TREATISE ON
INVERTEBRATE PALEONTOLOGY

Part B
PROTOCTISTA 1

Volume 1:
Charophyta

MONIQUE FEIST, COORDINATING AUTHOR

by MONIQUE FEIST, NICOLE GRAMBAST-FESSARD,
MICHÉLINE GUERLESQUIN, KENNETH KAROL, LU HUINAN,
RICHARD M. MCCOURT, WANG QIFEI, and ZANG SHENZEN

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PART B
PROTOCTISTA 1
VOLUME 1: CHAROPHYTA
(Moellerinales, Sycidiales, Charales)

MONIQUE FEIST, NICOLE GRAMBAST-FESSARD, MICHELINE GUERLESQUIN,
KENNETH KAROL, LU HUINAN, RICHARD M. MCCOURT, WANG QIFEI, AND
ZANG SHENZEN

INFORMATION ON TREATISE VOLUMES ................................................................. vi
EDITORIAL PREFACE (Roger L. Kaesler) ....................................................................... viii
STRATIGRAPHIC DIVISIONS ........................................................................................ xi
COORDINATING AUTHOR’S PREFACE (Monique Feist) .................................................. xii
REPOSITORIES AND THEIR ABBREVIATIONS ................................................................ xiv
MORPHOLOGY (Micheline Guerlesquin and Monique Feist) .............................................. 1
Morphology of Living Charophyta .................................................................................. 1
Morphology of Fossil Charophyta .................................................................................. 12
MINERALIZATION (Monique Feist) .................................................................................. 24
Mineral Composition ..................................................................................................... 24
Isotopic Composition ..................................................................................................... 24
TECHNIQUES FOR PREPARATION AND STUDY OF FOSSIL CHAROPHYTA (Monique Feist) ......... 26
Release from Matrix .................................................................................................... 26
Concentration of Fossils ............................................................................................. 26
Cleaning ....................................................................................................................... 27
Coloration .................................................................................................................... 27
Preparing Thin Sections of Gyrogonites ...................................................................... 27
Observation and Photography ...................................................................................... 28
Measurements .............................................................................................................. 28
ECOLOGY AND PALEOECOLOGY (Monique Feist and Micheline Guerlesquin) ..................... 29
Water Quality .............................................................................................................. 29
Substratum .................................................................................................................. 29
Depth .......................................................................................................................... 30
Light ............................................................................................................................ 30
Temperature ............................................................................................................... 30
Salinity ....................................................................................................................... 30
Alkalinity .................................................................................................................... 32
Content of Lime in Water ............................................................................................ 32
Modes of Life of Fossil Genera ................................................................................... 32
Fossil Genera with Extant Representatives ................................................................... 32
Totally Extinct Genera ............................................................................................... 33
Paleoecology of Paleozoic Charophytes: Were They Marine? ....................................... 33
BIOGEOGRAPHY (Micheline Guerlesquin and Monique Feist) .......................................... 36
Introduction .................................................................................................................. 36
Areas of Distribution .................................................................................................... 36
STRATIGRAPHIC DISTRIBUTION AND PALEOBIOGEOGRAPHY (Monique Feist and Nicole Grambast-Fessard) ................................................................. 39
INFORMATION ON TREATISE VOLUMES

Parts of the *Treatise* are distinguished by assigned letters with a view to indicating their systematic sequence while allowing publication of units in whatever order each is made ready for the press. Copies can be obtained from the Publication Sales Department, The Geological Society of America, 3300 Penrose Place, P.O. Box 9140, Boulder, Colorado 80301, www.geosociety.org.

PUBLISHED VOLUMES


Part C. *Protista* 2 (Sarcodina, Chiefly “Thecamoebians” and Foraminiferida), Volumes 1 and 2, xxxi + 900 p., 653 fig., 1964.


Part O. ARTHROPODA 1 (Arthropoda General Features, Protarthropoda, Euarthropoda
General Features, Trilobitomorpha), xix + 560 p., 415 fig., 1959.
Part O, Revised. ARTHROPODA 1 (Trilobita: Introduction, Order Agnostida, Order
Part P. ARTHROPODA 2 (Chelicera, Pycnogonida, Palaeoisopus), xvii + 181 p., 123 fig.,
1955 [1956].
Part R. ARTHROPODA 4, Volumes 1 and 2 (Crustacea Exclusive of Ostracoda, Myriapoda,
Hexapoda), xxxvi + 651 p., 397 fig., 1969.
Part S. ECHINODERMATA 1 (Echinodermata General Features, Homalozoa, Crinozoa,
exclusive of Crinoidea), Volumes 1 and 2, xxx + 650 p., 400 fig., 1968 [1967].
Part T. ECHINODERMATA 2 (Crinoidea), Volumes 1–3, xxxviii + 1,027 p., 619 fig., 1978.
Part W. MISCELLANEA (Conodonts, Conoidal Shells of Uncertain Affinities, Worms, Trace
Part W, Revised. MISCELLANEA, Supplement 1 (Trace Fossils and Problematica), xxi + 269
Part W, Revised. MISCELLANEA, Supplement 2 (Conodonts), xxviii + 202 p., frontis., 122
fig., 1981.

THIS VOLUME


VOLUMES IN PREPARATION

Part B. PROTOCTISTA 1 (Chrysomonadida, Coccolithophorida, Diatomacea, Pyrrhophyta,
etc.).
Part E, Revised. PORIFERA (additional volumes).
Part F, Revised. Cnidaria (Scleractinia).
Part G, Revised. BRYOZOA (additional volumes).
Part H, Revised. BRACHIOPODA (additional volumes).
Part K, Revised. MOLLUSCA 3 (Nautiloidea).
Part L, Revised. MOLLUSCA 4 (Ammonoidea) (additional volumes).
Part M. MOLLUSCA 5 (Coleoidea).
Part O, Revised. ARTHROPODA 1 (Trilobita) (additional volumes).
Part Q, Revised. ARTHROPODA 3 (Ostracoda).
Part T, Revised. ECHINODERMATA 2 (Crinoidea).
Part V, Revised. GRAPTOLITHINA.
Part W, Revised. TRACE FOSSILS.
EDITORIAL PREFACE

ROGER L. KAESLER
[The University of Kansas]

From the outset the aim of the Treatise on Invertebrate Paleontology has been to present a comprehensive and authoritative yet compact statement of knowledge concerning groups of invertebrate fossils. Typically, preparation of early Treatise volumes was undertaken by a small group with a synoptic view of the taxa being monographed. Two or perhaps three specialists worked together, sometimes co-opting others for coverage of highly specialized taxa. Recently, however, both new Treatise volumes and revisions of existing ones have been undertaken increasingly by teams of specialists led by a coordinating author. This volume has been prepared by such a team.

Given the aim of the Treatise, one might be excused for wondering about our decision, following the earlier lead of Raymond C. Moore when he first organized the project, to include in the Treatise on Invertebrate Paleontology the phylum Charophyta. Invertebrates, after all, are defined as animals without backbones. Of all the kinds of organisms that are likely to make it into the Treatise, the charophytes are perhaps the least animal-like. On the contrary, they are among the most plantlike of the algae, and indeed some authors have regarded the charophytes as the basal group of kingdom Plantae.

The present arrangement, of course, stems from Moore’s sense of practicality and his interest in completeness. From the outset his plan was to include a number of taxa of protists in the Treatise. Some of the groups that are related to the charophytes—in the same kingdom at least—are among the most useful and intensively studied kinds of fossils. To have omitted the order Foraminiferida from the Treatise, for example, would have done a great disservice to paleontology as a whole.

Part C of the Treatise covers the order Foraminiferida, now regarded by Margulis and Schwartz (1998) as class Foraminifera of the phylum Granuloreticulosa. Part D, a rather slim volume, details the radiolarians, which comprise two classes of the phylum Actinopoda (Margulis & Schwartz, 1998). Part B, of which this is the first volume, is intended to deal with all the plantlike protists: calcareous nannoplankton, benthic calcareous algae, dinoflagellates, silicoflagellates and ebridians, diatoms, and, herein, the charophytes.

We have departed from Moore’s original plan in one major way that may disturb some systematists. The part of the Treatise that deals with foraminifera (in two volumes) is labeled formally as C Protista 2(1) and C Protista 2(2). The radiolarian Treatise is D Protista 3. Clearly Moore intended the present volume and others that deal with the plantlike protists to be formally B Protista 1. We have, instead, labeled this volume B Protoctista 1, following Margulis and others (1990), Margulis, McKhann, & Olenedzenski (1992), Margulis & Schwartz (1998), and L. Margulis (personal communication, 2004). Brown (1993, p. 2,389), in a widely used dictionary defined protist as follows: “A member of the kingdom Protista of simple organisms regarded as intermediate between or distinct from animals and plants, including protozoans, algae and (now less commonly) bacteria and fungi; esp. a unicellular eukaryote, a protozoan or single-celled alga.”

Margulis and Schwartz (1998, p. 112) pointed out that for more than one hundred years the term protist has connoted a single-celled organism. The basis for grouping single-celled organisms separately from multicellular forms is no longer tenable for at least two reasons. First, the single-celled
prokaryotes and the single-celled eukaryotes are organized biologically in fundamentally different ways and ought not to be classified together in the kingdom Protista. Second, many of the predominantly single-celled eukaryote phyla have multicellular members that have evolved independently of each other. Margulis and Schwartz (1998, p. 112) capped their argument by pointing out that Copeland (1956) along with numerous 19th-century biologists recognized "the absurdity of referring to giant kelp by the word 'protist,' a term that had come to imply unicellularity and, thus, smallness." Use of the kingdom Proctista obviates this absurdity, and we have adopted herein the term for that reason.

Users of previous volumes of the Treatise have found in the Editorial Preface details pertaining to use of the International Code of Zoological Nomenclature (Ride & others, eds., 1999; please refer to the most recent Treatise volume, Part E(R), vol. 3, 2004, for guidance about preparation of manuscript according to zoological nomenclature). The charophytes, of course, are governed by the International Code of Botanical Nomenclature (Greuter & others, 2000), the provisions of which are in many instances quite unlike those of the ICZN. In delving into the use of the botanical code, we on the Treatise editorial staff have been assisted by E. L. Taylor, C. H. Haufler, both of The University of Kansas, and M. Feist, the coordinating author of this volume. Nomenclatorial codes tend to be rather legalistic and difficult to navigate. Fortunately, a number of sources are available that guide the interested invertebrate paleontologist who is dealing with the ICBN for the first time. One source that we found to be most useful is the set of notes by Fensome and Williams (2004).

The charophyte Treatise has had a rather interesting history. R. E. Peck was the original author of the volume. He worked with both R. C. Moore and Curt Teichert. In 1983 Peck turned over his manuscript and responsibility for the volume to R. M. Forester, who enlisted the help of M. Feist and N. Grumbast-Fessard. Dr. Peck died in 1984, and in 1991 pressure from his other work necessitated that Dr. Forester resign his Treatise responsibilities. In 1995 J. A. Eyer offered to assist with the project but given the active work of Drs. Feist and Grumbast-Fessard did not get involved further. Dr. Feist, as coordinating author, and her team made steady progress. They were assisted by the preliminary editorial work of R. M. McCourt.

Some languages, most notably the Polish and Czech languages, are enriched with the use of diacritical marks that provide enhanced alphabetical diversity. While celebrating diversity, we have nevertheless elected to omit such marks from Polish and Czech geographical terms used in the Treatise. We continue to insert diacritical marks into authors’ names. Two factors have led us to this editorial decision. First, we in the Treatise editorial office typeset electronically all the pages, and such diacritical marks must be inserted by hand into the final computer-prepared pages. This is a costly and time-consuming operation that is fraught with the possibility of introducing errors. Second, in the burgeoning information age of the new millennium, databases and schemes for information retrieval will be of critical importance in managing paleontological information. Stability and uniformity of terminology are requisites of database-management systems, and the use of diacritical marks and computer technology are likely to remain incompatible for some time to come. We hope that linguistic purists will be tolerant of this transgression, which we have undertaken solely in the interest of expediency, consistency, and information retrieval.

In this volume we have taken special pains to acknowledge authorship of chapters and subsections. Readers citing the volume are encouraged to pay close attention to the actual authorship of a chapter or subsection. Stratigraphic ranges of taxa have been compiled from the ranges of lower taxa. In all instances, we have used the range-through method of describing ranges. In instances,
therefore, where the work of paleontology is not yet finished, some ranges of higher taxa will not show gaps between the ranges of their subtaxa and may seem to be more complete than the data warrant.

While editor of the *Treatise*, the late Professor Curt Teichert once remarked that a published *Treatise* volume is a progress report and should by no means be regarded as the last word on the systematics and paleontology of the organisms discussed. All of us associated with publishing this volume hope that it will stimulate a burst of activity of research on the charophytes.

**ACKNOWLEDGMENTS**

The Paleontological Institute’s Assistant Editors for Text, Jean Burgess and Jill Hardesty, and the Assistant Editor for Illustrations, Jane Kerns, have faced admirably the formidable task of moving this volume through the various stages of editing and into production. In this they have been assisted ably by other members of the editorial team including Mike Cormack with his outstanding computer skills, Chasity Gaultney with her work on illustrations, and Denise Mayse with general support. Jill Krebs, the remaining member of the Paleontological Institute editorial staff, is involved with preparation of PaleoBank, the paleontological database for future *Treatise* volumes, and has not been closely involved with this volume.

It is quite unlikely that this volume would have been published without the efforts of Monique Feist. She was the driving force behind the volume and has been a paragon as a coordinating author. Her synoptic view of the charophytes, her skill in bringing together an international team of specialists, and her careful attention to detail have made the work of the editors much easier. We are grateful to her for her dedication.

Roger L. Kaesler
Lawrence, Kansas
May 3, 2005

**REFERENCES**


STRATIGRAPHIC DIVISIONS

The major divisions of the geological time scale are reasonably well-established throughout the world, but minor divisions (e.g., subseries, stages, and substages) are more likely to be provincial in application. The stratigraphic units listed here represent an authoritative version of the stratigraphic column for all taxonomic work relating to this volume. They are adapted from the International Stratigraphic Chart, and units are approved by the International Commission on Stratigraphy (ICS) and ratified by the International Union of Geological Sciences (IUGS). A copy of the complete chart can be obtained at the following website: http://www.iugs.org/iugs/pubs/intstratchart.htm.

Cenozoic Erathem
   Neogene System
      Holocene Series
      Pleistocene Series
      Pliocene Series
      Miocene Series
   Paleogene System
      Oligocene Series
      Eocene Series
      Paleocene Series

Mesozoic Erathem
   Cretaceous System
      Upper Cretaceous Series
      Lower Cretaceous Series
   Jurassic System
      Upper Jurassic Series
      Middle Jurassic Series
      Lower Jurassic Series
   Triassic System
      Upper Triassic Series
      Middle Triassic Series
      Lower Triassic Series

Paleozoic Erathem
   Permian System
      Lopingian Series
      Guadalupian Series
      Cisuralian Series
   Carboniferous System
      Pennsylvanian Subsystem
      Mississippian Subsystem
   Devonian System
      Upper Devonian Series
      Middle Devonian Series
      Lower Devonian Series
   Silurian System
      Pridoli Series
      Ludlow Series
      Wenlock Series
      Llandovery Series
   Ordovician System
      Upper Ordovician Series
      Middle Ordovician Series
      Lower Ordovician Series
   Cambrian System
      Furongian Series
      Middle Cambrian Series
      Lower Cambrian Series
The Charophyta, commonly called charophytes or stoneworts, are green algae that occur worldwide, sometimes abundantly, in fresh and brackish water. Long considered a distinctive group, recent morphological and molecular studies have shown conclusively that charophytes are members of the evolutionary lineage of green algae that gave rise to land plants. Their importance is enhanced by a fossil record more complete and well studied than nearly any other calcareous algae, with the exception of the Dasycladales.

Extant charophytes are of little commercial importance; however, they are of great scientific value. Their primary importance is as model organisms in studies of membrane electrophysiology and cell physiology; and ecological studies are often in relation to recent problems of water management (see chapter on Ecology, p. 29).

Although fossil charophytes were reported as early as the 18th century (Schreber, 1759), most charophyte research has been performed within the last century. After the first attempts to establish a coherent classification of the group (see chapter on Classification, p. 83) authors paid attention to the description of assemblages, first in the Paleozoic of Russia (Karpinsky, 1906) and in the Paleozoic and Mesozoic of North America (Peck, 1934a, 1934b, 1938). Studies of Tertiary charophyte floras started in England (Reid & Groves, 1921); then they were developed in Germany (Mädler, 1955), Sweden (Horn af Rantzien, 1959b), France, England, Belgium (Grambast, 1958, 1959b, 1962), and in the former USSR (Maslov, 1966a).

At the same time, new observations of particular characters of the gyrogonite (basal plate, apical aperture, and ornamentation) facilitated the distinction of genera and species (Grambast, 1956a, 1956c, 1957). Grambast (1964) also revealed the existence of phylogenetic relationships within the charophytes and especially within the family Clavatoraceae, whose lineage to the plant kingdom is quite remarkable (see chapter on Evolutionary History, p. 60).

Charophytes are represented in the fossil record mainly by the calcified female fructifications, consisting of the gyrogonite and utricle. These fructifications are broadly spherical bodies, ranging from 200 to 3,500 µm. Fossil charophytes provide an excellent source of stratigraphic data, which have numerous applications in paleontology. Their distribution in space and time has provided the basis for establishing biozonal scales (see chapter on Stratigraphic Distribution, p. 39).

Research developed in the last twenty years has been concerned primarily with the application of cladistic analyses and molecular biology to infer phylogenetic relationships both within the Charophyta and the plant kingdom (see chapters on Evolutionary History and Molecular Phylogeny, p. 60 and p. 77, respectively).

Fossil and extant charophytes are often studied independently by different groups of researchers. The present volume brings together knowledge of fossil and extant forms; it is thus intended to be a synthesis that is useful to a wide variety of scientists who study charophytes. The group comprises 86 genera, 12 families, and 3 orders, which are described in this volume, the first edition of the Treatise to include coverage of this important group.

We wish to thank the following colleagues who have given permission to reproduce illustrations and in many cases have provided original artwork: Dr. Jean-Pierre Berger, Institut de Geologie, Fribourg, Switzerland; M. Hagen Has and Dr. Hans Kerp, Forschungsstelle für Paläobotanik, West-
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We are grateful to Dr. Gilbert Klapper, Department of Geology, University of Iowa, Iowa City, USA, and to Dr. Richard McCourt, Academy of Natural Sciences, Philadelphia, USA, for reviewing portions of the manuscript. We thank M. Michel Pons who assisted with photography, and Jacqueline Courbet and Laurence Meslin for preparing original drawings, all from the Laboratoire de Paléontologie, Université Montpellier II, Montpellier, France.
## REPOSITORIES AND THEIR ABBREVIATIONS

Abbreviations and locations of museums and institutions holding type material, which are used throughout the volume, are listed below.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Location and Details</th>
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<tbody>
<tr>
<td>AGE</td>
<td>Archiv für Geschiebekunde, Geologisch-Paläontologisches Institut, Hamburg, Germany</td>
</tr>
<tr>
<td>AI</td>
<td>Institute of Geological Sciences, Polish Academy of Sciences, Kraków, Poland</td>
</tr>
<tr>
<td>AMNH</td>
<td>American Museum of Natural History, New York City, New York, USA</td>
</tr>
<tr>
<td>AM or AMu</td>
<td>Australian Museum, Sydney, Australia</td>
</tr>
<tr>
<td>BGMRH</td>
<td>Bureau of Geology and Mineral Resources of Henan, Henan, China</td>
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<tr>
<td>BGR</td>
<td>Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Germany</td>
</tr>
<tr>
<td>BGS</td>
<td>British Geological Survey, MPK collection, Nottingham, United Kingdom</td>
</tr>
<tr>
<td>BIG</td>
<td>Beijing Institute of Geology, Beijing, China</td>
</tr>
<tr>
<td>BM</td>
<td>Berlin Museum, Berlin, Germany</td>
</tr>
<tr>
<td>BMNH</td>
<td>British Museum (Natural History), London, United Kingdom</td>
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<tr>
<td>BMS</td>
<td>Buffalo Museum of Science, Buffalo, New York, USA</td>
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<td>BPGNC</td>
<td>Bureau of Petroleum Geology of North China, Zhengzhou, Henan, China</td>
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<td>BPNWC</td>
<td>Bureau of Petroleum of North West China, Wulumuqi, Xinjiang, China</td>
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<td>BSPGM</td>
<td>Bayerische Staatsammlung für Paläontologie und historische Geologie, München, Germany</td>
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<tr>
<td>BYU</td>
<td>Geology Department, Brigham Young University, Provo, Utah, USA</td>
</tr>
<tr>
<td>CCG</td>
<td>Chengdu College of Geology (now Chengdu University of Technology), Chengdu, Sichuan, China</td>
</tr>
<tr>
<td>CEGH-UNC</td>
<td>Cátedra de Estratigrafía y Geología Histórica, Universidad Nacional de Córdoba, Córdoba, Argentina</td>
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<tr>
<td>CSGM</td>
<td>Central Siberian Geological Museum, United Institute of Geology, Geophysics, &amp; Mineralogy, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia</td>
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<tr>
<td>CU</td>
<td>University of Cincinnati, Cincinnati, Ohio, USA</td>
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<td>CUG</td>
<td>Colgate University, Geology Department Collections, Hamilton, New York, USA</td>
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<td>CPC</td>
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<td>CRICYT</td>
<td>Centro Regional de Investigaciones Científicas y Tecnológicas, Mendoza, Argentina</td>
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<td>DNPM</td>
<td>Departamento Nacional da Produção Mineral, Rio de Janeiro, Brazil</td>
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<tr>
<td>FEGI</td>
<td>Far East Geological Institute, Russian Academy of Sciences, Vladivostok, Russia</td>
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<tr>
<td>FM</td>
<td>Field Museum (Natural History), Chicago, Illinois, USA</td>
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<tr>
<td>FUB</td>
<td>Freie Universität Berlin, Institut für Geologische Wissenschaften, Fachrichtung Paläontologie, Berlin, Germany</td>
</tr>
<tr>
<td>GII</td>
<td>Institut für Geologie und Paläontologie der Universität Innsbruck, Innsbruck, Austria</td>
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<td>GIK</td>
<td>Geologisch-Paläontologisches Institut, Universität zu Köln, Köln, Germany</td>
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<tr>
<td>GISO</td>
<td>Geological Institute of Shengli Oil Field, Dongying, Shandong, China</td>
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<td>GMU</td>
<td>Geological Museum, Ukrainian Academy of Sciences, Kiev, Ukraine</td>
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<td>GPIMH</td>
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<td>GSC</td>
<td>Geological Survey of Canada, Ottawa, Canada</td>
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<td>GSWA</td>
<td>Geological Survey of Western Australia, East Perth, Australia</td>
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<td>HM</td>
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<td>IGASB</td>
<td>Institute of Geology, Academia Sinica, Beijing, China</td>
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<td>IGPTU</td>
<td>Institut und Museum für Geologie und Paläontologie, Tübingen Universität, Tübingen, Germany</td>
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<td>IPFUB</td>
<td>Institut für Paläontologie, Freie Universität, Berlin, Germany</td>
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<td>IPPAS</td>
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<td>Institut für Paläontologie, Universität Bonn, Bonn, Germany</td>
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<td>IPUM</td>
<td>Instituto di Paleontologia, Università di Modena, Modena, Italy</td>
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<tr>
<td>MCCA</td>
<td>Museo Comunale in Cortina d’Ampezzo, Cortina d’Ampezzo, Italy</td>
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MCZ: Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA
MFGI: Museum Far Eastern Geological Institute, Vladivostok, Russia
MGSB: Museo Geologico, Seminari Conciliar, Barcelona, Spain
MHGI: Museum of the Hungarian Geologic Institute, Budapest, Hungary
MIGT: Museum, Institute of Geology, Dushambe, Tajikistan
MLGIN: Micropalaeontological Laboratory, Geological Institute, Academy of Sciences, Moscow, Russia.
MLP: Collection Paleobotanica, Museo de la Plata, La Plata, Argentina
MMMN: Manitoba Museum of Man and Nature, Winnipeg, Canada
MMF: Geological and Mining Museum, Sydney, Australia
MNCN: Museo Nacional de Ciencias Naturales, Madrid, Spain
MNHN: Muséum National d'Histoire Naturelle de Paris, Paris, France
MNMPB: Magyar Nemzeti Museum, Budapest, Hungary
MNS: Museum für Naturkunde, Stuttgart, Germany
MUZ IG: Museum of the State Geological Institute, Warsaw, Poland
NMH: Natural History Museum, London, United Kingdom
NIGP: Nanjing Institute of Geology and Palaeontology, Nanjing, China
NIGPAS: Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing, China
NIUPGAS: Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing, China
NMV: National Museum of Victoria, Melbourne, Australia
NRM: Naturhistoriska Riksmuseet (Swedish Museum of Natural History), Stockholm, Sweden
NYSM: New York State Museum, Albany, New York, USA
ODM: Old Dominion College, Norfolk, Virginia, USA
OSU: Ohio State University, Department of Geology, Columbus, Ohio, USA
OUZC: Ohio University Zoological Collections, Athens, Ohio, USA
PDMNH-P: Paleontological Department of the National Museum, Museum of Natural History, Prague, Czech Republic
PIUB: Paleontologische Institute of the University of Bonn, Bonn, Germany
PIUFB: Palaöontologisches Institut, Freie Universität Berlin, Berlin, Germany
PIUW: Palaöontologischen Instituts, Universität Wien, Vienna, Austria
PIUZ: Paleontological Institute, University of Zürich, Zürich, Switzerland
PIW: Institut für Paläontologie der Universität Würzburg, Würzburg, Germany
P-MD: Provincial Museum of Danzig, Danzig, Germany
PMUK: Palaeontological Museum, University of Kiev, Ukraine
PRM: Peter Redpath Museum, Montreal, Canada
PU: Princeton University, Princeton, New Jersey, USA
ROM: Royal Ontario Museum, Toronto, Canada
RMS: Palaeobotanical Department, Riksmuseum, Stockholm, Sweden
SAM: South Australian Museum, Adelaide, Australia
SGIP: Sammlung des Geologisch-Paläontologischen Institutes der Universität Palermo, Palermo, Italy
SGS: Geological Collection, Swedish Geological Survey, Uppsala, Sweden
SMF: Natur-Museum und Forschungs-Institut, Senckenberg, Germany
SPIE: Sammlung des Institut für Paläontologie, Universität Erlangen-Nürnberg, Erlangen, Germany
SPIML: Sammlung des Paläontologischen Institutes der Universität Marburg, Lahn, Germany
SPIT: Sammlung des Paläontologischen Institutes der Universität Tübingen, Tübingen, Germany
SSPHG: Staatliches Sammlung für Paläontologie und historische Geologie, München, Germany
SSSBGF: Stratigraphische Sammlung der Sektion Geowissenschaften der Bergakademie Freiberg, Freiberg, Germany
SUP: Sydney University, Department of Geology, Sydney, Australia
TMM: Texas Memorial Museum, University of Texas, Austin, Texas, USA
TsNIGER: Ts NIGER Museum, Russia
UA: University of Alberta, Edmonton, Alberta, Canada
UAF: University of Alaska, Fairbanks, Alaska, USA
UC: University of Cincinnati, Cincinnati, Ohio, USA
UCC: Chicago Natural History Museum, formerly in Walker Museum, Chicago, Illinois (see also FM), USA
UCM: Universidad Complutense de Madrid, Madrid, Spain
UG: University of Göttingen, Göttingen, Germany
UL: Lodz University, Institute of Geography, Lodz, Poland
UM: University of Minnesota, Minneapolis, Minnesota, USA
UMC: University of Missouri-Colombia, Colombia, Missouri, USA
UMG: University of Montana, Department of Geology, Missoula, Montana, USA
UMP: University Montpellier II, Department of Palaeontology, Montpellier, France. C. L. Grambast Collection; CF, M. Feist Collection; CM, M. Massieux Collection; CSM, I. Soulié-Märsche Collection
UNE: University of New England, Armidale, New South Wales, Australia
UPLGS: Université de Paris, Laboratoire de Géologie de la Sorbonne, Paris, France
USGS: U.S. Geological Survey, Type algae collection, Denver, Colorado, USA
USNM: U.S. National Museum, Washington, D.C., USA
U-SK: Universitäts-Sammlung zu Kiel, Germany
UTBEG: University of Texas, Bureau of Economic Geology, Austin, Texas, USA
VK: Theo Van Kemper Collection, Amsterdam, The Netherlands
WAGS: Western Australia Geological Survey, Perth, Australia
WAM: Western Australia Museum, Perth, Australia

WIF: Wadi Institute of Himalayan Geology, Dehra Dun, India
WMC: Woodwardian Museum, University of Cambridge, Cambridge, United Kingdom
WMNM: Westfälisches Museum für Naturkunde, Münster, Germany
YaFAN: Institute of Geology, Yakut Branch, Siberian Division AN SSR, Yakutsk, Russia
YPM: Yale Peabody Museum, New Haven, Connecticut, USA
ZPAL: Institute of Paleobiology, Polish Academy of Sciences, Warsaw, Poland