Foreword

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We refer here exclusively to the Polycystine Radiolaria, which live today in practically all marine environments, and have a fossil record that goes back to the Cambrian. The preservation of their delicate siliceous skeletons below the carbonate compensation depth gives them the potential to date the deep sea sedimentary deposits of ancient oceanic basins. This is especially true for radiolarites, which are notorious for their lack of other datable fossil materials. This specific advantage was recognized in the late 1970s, as was their significance and utility in providing age constraints necessary for geodynamic reconstructions and understanding the evolution of past oceanic realms.

This volume represents the current state of the taxonomy of Paleozoic radiolarian genera, as reached by the consensus of over a dozen radiolarian workers active in the field of Paleozoic radiolarian studies. The idea for its preparation matured during the 12th Conference of the International Association of Radiolarian Paleontologists (InterRad) in Nanjing, China (September 14-17, 2009). Its Mesozoic counterpart had just been published (O'Dogherty *et al.* 2009) and was on display during the Nanjing conference, so that we all were able to measure its important added value. The Paleozoic Genera Working Group (PGWG) of InterRad was thus set up to distill the current state of knowledge on Paleozoic radiolarian genera and to present it through an illustrated and annotated catalogue.

We benefitted immensely from the past experience that Luis O'Dogherty acquired during the preparation of the Mesozoic Catalogue. He generously shared with us all the know-how and templates he had used. Our task became so much easier by placing all pictures and data relevant to Paleozoic genera into this pre-established template. Keen to clarify taxonomic issues on radiolarians throughout the entire Phanerozoic, Luis had also established by that time a database of Paleozoic genera and their type species. This initial database, as well as the photos of type species scanned by Jean-Pierre Caulet and Noritoshi Suzuki, allowed Jessie Cuvelier to produce a "proto-catalogue" that was available for discussion during the first meeting of the PGWG.

This first meeting was organized at the University Lille 1 on September 1st to 3rd, 2011, just before the Silicofossil Group conference of The Micropalaeontological Society that

Fig. 1. — Participants to the first workshop of the Paleozoic Genera Working Group in Lille, France (September 2011). From left to right: Paulian Dumitrica, Noritoshi Suzuki, Taniel Danelian, Luis O'Dogherty, Martial Caridroit, Jonathan Aitchison, Paula Noble, Jörg Maletz, Kiyoko Kuwahara and Lauren Pouille.

Fig. 2. — Snapshot of the Lille workshop. From left to right: Paulian Dumitrica and Jonathan Aitchison check taxonomic information in the literature; Paula Noble, Martial Caridroit, Taniel Danelian and Noritoshi Suzuki discuss an aspect related to a genus illustrated in the "proto-catalogue".

was also held in Lille. The meeting gathered 10 participants (Fig. 1), whose task was to carefully evaluate each and every Paleozoic genus introduced in the literature so far, based on examination of the original papers, and to determine their validity (Fig. 2). Decisions were guided by the International Code of Zoological Nomenclature (ICZN). In rare cases where disagreement arose within the group, such matters were settled democratically. Although the primary aim of the PGWG was to deal with the taxonomic status of genera, higher level classification at order and family levels

were also discussed. The suprageneric classification of the "black book" (De Wever *et al.* 2001) served as a good starting point (Fig. 3). The black book also provided subjective synonyms for some genera and families, although one of its drawbacks is that there are no explanations for suggested synonymies. Fortunately, two of the authors were amongst us (Martial Caridroit and Paulian Dumitrica) and were able to provide some explanations, which we have included in the taxonomic chapter (Noble *et al.* 2017) on the occasions where our group has been in agreement.

After three full days of discussions in Lille we found that the time available was not sufficient; indeed, out of 344 genera, we had managed to evaluate only 258! The rest were left to be discussed at the second meeting of the PGWG, which was to be held in Cadiz (Spain) during March 25th and 26th, 2012, just before the 13th InterRad Conference (Figs 4 and 5). A revised "proto-catalogue" was prepared for this occasion. Over 40 genera amongst those already evaluated in Lille had to be rediscussed. It was decided that we should include a biostratigraphic chapter (Aitchison *et al.* 2017a) to underscore the importance of radiolarian biostratigraphy in the Paleozoic.

On May 29th, 2012, Martial Caridroit visited the Muséum national d'Histoire naturelle in Paris where he made new observations and took photomicrographs of the type material studied by Deflandre. His observations are integrated in the remarks of the taxonomic chapter (Noble *et al.* 2017).

Later that year the project benefitted greatly from the visit of some of the PGWG members in Lille (Jonathan Aitchison: September 23rd-25th, 2013, Paula Noble : invited Professor during October 2013, and Paulian Dumitrica: October 21st-23rd, 2013) during which time the entire catalogue was again reviewed and specific points were discussed in depth.

Only half of the PGWG was able to attend the 3rd meeting organized in Antalya (Turkey; Figs 6 and 7) on March 22nd, 2015, where a full day of discussions took place just before the start of the 14th InterRad. At this stage we had more or less finalized discussions on the evaluation and status of all radiolarian genera. What remained was the finalization of ideas about the presentation of the volume. It was decided that we should include an extensive taxonomic chapter that would serve as a companion to the illustrated catalogue. In this chapter, we would clearly refer to decisions made on synonymizing some genera, either following a taxonomic opinion stated in the literature or by writing a few remarks following our discussions. It was also decided that ages in the taxonomy chapter should be restricted to the age and occurrence of the type species, rather than the range and distribution of the whole genus, as this practice was followed in the Mesozoic catalogue. The rationale behind this relates to the taxonomic placement of all species within any given genera having not yet been evaluated. A separate biostratigraphy chapter would discuss the main evolutionary trends and biozonal schemes, with a limited presentation of range charts of only some selected biostratigraphically significant taxa, with minimal supporting text/tables/figures on distribution, and reference. The sabbatical of Paula Noble in Lille (October 2015-June 2016) allowed her to take the lead in preparing the taxonomic chapter, which she did with the benefit of working alongside Taniel Danelian, Martial Caridroit, Jessie Cuvelier, all at Lille.

Fig. 3. — Paulian Dumitrica wearing proudly the academic hat of Charles Barrois (a famous Professor of Geology at the University of Lille at the end of the 19th century and beginning of the 20th; he became a member of the French Academy of Sciences), while displaying the "black book" Radiolarians in the sedimentary record.

Fig. 4. — Second meeting of the PGWG in Cadiz, Spain (March 2012), which took place in an old Monastery converted to a hotel. From left to right: Lauren Pouille, Taniel Danelian, Paula Noble, Paulian Dumitrica, Andreas Braun, Jonathan Aitchison, Noritoshi Suzuki, Kiyoko Kuwahara and Martial Caridroit.

Fig. 5. — Snapshot of the meeting in Cadiz. From left to right: Qinglai Feng, Paulian Dumitrica, Jonathan Aitchison, Taniel Danelian, Noritoshi Suzuki and Paula Noble.

Danelian *et al.* (2017) take a historic view of research activity of Paleozoic radiolarians through the yearly introduction of new radiolarian genera since the end of the 19th century. It is particularly interesting to note that the presence of this plankton group in the lower Paleozoic (Ordovician) strata had been established by the 1890s. Paleozoic radiolarians were practically ignored afterwards for over half a century until the discovery of some aberrant forms that led George Deflandre to recognize their evolutionary implications. As with all microfossils, improved taxonomic knowledge of radiolarians has naturally followed the evolution of optical technology and development of microscopes, especially with the routine use of the scanning electron microscopes in academia since the late 1970s. Consequently, the late 1970s to 1990s were "fast years", driven mainly by the potential of Paleozoic radiolarians to decipher the structure and tectonic evolution of accretionary complexes and mountain belts. Interest on the early evolution of radiolarians in the early Paleozoic and their biotic response throughout the Permian-Triassic transition have been the main drivers since then.

The illustrated catalogue presented by Caridroit *et al.* (2017) crystallizes the essence of years of discussions within the entire working group to evaluate the taxonomic status of each radiolarian genus ever introduced and its family placement. Its format is very similar to that of the Mesozoic catalogue. Each genus is illustrated by the original photo of the holotype of its type species, and the full attribution for genus and type species is provided. Additionally, the status of each genus is clearly indicated, whether it be a valid senior synonym, a junior synonym, homonym, *nomina dubia* or *nomina nuda*. Genera are organized within families (whenever this was clear) and orders with an alphabetic order. Subfamilies were not evaluated and are purposefully omitted from the hierarchical scheme. Each genus bears a unique taxon code. Two appendices are provided, which allow for a rapid search of a genus and its status. One appendix displays the genera within alphabetic order, whereas the other one presents them sorted according to their classification in orders and families. From the latter appendix, one can see at a glance that out of the 208 valid Paleozoic genera, 24 are assigned to the Albaillellarian order, 24 to Archaeospicularia, 58 to Entactinaria, 28 to Latentifistularia, 12 tentatively to Nassellaria, 32 to Spumellaria, and the remaining 30 genera cannot be placed for the moment in any of the established orders.

Noble *et al.* (2017) present a necessary companion text to the illustrated catalogue, with the aim of providing the reader with pertinent information for each genus. This chapter provides the original diagnosis and/or description for each genus in the original language (e.g. French, German, Russian and Chinese) in which it was published, as well as in its English translation. It also provides the age and location of the type material for each type species. More importantly, it details the taxonomic operations that had to be undertaken following the discussions of the PGWG; in this way, out of the 344 genera ever introduced as radiolarians only 208 (60%) were found to be valid, while 82 are considered as junior synonyms, 35 others as *nomina dubia* and two as *nomina nuda*. Explanatory remarks are provided

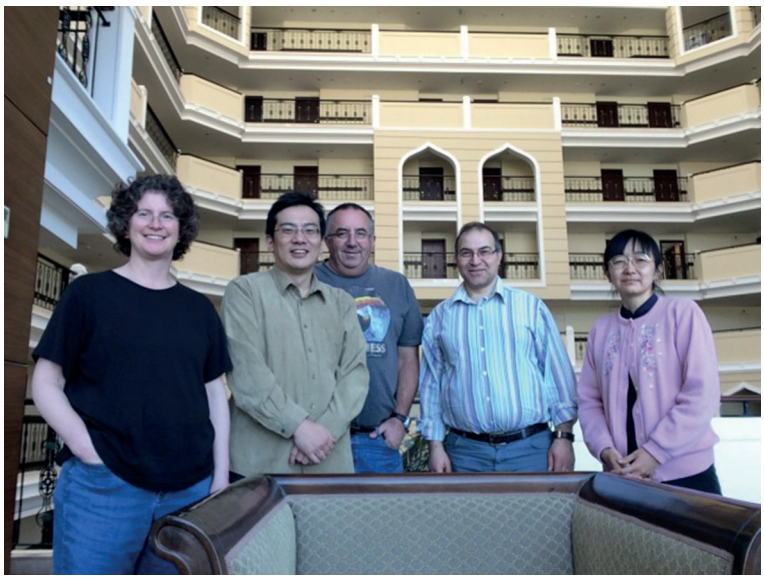

Fig. 6. — PGWG participants of the meeting in Antalya. From left to right : Paula Noble, Noritoshi Suzuki, Jonathan Aitchison, Taniel Danelian and Kiyoko Kuwahara.

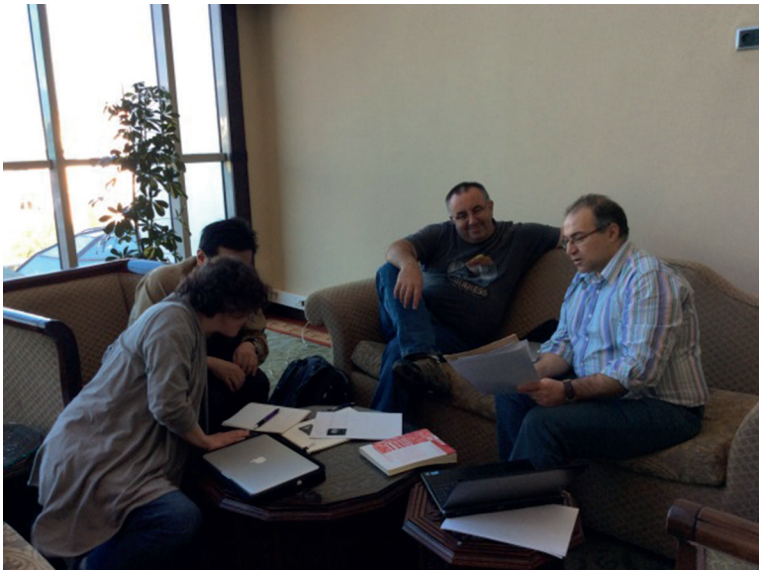

Fig. 7. — A snapshot of the PGWG meeting in Antalya.

for all the latter three categories and more specifically for junior synonyms, which were arrived at by the PGWG or had appeared in the black book previously without explanation. The same holds true for the ten genera that have been introduced erroneously as radiolarians, most of them being siliceous sponge spicules. If the current concept of a valid genus was found to differ substantially from the original diagnosis or description, through emended diagnoses introduced by subsequent workers, the sense of its usage is clarified (*sensu*).

Aitchison *et al.* (2017a) provide a synthesis of radiolarian zonations proposed for the entire Paleozoic. They discuss the latest chronostratigraphic calibration and the biostratigraphically significant assemblages system after system, highlighting at the same time the most characteristic taxa and available age constraints of these assemblages. This synthesis is illustrated by a chronostratigraphic chart that allows one to see at a glance the sequence of the over 90 radiolarian assemblages used in Paleozoic biostratigraphy, as well as the age range of some key genera and species. One major issue that remains for many of these assemblages is to test how widely they can be applied, especially for those zonal schemes that are based on well-preserved material (e.g. from concretions). In spite of the major progress achieved the last 20-25 years in improving the understanding of early Paleozoic radiolarian taxonomy, diversity and faunal changes, late Paleozoic biostratigraphy still remains much better developed, largely thanks to the evolutionary diversification of albaillellids since the Late Devonian. The most detailed radiolarian biostratigraphic scheme for the entire Paleoozoic is that available for the Permian, not only because

it contains the most numerous assemblages but also because a number of evolutionary lineages and events are available.

Aitchison *et al.* (2017b) present, for the first time, a complete list of 2323 Paleozoic radiolarian species/subspecies described between 1880 and 2016. This is only an objective record of what can be found in the literature and does not provide any taxonomic status evaluation or revision. It may thus include invalid taxa (junior synonyms, *nomina dubia* and *nomina nuda*), and taxa that have been erroneously assigned to various genera. For this reason, the stratigraphic range of each genus was expressly not compiled from this list and included in previous parts of the catalogue.

In conclusion, in spite of the considerable progress achieved since the 1970s in the study of Paleozoic Radiolaria, much work still remains to clarify their taxonomy and exploit their biostratigraphic potential. There is an increasing need for a concerted effort to evaluate the taxonomic status of the existing corpus of described species, their phylogenetic relationships and age ranges. Taxonomic and biostratigraphic progress will help better address a number of macroevolutionary questions.

At the end of this adventure we would like to thank all members of the PGWG for their wonderful participation to the various meetings and their patience. We would like to thank warmly all the reviewers of the various papers in this volume for their constructive comments and the Chief Editor of *Geodiversitas*, Dr Didier Merle, for his continuous support and understanding over these last few years. Last but not least, we would like to acknowledge and thank warmly Emmanuel Côtez for his talented handling of all our manuscripts and the hard work he has put in producing and correcting the galley proofs.

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