Increasing knowledge on biodiversity patterns and climate changes in Earth's history by international cooperation: introduction to the proceedings IGCP 596/SDS Meeting Brussels (2015)

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Introduction

Current and future climate change is a global issue that can be addressed only by international cooperation. Climate modelling is a useful tool for a better understanding of climatological processes but is significantly enhanced by the knowledge of organisms and changing biodiversity in deep time. The mid-Palaeozoic was a time of rapid, fundamental change in Earth's climate systems resulting in significant sea-level fluctuations and catastrophic changes in ocean chemistry producing global oceanic anoxia. Ecosystems were severely impacted by a series of mass extinctions and ecological perturbations (e.g. virtual loss of reef ecosystems) that fundamentally changed the trajectory of life on Earth. Fluctuations in the physical environment during these biotic crises are usually (but not always) revealed in the sedimentary record as black shales and as

geochemical excursions in Devonian sediments. Regardless of methodology, all the analyses conclude that the mid-Palaeozoic was a time of multiple anoxic events and associated biotic crises that spanned many millions of years. Thus, an understanding of the major abiotic and biotic factors that shaped our planet and its ecosystems in the past is essential to the understanding of natural processes and the effects of human-induced global change at present and for forecasting possible future developments. In other words, knowledge on past systems is essential if we want to model future climate with confidence. Furthermore, it seems important to increase knowledge in areas and countries which are underrepresented in terms of climate change and event research in the mid-Palaeozoic. In that respect, IGCP projects, supported by IUGS and UNESCO, serve as door-opener in many countries. In the framework of the IGCP 596, we visited many countries in several continents. Fieldwork was often difficult and a real challenge (Figs. 1 and 2).

Regardless of methodology such as geochemistry, geophysics or facies analysis, the detailed knowledge of fossils is crucial. Thus, alpha taxonomy remains the fundamental basis for any investigation of the evolution of life on Earth, including fields of phylogenetic analysis, historical biodiversity, biogeography and biostratigraphy. Today, there is a lack of awareness of the fundamental importance of systematics and/or biostratigraphy. Taxonomy is crucial to high-resolution biostratigraphy. The ongoing decline in research and expertise in that special field in palaeontology jeopardises future macroevolutionary and biostratigraphic studies. Thus the collaboration between IGCP 596 and the international Subcommission on Devonian Stratigraphy (SDS) also tried to involve specialists working on different fossil groups to the extent possible. In that sense, many progress reports related to the revision and erection of new taxa were linked with the Palaeobiology Database (<http://paleodb.org/>).

This article is a contribution to the special issue '*Climate change and biodiversity patterns in the mid-Palaeozoic*'

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Fig. 1 **a** Taking samples from a Late Devonian section with a stone saw along a steep cliff in Vietnam, June 2017. **b** On the way from the field, special SDS sampling fieldtrip to Zeravshan Range, Southern Tien Shan, Uzbekistan, August 2015. **c** Participants of the fieldtrip to the Carnic Alps, July 2015. **d** Preparing samples for transport in front of a nomad tent, SDS/IGCP 596 field workshop in Mongolia, August 2014

Past activities and future challenges

The International Geoscience Programme (IGCP; project 596 on *Climate Change and Biodiversity Patterns in the Mid-Palaeozoic*) and the SDS look back on a long-lasting, fruitful cooperation producing a very large number of scientific papers as well as special issues and books for the general society (e.g. Becker and Kirchgasser 2007; Königshof 2009; Brett et al. 2011; Becker et al. 2016; Suttner et al. 2016; Mottequin et al. 2017, this issue), which greatly increased knowledge in many respects. The primary goal of IGCP 596 was to assess the intensity of mid-Palaeozoic climate change and its impact on biodiversity both in marine and terrestrial successions. After five successful years of international research, the project received the OET (on extended term, without funding) status in 2016. Consequently, 2017 was the last year of the project and it is the aim of the co-leaders and other colleagues to summarise the main results of the project in a ‘review’ publication.

Meanwhile, some colleagues have established a successor IGCP project on magnetic susceptibility and cyclostratigraphy. Milankovitch cycles (obliquity, eccentricity and

precession) result in changes in the distribution of solar energy over seasons, as well as over latitudes, on time scales of ten thousands of years to millions of years. These changing patterns in insolation have induced significant variations in Earth’s past climate and, as a consequence, on biodiversity patterns. In recent years, major improvements of the Geologic Time Scale (GTS) have been proposed through the application of cyclostratigraphy, mostly for the Mesozoic and Cenozoic. However, for the Palaeozoic, major uncertainties ($> \pm 1$ Myr) on the numerical age of stage boundaries still exist. In order to reduce these uncertainties, and thus to improve the precision and accuracy of the Palaeozoic time scale, we intend to explore the application of cyclostratigraphy and astrochronology. The new IGCP project (IGCP 652; *Reading geologic time in Paleozoic rocks: the need of an integrated stratigraphy*; 2017–2021) which was accepted in February 2017 will improve our knowledge of the Palaeozoic climatic system and its sensitivity to Milankovitch climate forcing. The leaders of the successor project (for further information please contact http://www.geolsed.ulg.ac.be/IGCP_652/index.html) are committed to continuing the excellent collaboration with SDS and participation is most welcome!

Fig. 2 **a** Raising thunderstorm in the higher mountains in Mongolia (August 2014), close to the Chinese border (Baruunhuurai Terrane), which led to the loss of several tents. **b** Participants of the joint IGCP 596/ IGCP 580 field workshop (August 2014) at the Mongolian–Chinese

border. **c** Some participants of the joint IGCP 596/SDS field symposium in the eastern Anti Atlas of SE Morocco, March 2013. **d** Participants of the SDS/IGCP 596 joint fieldtrip in the Urals, July 2011

Contributions to the special issue

The Special Issue on ‘*Climate change and biodiversity patterns in the mid-Palaeozoic*’ includes 18 significant contributions that are sorted roughly in a stratigraphical order (Early Devonian to Early Carboniferous). The publications have a focus on biostratigraphy, events in the Palaeozoic, sedimentology/facies, magnetic susceptibility and cyclicity, palaeobiogeography and palaeoecology. All contributions to the Special Issue are a result of the successful joint IGCP 596/SDS collaboration and most contributions were presented at the Brussels meeting organised in 2015 at the Royal Belgian Institute of Natural Sciences (Fig. 3). The abstracts of all communications presented during this meeting are available in Mottequin et al. (2015). Contributions cover a wide range of topics and depositional settings in Australia, Europe (Belgium, Czech Republic, Germany, Latvia), Iran, Kyrgyzstan, Russia, Thailand and Vietnam. On behalf of the Guest Editors, we would like to express our sincere thanks to all contributing authors, the following reviewers: Thomas R. Becker, Carlton E. Brett, Gaël Clément, Pedro

Cózar, Claudia Dojen, David. K. Elliott, Yuri Gatovsky, Peter E. Isaacson, Patrick N. Wyse Jackson, Phillippe Janvier, Christian Klug, Jiří Kalvoda, Aleksey Kim, Peter Königshof, Jau-Chyn Liao, John E.A. Marshall, Hanna Matyja, Bruno Milhau, Bernard Mottequin, Svetlana Nicolaeva, Ewa Olempska, Matthias Piecha, Catherine Reid, Sergio Rodriguez, Valeri Sachanski, Norman Savage, Ladislav Slavík, Jose I. Valenzuela-Rios and Dieter Weyer as well as to a number of anonymous reviewers for their very helpful and constructive comments! We are convinced that this Special Issue provides valuable information on mid-Palaeozoic biotas, palaeoecosystems, events and evolutionary patterns. We are very grateful to Johnny Waters (Appalachian State University, Boone, USA) for his useful comments and improvement of the English language.

In the first publication, **Blieck (2017)** attempts successfully to evaluate the Great Eodevonian Biodiversification Event by investigating a group of fossil jawless vertebrates known as heterostracans and tries to relate it to global and biotic factors. The author provides convincing arguments that the Early Devonian peak in biodiversity in the marine realm

◀ **Fig. 3** Part of the participants of the joint IGCP 596/SDS Conference at the front of the Royal Belgian Institute of Natural Sciences, Brussels (September 2015). 1: José Ignacio Valenzuela Ríos (Spain); 2: Pilar Navas-Parejo (Mexico); 3: Tomáš Kumpán (Czech Republic); 4: William Kirchgasser (USA); 5: Yarinpil Ariunchimeg (Mongolia); 6: Myriam Matteucci (Italy); 7: Thomas Suttner (Austria); 8: Jau-Chyn Liao (Spain); 9: Erika Kido (Austria); 10: Aneta Hušková (Czech Republic); 11: Ladislav Slavík (Czech Republic); 12: Nadezhda Izokh (Russia); 13: Sofie Gouwy (Canada); 14: Ondřej Bábek (Czech Republic); 15: Irina Evdokimova (Russia); 16: Sersmaa Gonchigdorj (Mongolia); 17: Baljinnyam Sukhebaatar (Mongolia); 18: Claire Derycke (France); 19: Julien Denayer (Belgium); 20: Ariuntogos Munkhjargal (Mongolia); 21: Matthias Sinnesael (Belgium); 22: Cameron Batchelor (USA); 23: Thomas Becker (Germany); 24: Pierre Gueriau (France); 25: Bruno Mistiaen (France); 26: Alain Blicke (France); 27: Stephan Helling (Germany); 28: Stijn Goolaerts (Belgium); 29: Sébastien Maillet (France); 30: Enzo Farabegoli (Italy); 31: Valentine Scaut (Belgium); 32: Eberhard Schindler (Germany); 33: Peter Königshof (Germany); 34: Rainer Brocke (Germany); 35: Charlotte Stephenson (UK); 36: Catherine Crônier (France); 37: Jana Anger (Germany); 38: Jean-Georges Casier (Belgium); 39: Fatima Malti (Algeria); 40: Marina Soboleva (Russia); 41: Dmitrii Sobolev (Russia); 42: Denise Brice (France); 43: Carlton Brett (USA); 44: Hanna Matyja (Poland); 45: Maria Cristina Perri (Italy); 46: Marek Narkiewicz (Poland); 47: Katarzyna Narkiewicz, (Poland); 48: Martin Brazeau (UK); 49: Pierre Bultynck (Belgium); 50: Ulrich Jansen (Germany); 51: Mehrdad Sardar Abadi (Iran); 52: Sven Hartenfels (Germany); 53: Damien Pas (Belgium); 54: David Millward (UK); 55: David Carpenter (UK); 56: Tim Smithson (USA); 57: James Zambito (USA); 58: Emma Reeves (UK); 59: Sören Stichling (Germany); 60: Jean-Marc Marion (Belgium); 61: Marie Coen-Aubert (Belgium); 62: Edouard Poty (Belgium); 63: Johnny Waters (USA); 64: Nuramkhaan Manchuk (Mongolia); 65: Byambajav Uugantsetseg (Mongolia); 66: Nabila Bounceur (Belgium); 67: Christopher M. Berry (UK); 68: Olga Minina (Russia); 69: Alena Kurilenko (Russia); 70: Catherine Girard (France); 71: Svetlana Nikolaeva (Russia); 72: Vadim Glinskiy (Russia); 73: Xavier Devleeschouwer (Belgium); 74: Claudia Spalletta (Italy); 75: Ervīns Lukševičs (Latvia); 76: Sébastien Olive (Belgium); 77: Cyrille Prestianni (Belgium); 78: Luiza Ponciano (Brazil); 79: Carlo Corradini (Italy); 80: Anne-Christine Da Silva (Belgium); 81: Hocine Djouder (Belgium); 82: Sarah Carmichael (USA); 83: John E.A. Marshall (UK); 84: Gabriela Lia Ivanishevich (Argentina); 85: Juan José Rustán (Argentina); 86: Petra Tonařová (Czech Republic); 87: Bernard Mottequin (Belgium); 88: Yury A. Gatovsky (Russia)

corresponds to an important episode of life on Earth. Plate tectonic activity and increasing denudation at the Silurian-Devonian transition led to cumulative deposits of Old Red Sandstone which favoured, at least locally, a sea-level rise with widening of nearshore and transitional land-sea niches where heterostracans and other vertebrates flourished. Those changes correlate with a warm tropical climate (at least at the acme of the diversification peak in the Lochkovian) and other chemical conditions of the ocean that favoured a peak of primary production and of planktonic diversity and abundance (at least acritarchs). (*Palaeobiodiversity and Palaeoenvironments* 97(3) doi: [10.1007/s12549-016-0260-1](https://doi.org/10.1007/s12549-016-0260-1)).

The publication by **Mavrinskaya and Artyushova (2017)** provides an important contribution to the knowledge of the distribution of conodont faunas around the Lochkovian-

Pragian boundary sampled in the Mindigulovo section in the western slope of the southern Urals. The conodont fauna is characterised by predominantly cosmopolitan taxa. The relevance of this study is the striking similarity of conodont faunas with other important regions of Peri-Gondwana and Euramerica. (*Palaeobiodiversity and Palaeoenvironments* 97(3) doi: [10.1007/s12549-017-0292-1](https://doi.org/10.1007/s12549-017-0292-1)).

Nikolaeva et al. (2017) describe a Zlichovian ammonoid fauna recorded from a section of neritic deposits in South Tien Shan, Kyrgyzstan. The occurrence of other faunal elements such as brachiopods, crinoids, corals, conodonts and other fauna allows a correlation between pelagic and more neritic successions of the Zlichovian. Based on their first results, the Sandalian Regional Stage might be correlated with the *Erbenoceras* beds sensu Becker and House (1994). The publication contributes to the discussion of the subdivision of the Emsian into substages. (*Palaeobiodiversity and Palaeoenvironments* 97(3) doi: [10.1007/s12549-017-0291-2](https://doi.org/10.1007/s12549-017-0291-2)).

Tonařová et al. (2017) describe in detail for the first time Emsian chitinozoans and jawed polychaete fauna from the Prague Basin (Czech Republic). The results are correlated with other northern Gondwana regions. Based on their faunal assemblages and geochemical results, the onset of the Daleje transgression is obviously linked with higher terrigenous input, and also corresponds to changes in the chitinozoan assemblages as well as in the size and abundance of prasinophytes. Their results suggest the greater importance of the base of the *Nowakia elegans* Zone, marking the onset of the transgression combined with a distinct faunal turnover in the carbonate-dominated environment of the Prague Basin. (*Palaeobiodiversity and Palaeoenvironments* 97(3) doi: [10.1007/s12549-017-0274-3](https://doi.org/10.1007/s12549-017-0274-3)).

A rich ostracod fauna from an open-marine palaeo-environment from the Emsian/Eifelian boundary interval in Belgium is described by **Casier et al. (2017)**. This is the first description of that stratigraphic interval based on ostracods in the southern border of the Dinant Synclinorium. The fauna exhibits close relations with the Eifel Mountains in Germany as well as the Holy Cross Mountains in Poland. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-016-0236-1](https://doi.org/10.1007/s12549-016-0236-1)).

The following contribution has a focus on the Rhenish Massif (Eifel Synclines), a classical study area for Devonian rocks. **Brocke et al. (2017)** apply a multidisciplinary method set in order to investigate small-scale cycles in a monotonous calcareous mudstone from the Middle Devonian in the Hillesheim Syncline (Eifel area, Germany). Based on magnetic susceptibility data, sedimentology and palynofacies analysis, the investigated section indicates small-scale environmental oscillations. The combined application of variations in the palynological record and magnetic susceptibility data provide very useful insights into depositional

processes, cyclostratigraphy as well as climate changes in the Middle Devonian. The observed oscillations most probably represent small-scale, Milankovitch band climatic cycles. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-017-0289-9](https://doi.org/10.1007/s12549-017-0289-9)).

Kurilenko and Minina (2017) provide new palynological data from the Devonian (Givetian to Famennian) of Transbaikalia, an area where the Devonian succession is lacunar and outcrops discontinuously. Based on their results, it is possible to correlate Devonian sediments of the Eastern Transbaikalia Aga Zone with the Western Transbaikalia Vitimkan-Tsipa Zone. In terms of palaeobiogeography, the results which are based on palynological assemblages support the assumption that the Vitimkan-Tsipa Basin was most probably linked to the Mongol-Okhotsk Basin at that time. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-017-0275-2](https://doi.org/10.1007/s12549-017-0275-2)).

The following two publications describe Devonian sections in Southeast Asia. The publication by **Königshof et al. (2017b)** focus on possible equivalents of global Devonian bioevents from the eastern Palaeotethys in northeast Vietnam, which was hitherto almost a *terra incognita* from the Devonian bioevent viewpoint. The pelagic facies setting of the Si Phai section, which is characterised by rare fauna, mainly composed of conodonts, styliolinids, trilobites and cephalopods, is very similar to other pelagic sections known from western Thailand. The middle to upper Devonian sediments do not provide a continuous sedimentological record but the conodont record enables to pinpoint some events, such as the Kačák and the Lower Kellwasser events. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-016-0253-0](https://doi.org/10.1007/s12549-016-0253-0)).

Udchachon et al. (2017) describe a section of the Loei fold belt (Indochina Terrane) in northeastern Thailand. The succession ranges from Middle Devonian to Famennian and is characterised by siltstones, sandstones, carbonates and cherts with intercalations of volcanoclastics. Most parts can be correlated with section in South China. The entire succession is also comparable to facies settings in the southern Rhenish Massif, Germany. Thanks to facies analysis and new biostratigraphic data the authors introduce a new facies model for the investigated area in northeastern Thailand. Accordingly, a depositional setting close to a continental margin is most likely. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-017-0294-z](https://doi.org/10.1007/s12549-017-0294-z)).

Two successive publications provide new data on a section in Iran. **Königshof et al. (2017a)** studied the Zefreh section, a late Givetian to early Frasnian shallow-water section in central Iran. The multidisciplinary approach provides detailed information on the facies changes on a carbonate ramp. Microfacies analysis allowed the discrimination of 12 microfacies reflecting supratidal to open-marine palaeoenvironments. Geochemical redox proxies indicate a

generally oxygen-rich palaeoenvironment. Sedimentary provenance using various trace elements suggests that the sediments are most likely derived from continental arc volcanics and support the previously published plate tectonic interpretations. A sea-level rise recorded in the Zefreh section close to the Givetian-Frasnian boundary represents probably the so-called Frasnian Event. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-017-0272-5](https://doi.org/10.1007/s12549-017-0272-5)).

Ernst et al. (2017) present a report on new bryozoan findings from the Late Devonian (Frasnian) part of the Zefreh section in central Iran, an area little is known on bryozoans so far. They describe two new species: the trepostome *Coeloclemis zefrehensis* sp. nov. and the rhabdomesine cryptostome *Euthyrhombopora tenuis* sp. nov. The latter is the oldest record of the genus *Euthyrhombopora*. Palaeobiogeography of bryozoan species is discussed which supports the assumption that central Iran was most probably connected to the southern rim of Europe during most of the Palaeozoic. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-016-0269-5](https://doi.org/10.1007/s12549-016-0269-5)).

Casier (2017) describes in detail ecological changes of ostracods around the Frasnian/Famennian (F/F) boundary in the southern border of the Dinant Synclinorium. His findings prove that the Late Devonian mass extinction is related to a period of hypoxia of marine waters which is marked by the occurrence of the Myodocopid Mega Assemblage. A regression which occurs close to the F/F boundary is suggested by the occurrence of ostracods indicative of semi-restricted water conditions in several sections. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-017-0278-z](https://doi.org/10.1007/s12549-017-0278-z)).

The publication by **Vachard et al. (2017)** deals with the Late Devonian (mid-Famennian) Baelen mud mounds in Belgium and new taxonomic and palaeoecological results on problematical protists *Serrisinella* and *Dreesenulella*. Their results provide new information on the palaeobathymetry of the Baelen mud mounds and support sedimentological evidence for their relative shallow carbonate ramp depositional setting. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-016-0263-y](https://doi.org/10.1007/s12549-016-0263-y)).

Lüddecke et al. (2017) describe a middle Famennian section in the northern Rhenish Massif (Upper Ballberg Quarry) based on conodont stratigraphy and microfacies data. The microfacies analysis exhibits a rather uniform lithology of mainly bioturbated, microsparitic mud-wackestones which point to an outer shelf palaeoenvironment. The distinctive fluctuations in conodont assemblages despite a monotonous lithology prove the refined conodont biofacies analysis have potential to reconstruct palaeoenvironmental changes with a much higher precision than microfacies analysis in that special case. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-017-0288-x](https://doi.org/10.1007/s12549-017-0288-x)).

Lebedev and Lukševičs (2017) investigated the tetrapodomorph fish *Glyptopomus bystrowi* from the Upper Famennian of Latvia and central Russia in detail. Thanks to the excellent preservation of isolated elements, it was possible to describe internal cranial structures such as the posterodorsolateral expansion of prenasal pits, the passage of some nerves and blood vessels, which were unknown in the previously described species of this genus. The authors show that the vertebrate assemblages from the investigated areas fit within the *Bothriolepis ciecare* placoderm Zone (VII), which corresponds to the Upper *postera*–Lower *expansa* conodont Zone interval. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-016-0249-9](https://doi.org/10.1007/s12549-016-0249-9)).

Söte et al. (2017) provide an important contribution to the ongoing discussion on the Devonian/Carboniferous (D/C) boundary. They present a bed-by-bed study of the Reigen Quarry (Rhenish Massif, Germany) based on a detailed stratigraphy. The authors describe new conodont assemblages from that section and discuss the ranges of different species in the frame of the revision of the D/C boundary. They also provide new data on conodont biofacies and describe a new *Neopolygnathus* biofacies that previously has not been recorded from deep-water pre-Hangenberg Crisis strata. The description of the ammonoid fauna, facies development and regional correlation complement this interesting contribution. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-017-0287-y](https://doi.org/10.1007/s12549-017-0287-y)).

The first-order global Hangenberg Crisis strongly affected the marine ecosystems with severe losses within the tabulate and rugose corals amongst other organisms. **Denayer and Webb (2017)** describe earliest Mississippian rugose corals from Australia and compare them with occurrences in other regions. At the global scale, the earliest Tournaisian rugose coral genera share several characters of post-disaster taxa, whereas the Australian genera are not post-disaster taxa but represent final branches of lineages that already evolved during the Late Devonian. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-016-0261-0](https://doi.org/10.1007/s12549-016-0261-0)).

Sardar Abadi et al. (2017) investigated the Early Carboniferous foraminiferal assemblages of the Mobarak Formation in the Alborz Basin, Iran. Ivorian foraminiferal proliferation follows a cyclic pattern; a first cyclic episode was followed by two distinct pulses of second proliferation and diversification. These latter episodes of foraminiferal recolonization of the Alborz Basin coincide with the first foraminiferal radiation at the same time in other Peri-Gondwanan microcontinents. The occurrence of specific taxa in the Mobarak Formation is linked to transgressions and migrations of Noth Palaeotethyan fauna. The pulses are linked with global eustatic sea-level fluctuations caused by climate oscillations (Early Carboniferous glaciation) and follows a fourth-order

ocean-level fluctuations. (*Palaeobiodiversity and Palaeoenvironments* 97(3); doi: [10.1007/s12549-017-0281-4](https://doi.org/10.1007/s12549-017-0281-4)).

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