoluminescence, electron microscopy, and Raman spectroscopy of experimentally and naturally shocked zircon crystals. One of the purposes of this investigation was to understand the capability of the SEM-CL technique and Raman spectroscopy to determine whether specific CL or Raman effects in zircon/scheelite-structure could be utilised to determine particular shock pressure stages. The next paper was "Shock-metamorphosed zircon in terrestrial impact craters" [5]. The authors compared zircon grains from the Ries, Popigai and Chicxulube craters, which were subjected to pressures of up to 80 GPa. Since then, papers on the topic of where Raman spectroscopy was used to study zircons in terrestrial and extraterrestrial impacts (Figure 2) have been published every year. The maximum number of publications was five in 2021.<br><br>Eleven papers (55% of reviewed studies in journals) were published in specialized journals, <i>Meteoritics and Planetary Science</i> [5,39,41,42,46,47,54] and <i>Earth and Planetary Science Letters</i> [45,48,52], and ACS Earth and Space Chemistry [53]. Nine papers (45%) were presented in journals of wide scope of geology, mineralogy and petrology: <i>Geology</i> [29], <i>Gondwana Research</i> [43], <i>American Mineralogy</i> [37], <i>Canadian Journal of Earth Sciences</i> [40], <i>Contributions to Mineralogy and Petrology</i> [23,51], <i>Acta Mineralogica Petrographica</i> [38], <i>Journal of Geophysical Research</i> [43] and <i>Geophysical Research Letters</i> [49]. Nineteen papers were published in high level | Lines: 211-250                  |



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|                      |        | <p>journals of first and second quartile (SCImago). Book chapters were published in specialized books (100%) on study impact craters <i>The ICDP-USGS Deep Drilling Project in the Chesapeake Bay impact structure: Results from the Eyreville Core Holes, Cratering in Marine Environments and on Ice</i>, and <i>Geological and Geo-Environmental Processes on Earth</i> and proceedings of the homonymous international conference on all aspects of impact cratering and planetary science “Large Meteorite Impacts and Planetary Evolution V, VI”.</p> <p>Zircon-related phases reported: zircon, reidite, ZrO<sub>2</sub>. Microstructures in zircon and related phases reported: grain-size reduction, microtwins, granular texture, planar microstructure (PFs, PDFs), planar deformation, microporosity, lamellae reidite in zircon grain, lamellae and granular reidite, ZrO<sub>2</sub>, granular mixture of zircon and ZrO<sub>2</sub>, subparallel linear fractures, non-planar fractures.</p> <p>In all studies, the Raman peak position was presented and phase identification was performed. Raman spectra were not shown in [29,39] (8% of reviewed studies). Only five studies [5,23,29,30,51] used mapping to study zircon (20%). In 11 studies [2–5,7,23,29,30,38,40,46,50,51] Raman data were used to make conclusions about the zircon radiation damage (44%): radiation dose was calculated based on U, Th, and Pb concentration and ages by data isotope methods in three studies [37,52,54] (12%), and equivalent radiation dose D<sub>eq</sub> was estimated using the FWHM Raman band ν<sub>3</sub>(SiO<sub>4</sub>) in four studies [23,29,30,46] (16%). In seven studies [4,5,7,38,40,50,51], the radiation damage degree was qualitatively estimated based on the widening of the zircon Raman bands (28%). Only nine of the reviewed works conducted investigation by the EBSD method (36%).</p>   |                                 |
| Results of syntheses | 20a    | <p><b>For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.</b></p> <p>The characteristics presented in Table 2 were analyzed in combinations to conduct syntheses in three issues: (A) the number of studies per year and influence factors; (B) the categorization of studies in accordance with the object of the studies; (C) the main application of Raman data (phase identification, radiation damage, orientation effects).</p>  |                                 |
|                      | 20b    | <p><b>Present results of all statistical syntheses conducted. If meta-analysis was conducted, present for each the summary estimate and its precision (e.g., confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.</b></p> <p>(A) The number of studies per year and influence factors:</p> <p>The history of the application of Raman spectroscopy to the study of impactite zircons is presented in Figure 2. There is an inextricably link between the development of Raman spectroscopy to study zircons of various terrestrial rocks, and the development of the EBSD technique in the early 2000s. The number of publications reporting EBSD and Raman data has started to expand since 2017. However, even today, the society of specialists in zircon deformations only pays little attention to the Raman method. It is probable that the unpopularity of the method is due to the underestimation of the possibilities of the method. According to the Scopus database, the number of articles with the words “zircon” and “EBSD” was 141 publications in 2021, of which only four reported the Raman spectra of zircons (Figure 2). There was a narrowly utilitarian use solely for assessing the degree of metamict and identifying polymorphs. It is probable that the unpopularity of the method is due to the underestimation of the possibilities of the method.</p> <p>(B) The categorization of studies in accordance with the object of the studies:</p> <p>According to the main results obtained and the publication structure, the reviewed studies could be roughly divided into two categories:</p> <p>(1) Acquisition of new data and characterization of geological structures (19 publications): terrestrial impact craters [7,22,39,42,44,45,47,48,50–52,54] and lunar breccia 37,40,41,43,46,49,53]. These works are devoted to the issue of dating impact and post-impact events [39,41,43,44,49,51], study of pressure–temperature paths at extreme conditions [7,22,42,45,47,48,52,54], obtaining data on radiation and thermal</p> | Lines: 254–273                  |





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|                       |        | <p>history [40,46], geochemical and mineralogical characterization [53], investigation of potentially new craters and identification of impact processes signs [50]. In these 19 papers, Raman spectroscopy was recorded in zircon mainly to reveal polymorphic modifications of ZrSiO<sub>4</sub> (zircon, reidite, ZrO<sub>2</sub>) by the presence of the corresponding Raman bands in spectra. The presence of polymorphs is a fairly reliable thermobarometer [1,2,8]. In publications [7,22,37,46,50,51], the authors made conclusions about the degree of zircon metamictization at a qualitative or quantitative level by virtue of the band broadening or measurement of the full width at half maximum (FWHM) of the Raman band B<sub>1g</sub>(1008 cm<sup>-1</sup>) interpreted as the asymmetric stretching vibration mode <math>\nu_3(\text{SiO}_4)</math> [20,31,52];</p> <p>(2) Investigation of different or specific deformations and identification of their textural or spectroscopic features (six publications): [4,5,23,29,30,38]. In these six papers, a more detailed study using Raman spectroscopy, its original application, and the identification of Raman spectra in shocked zircons were presented. The authors proposed using Raman spectroscopy to diagnose the impact origin of zircons [4,5,23,38], to assess the degree of zircon metamictization [4,5,23,29,30], and to reveal orientation effects [4,29,30].</p> <p>(C) The main application of Raman data (phase identification, radiation damage, orientation effects).</p> <p>In all studies, Raman peak position was presented and phase identification was performed. Raman spectra were not shown in [29,39] (8% of reviewed studies). Only five studies [5,23,29,30,51] used mapping to study zircon (20%). In 11 studies [2–5,7,23,29,30,38,40,46,50,51] Raman data were used to make conclusions about the zircon radiation damage (44%): radiation dose was calculated based on U, Th, and Pb concentration and ages by data isotope methods in three studies [37,52,54] (12%), equivalent radiation dose <math>D_{\text{eq}}</math> estimated using FWHM Raman band <math>\nu_3(\text{SiO}_4)</math> in four studies [23,29,30,46] (16%). In seven studies [4,5,7,38,40,50,51], the radiation damage degree was qualitatively estimated based on the widening of the zircon Raman bands (28%). Only nine reviewed works conducted investigation by the EBSD method (36%).</p> |                                 |
|                       | 20c    | <p><b>Present results of all investigations of possible causes of heterogeneity among study results.</b></p> <p>Homogeneity of the characteristic value in columns “publications”, “microstructures in zircon and related phases”, and “phase identification” was found. Monotonous or stepwise increases in the number of “publications” and “EBSD data presented” over the years have been found. The behavior of “Spectra”, “Maps”, “Measured parameters”, “Radiation damage”, and “Orientation effect” characteristics were heterogeneous due to presence of outstanding studies where detailed investigation by Raman method was conducted.</p>   |                                 |
|                       | 20d    | <p><b>Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.</b></p> <p>The design of the table 2 and data items were universal for each study. The set of columns characterized each study well, to achieve the review objectives.</p> <p>The robustness of the synthesized results was checked by randomly excluding one study.</p>  |                                 |
| Reporting biases      | 21     | <p><b>Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.</b></p> <p>No data</p>   |                                 |
| Certainty of evidence | 22     | <p><b>Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.</b></p> <p>No data</p>   |                                 |
| <b>DISCUSSION</b>     |        |  |                                 |



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| Discussion                | 23a    | <p><b>Provide a general interpretation of the results in the context of other evidence.</b></p> <p>A total of 25 research publications were, therefore, selected for the present review. Among the publications were 20 scientific articles and 5 book chapters. Terrestrial impact structure was studied in 18 papers, while only 4 studies investigated lunar breccia samples and 3 were devoted to lunar meteorites.</p> <p>(A) According to the main results obtained and the publication structure, the reviewed studies were roughly divided into two categories: Acquisition of new data and characterization of geological structures (19 publications), and investigation of different or specific microstructural deformations and identification of their textural or spectroscopic features (6 publications);</p> <p>(B) The history of the application of Raman spectroscopy to the study of impactite zircons is inextricably linked with the development of Raman spectroscopy to study zircons of various terrestrial rocks and the development of the EBSD technique in the early 2000s. The number of publications reporting EBSD and Raman data has started to expand since 2017. However, even today, the society of specialists in zircon deformations only pays little attention to the Raman method. It is probable that the unpopularity of the method is due to the underestimation of the possibilities of the method;</p> <p>(C) The main applications and capabilities of the Raman method in the study of shocked zircon, and its advantages over the traditionally used EBSD, were highlighted in this review: (1) Radiation damage degree at the moment of impact and the study of the annealing history are of particular importance for impactite zircons. The effect of widening Raman bands due to deformation should be taken into account in interpreting the amorphization reasons of shocked zircon, and in understanding the annealing history. For this, it is necessary to calculate and measure the damage degree by Raman spectra; (2) Mapping of the Raman band intensity ratios can be effectively used to find and visualize inhomogeneities in the crystal lattice orientation. Thus, the difference in texture, manifested in the Raman bands ratio of B1g/Eg mapping and metamictization degree maps, is a new signature of shock deformation features in zircon, which could be used as a Raman marker of shocked zircon; (3) In the case of nano-sized phase mixtures, the EBSD method demonstrates the smoothed low quality Kikuchi patterns, which often create problems in the detection of polymorph phases in grain. In contrast, Raman spectra usually contain components of even nano-sized mixture phases. The different nature of Raman spectroscopy and EBSD methods motivate usage of both techniques to study polymorph mineral phases in zircon, depending on phase's size. The reliable marker of Raman spectrum, which could be considered as unique for shocked zircon, is the presence of Raman bands of high-pressure polymers, reidite and ZrO<sub>2</sub>.</p> | Lines: 651-692                  |
|                           | 23b    | <p><b>Discuss any limitations of the evidence included in the review.</b></p> <p>The included evidence was based on the collected data in Table 2. The evidence was performed by one author; hence the design and presentation style could be subjective. However, results of synthesis and discussion should not depend on the bias of the author.</p>  |                                 |
|                           | 23c    | <p><b>Discuss any limitations of the review processes used.</b></p> <p>The review processes were determined so as to achieve reliable results. However, it was limited by three databases.</p>   |                                 |
|                           | 23d    | <p><b>Discuss implications of the results for practice, policy, and future research.</b></p> <p>In the systematic review, the capabilities of Raman spectroscopy were highlighted, and possibly this will initiate future progress in the study of impact zircons.</p>   |                                 |
| <b>OTHER INFORMATION</b>  |        |  |                                 |
| Registration and protocol | 24a    | <b>Provide registration information for the review, including register name and registration number, or state</b>  |                                 |





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|  |        | <b>that the review was not registered.</b><br>No data.  |                                 |
|  | 24b    | <b>Indicate where the review protocol can be accessed, or state that a protocol was not prepared.</b><br>No data.   |                                 |
|  | 24c    | <b>Describe and explain any amendments to information provided at registration or in the protocol.</b><br>No data.  |                                 |
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| Competing interests                            | 26     | <b>Declare any competing interests of review authors.</b><br>The author declares no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.  |                                 |
| Availability of data, code and other materials | 27     | <b>Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.</b><br>The review and PRIMA checklist is available in Open Access.  |                                 |

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