TREATISE ON
INVERTEBRATE PALEONTOLOGY

Part E

PORIFERA

Revised
Hypercalcified Porifera
Volume 4

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PART E
PORIFERA
Revised
HYPERCALCIFIED PORIFERA, Volumes 4 and 5

By F. Debrenne, Willard D. Hartman, Stephen Kershaw, P. D. Kruse, Heldur Nestor, J. Keith Rigby Sr., B. Senowbari-Daryan, Colin W. Stearn, Carl W. Stock, Jean Vacelet, Barry D. Webby, Ronald R. West, Philippe Willenz, Rachel A. Wood, and A. Yu. Zhuravlev

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COORDINATING AUTHOR'S PREFACE

Barry D. Webby

Volumes 4 and 5 complete the revision of the *Treatise on Invertebrate Paleontology,* Part E, Porifera. The volumes focus on groups called, collectively, hypercalcified sponges (Termier & Termier, 1973): that is, encompassing all forms that acquired a mainly nonspicular, basal skeleton of calcium carbonate to support and maintain the organism's soft tissues, with it usually mantling above, but occasionally investing part of the associated substrate. The types of hypercalcified skeleton became well adapted, especially in Phanerozoic reef habitats, across a range of distinctly different fossil groups of demosponges and calcareans. The volumes aim: (1) to present comprehensive introductions and systematic descriptions of the main hypercalcified fossil sponge groups—namely, the archaeocyaths, stromatoporoids, and chaetetids; (2) to provide an introduction and systematic descriptions of the comparatively few hypercalcified demosponge and calcarean taxa that are still living; and (3) to add an introduction about the other hypercalcified demosponges and calcareans, represented by the sphinctozoan- and inozoan-type morphologies, to the systematic descriptions of these forms contributed previously in Volume 3 of the *Treatise,* Part E, Porifera, Revised, by Robert M. Finks and J. Keith Rigby (2004d).

Siliceous spicules were secreted by the soft tissue and acted in a variety of support roles in living hypercalcified demosponges. Commonly, they were secondarily accreted to their basal skeletons by calcareous cements. Alternatively, they may have remained as discrete elements in the body of the sponge, or, during the life of the sponge, they may have been initially secreted then reabsorbed in the skeleton, or these siliceous spicules were never secreted. Calcareous spicules, on the other hand, were secreted only in hypercalcified calcareans, with some developing in association with an initial spicular skeleton, or becoming incorporated secondarily in carbonate cementation of the solid basal skeleton. In fossil counterparts, the spicules are seldom recorded in their original state; typically, they show significant levels of diagenetic alteration and are, in consequence, largely preserved as spicule pseudomorphs. Such structures are not uncommon in Mesozoic stromatoporoids (Wood, 1987) and have been identified also in late Paleozoic and Mesozoic chaetetids (Gray, 1980). However, spicule pseudomorphs have not been confirmed positively in the major hypercalcified groups such as archaeocyaths and Paleozoic stromatoporoids.

All the main hypercalcified fossil sponge groups exhibit direct or indirect evidence of aquiferous systems that supported their inferred filter-feeding activities as sponges. These features may comprise: (1) astrorhizal structures as surface impressions in the chaetetids and of surface imprints and internal canals in the stromatoporoids; (2) occurrences of porous outer and inner walls and a central cavity in the archaeocyaths; and (3) astrorhizal structures, pores in outer and inner walls, and a spongocoel (= central cavity) in sphinctozoans and inozoans.

The archaeocyaths, stromatoporoids, and chaetetids are described systematically here, for the first time in a *Treatise* volume, as members of the phylum Porifera. In some contexts, the concept of morphological grade of construction has been applied to these higher-level subdivisions, though independent taxonomic categories up to the level of classes still continue to be maintained for the description of the nonspiculate archaeocyaths and the Paleozoic stromatoporoids. The affinities of these various fossil groups have long been discussed in relation to living sponges and other groups. Kirkpatrick (1908, 1909, 1910a, 1910b, 1910c, 1911, 1912a, 1912b, 1912c, 1912d, 1912e, 1912f) was the first to thoroughly survey the characteristics of a number of living hypercalcified sponges, including the crustlike forms of one species in particular, *Merlia normani* KIRKPATRICK, 1908, which he recognized as having siliceous spicules in the living tissue as well as a supplementary calcareous skeleton. In discussion of its possible relationships, he suggested that some Paleozoic fossils, including stromatoporoids, chaetetids, and others, had "essentially the same nature as *Merlia*" (KIRKPATRICK, 1912a, p. 502) and that this genus may have been "a solitary survivor" from Paleozoic times. It is unfortunate that his ideas, published in subsequent years, across a broad range of topics on living organisms, fossils, and rocks, became increasingly idiosyncratic and untenable. Nevertheless, he must continue to be credited with recognizing correctly the links between living hypercalcified sponges and the stromatoporoids and chaetetids at a time when these latter groups were consistently treated as hydrozoans.

More than a half century later, HARTMAN and GOREAU (1970, 1972) rediscovered and properly documented many of the living sponges with hypercalcified skeletons in the Caribbean, and, contemporaneously, VACELET (1964, 1970, 1977a) commenced his remarkable series of discoveries in the Mediterranean and Indo-Pacific, which together allowed poriferan connections to be firmly established for the various fossil groups—such as stromatoporoids and chaetetids, as well the sphinctozoans—that exhibited hypercalcified skeletons.

The Archaeocyatha was treated as a separate phylum between the late 1940s and 1980s, though greater affinities were accorded to the sponges than other groups. However, the rediscoveries of living hypercalcified sponges and the recognition of a chambered, nonspiculate, sphinctozoan called *Vaceletia crypta* (VACELET, 1977b), which shows close similarities to the architecture and skeletal structure of archaeocyaths, have led to a reappraisal and suggestions that the archaeocyaths are closer taxonomically to phylum Porifera (DEBRENNE & VACELET, 1984) than previously thought. More recently, the archaeocyaths were adopted as a separate class of phylum Porifera (see DEBRENNE, ZHURAVLEV, & KRUSE, 2002, p. 1546).

NOMENCLATURAL CHANGES

Four alternative names—coralline sponges, sclerosponges, pharetronids, and ischyrosponges—have been applied previously to denote broadly equivalent (= synonymous) informal groupings of the presently accepted term hypercalcified sponges (including the hypercalcified demosponges and hypercalcified calcareans, respectively). The coralline sponges were presumably so termed because of their superficial resemblances to coral colonies and occupation as encrustations or other skeletal growths of similar reef-type settings. The term used informally by HARTMAN (1969, p. 1; HARTMAN & GOREAU, 1970, p. 228) was applied generally to all living sponges with calcified basal skeletons, astrorhizal structures, and spicules, either siliceous or calcareous. The generalized conception of the term has since been broadened to encompass these particular living forms, as well as the array of fossil representatives, particularly of stromatoporoids and chaetetids (see, for example, WOOD, 1990b, p. 225–234; REITNER, 1992, p. 1; WÖRHEIDE, 1998, p. 1–88; REITNER & others, 2001, p. 219–223, 228, 231–234; REITNER & WÖRHEIDE, 2002, p. 58–68).

There is no longer justification for retaining the informal name coralline, especially given that, in terms of taxonomic classification, neither the living forms nor fossil stromatoporoids and chaetetids have diagnostic features in common with representative cnidarian corals and hydrozoans. The only superficial resemblances between hypercalcified sponge groups like stromatoporoids and chaetetids, on the one hand, and tabulate corals, on the other, are, for example, where they develop similar growth habits as a result of sharing similar reef-building habitats. Nevertheless the two groups remain fundamentally different, so the current practice of naming particular types of skeletonized sponge as "coralline" should be discontinued (see WEBBY, 2010, p. 7).

The second name, sclerosponge, is based on class Sclerospongiae HARTMAN & GOREAU (1970, 1972). It was first used in a more restrictive sense to take account of living sponges that exhibited a massive aspicular basal skeleton of calcium carbonate (mainly aragonitic) and siliceous spicules that formed in the thin, overlying, veneerlike layer of living tissue—this latter sometimes becoming entrapped in the calcareous skeletal mass below—and the fossil counterparts, stromatoporoids and chaetetids. HARTMAN and GOREAU (1970, p. 228) proposed this higher taxon mainly to accommodate the remarkable record of living hypercalcified sponge species that they found in the fore-reef settings of the Caribbean, and their recognition of similarities with astrorhizal-bearing fossil stromatoporoids, as well as some members of the fossil Chaetetidae. Initially, the establishment of the class Sclerospongiae received widespread acceptance, even though HARTMAN and GOREAU (1970, p. 221) acknowledged that "a basal skeletal mass of aragonite [had] arisen independently within several different phylogenetic lines of the Demospongiae," and these same authors (1972, p. 144) admitted that similarities existed between sclerosponges and demosponges, particularly in the organization of their living tissue, cell types, and development (see HARTMAN, 1983, p. 116).

Additionally, Jean VACELET (1964, 1970, 1977a, 1983, 1985), in an important series of hypercalcified sponge discoveries from various parts of the world (in particular the Mediterranean and the Indo-Pacific regions), recognized that modern reef habitats exhibit a wider range of sponge groups than just those represented by a hypercalcified calcareous skeleton and the sclerosponge-type of hypercalcified skeleton with siliceous spicules, this latter regarded as derived from within a number of different orders of the class Demospongiae. Consequently, the higher-level sclerosponge grouping exhibits polyphyletic relationships, and therefore the formal use of the name should be abandoned.

ZITTEL (1878) introduced the third supra-familial group as Pharetrones, a name subsequently amended formally to Pharetronida by DE LAUBENFELS in 1955 (p. 97). VACELET (1991) later recognized such pharetronid-type skeletons as occurring within different subclasses of the Calcarea. They were composed of a massive hypercalcified skeleton—that is, either based on a reinforced spicular skeleton or a nonspicular rigid skeletal mass and usually associated with fused or free calcareous spicules. Consequently within the Calcarea, these pharetronid-type skeletons occur in different calcarean subclasses, and therefore comprise a group, which as a whole must also be interpreted as being polyphyletic in origin (VACELET, 1991, p. 261), and therefore this group name should no longer be used.

The fourth name, ischyrosponges, was based on the supra-familial grouping Ischyrospongiae TERMIER & TERMIER (1973, p. 286) and, as proposed, was likely to have the status of a superclass, given that it was considered to include three classes (Stromatoporoidea, Sclerospongia, and Pharetronidea). However, the name has been little used, even by H. TERMIER and G. TERMIER (1973) to promote this higher-level terminology and clearly proves to represent an even more polyphyletic grouping of forms than the Sclerospongiae, so its use should also be abandoned.

Preference should always be given to describing these forms broadly, and in general terms, as hypercalcified sponges, or, where their more specific relationships are known, as hypercalcified demosponges, hypercalcified calcareans, or heteractinids. The other main subdivision of hypercalcified sponges is based on the important skeletal differences that exist between the main fossil groups. Broadly, these groups comprise the archaeocyathans, chaetetids, stromatoporoids, sphinctozoans, and inozoans, as described herein.

EARLIER *TREATISE* COMPILATIONS

Previously the stromatoporoids and chaetetids were described in *Treatise* volumes as parts of the Coelenterata, and the archaeocyaths were considered to be an independent phylum. The stromatoporoids were regarded initially in the first edition of *Treatise,* Part F, Coelenterata by Marius Lecompte as belonging to class Hydrozoa (LECOMPTE, 1956, p. 107–144), whereas the chaetetids were described as tabulate corals by Dorothy Hill and Erwin Stumm in that same edition of the coelenterate *Treatise* volume (HILL & STUMM, 1956, p. 454–456). Then chaetetids were treated again more comprehensively by Dorothy Hill in Supplement 1 of the *Treatise,* Part F, Coelenterata (HILL, 1981, p. 506–520). The archaeocyaths were twice described as belonging to an independent phylum, first by Vladimir Okulitch, in a part of the first edition of the *Treatise,* Part E (Archaeocyatha and Porifera) (OKULITCH, 1955a, p. 1–20), and second, by Dorothy Hill in the second edition of the *Treatise,* Part E (Archaeocyatha) (HILL, 1972, p. 1–158).

The next revisions of *Treatise,* Part E, Porifera commenced with the publication of Volume 2: Introduction to the Porifera, by Robert M. FINKS, R. E. H. REID, and J. Keith RIGBY (2003), and Volume 3: Porifera (Demospongea, Hexactinellida, Calcarea) by the same authors in 2004. FINKS and RIGBY (2004d, p. 585–764) coauthored a substantial part (about one-third) of Volume 3 that was devoted to the systematic descriptions of the Hypercalcified Sponges, mainly those exhibiting sphinctozoan (= thalamid) and inozoan architectures. Included was a basic outline of the microstructure, morphological features, and the basis for informal subdivision into two groups, the Hypercalcified Demospongea and Hypercalcified Calcarea (FINKS & RIGBY, 2004d, p. 585–594). These groups had been referred to collectively in the past as pharetronids (after order Pharetrones of VON ZITTEL, 1878), with separation into morphological types: the chambered sphinctozoans (alternatively called thalamids, after DE LAUBENFELS, 1955), and the reticular (nonchambered) inozoans (see FINKS, 1983), with both latter names derived from STEINMANN (1882). FINKS and RIGBY (2004d, p. 590) recognized these names based on morphologic types as having some taxonomic value at the family level. However, at higher levels they are not taxonomically useful, as members of both sphinctozoan and inozoan types of constructions occur in both the class Demospongiae and the class Calcarea, and even one demosponge order (Agelasida HARTMAN, 1980b) has representatives of both morphological types, again emphasizing the polyphyly within these forms.

FINKS and RIGBY (2004c, p. 557–583) also included the exclusively Paleozoic (lower Cambrian–Permian) class Heteractinida as an independent, minor, poriferan group. It was also regarded as hypercalcified because, though it has dominantly a spicular skeleton composed of skeletal networks of various calcareous spicule types (mainly octactines, polyactines, or sexiradiates), it also has globular, saucer-shaped, or cylindrical skeletons that commonly become embedded, either partially or more completely, with coatings of cement of nonspicular calcium carbonate. On the other hand, PICKETT (2002, p. 1121) recognized the order Heteractinida as a separate member of the class Calcarea. It represents a group composed of distinctive calcareous octactine to polyactine spicule types and a rigid skeletal framework of nonspicular carbonate.

OUTLINE OF CONTRIBUTIONS TO THIS VOLUME

Much of the stimulus for the present revisions of fossil hypercalcified sponge groups stems from the spectacular rediscoveries from the late 1960s onward of living hypercalcified sponges, first by FINKS and RIGBY (in FINKS, REID, & RIGBY, 2004), and now, herein, in the sections on living hypercalcified

Porifera by Vacelet, Willenz, and Hartman; living and fossil hypercalcified chaetetid-type and post-Devonian stromatoporoid-type Demospongiae by West, Vacelet, Wood, Willenz, and Hartman; and living hypercalcified Calcarea by Vacelet. The so-called living fossils were reported mainly from the dimly lit areas of reefal habitats across a range of settings between sublittoral caves and bathyal cliffs in the tropical to subtropical waters of the Indo-Pacific and Caribbean, and more temperate waters of the Mediterranean and nearby Atlantic (HARTMAN, 1969; HARTMAN & GOREAU, 1970, 1972, 1975; VACELET, 1970, 1977a, 1985; WILLENZ & HARTMAN, 1999).

The rediscoveries of these unique living sponge faunas by Hartman, Vacelet, and others have done much to activate interest among paleontologists, especially those working on the various hypercalcified fossil groups. Consequently, closer linkages have been forged with neontologists, and a number of paleontologists have since applied various functional models based on some of the living hypercalcified forms to morphologically similar fossil taxa. In particular, for a decade or so, Stearn, West, Wood, Debrenne, and Zhuravlev have been attempting to explain aspects of the functional significance, living habits, and microstructures of their fossil taxa (mainly among stromatoporoids, chaetetids, and archaeocyaths), using examples from among the various extant hypercalcified sponge taxons as their models.

Hypercalcified sponges were considered to have acquired a rigid, nonspiculate calcareous basal skeleton in support of their growth within reef habitats by VACELET (1985), WOOD (1987, 1989), and others. They recognized also that the calcareous basal skeleton evolved independently in a number of unrelated sponge lineages through the Phanerozoic, each time developing a similarly convergent form. Furthermore, they regarded the calcareous basal skeleton as representing a morphological grade that appeared and disappeared repeatedly through time, surviving until today in five separate ordinal-level demosponge and three calcarean lines of evolutionary development. These repetitions in the development of a basal skeleton have resulted in many unrelated, relic, living hypercalcified sponge clades and led Vacelet and Wood, in particular, to conclude that the possession of a calcareous basal skeleton had limited phylogenetic significance within the phylum Porifera.

EXTANT AND FOSSIL DEMOSPONGIAE: CHAETETID-TYPE AND POST-DEVONIAN STROMATOPOROID-LIKE TAXA

Volume 4 provides a general introduction with outlines of the respective morphologies, modes of life, ecological significance, geographical distribution, and classification of the living relic sponge faunas, contributed by Vacelet, Willenz, and Hartman. The existing, described living hypercalcified sponge fauna of 19 genera are divided between the 10 genera of class Demospongiae (those belonging to 5 extant orders), and the 9 genera of class Calcarea (that are included in 3 extant orders). This comparatively small number of extant hypercalcified genera represents only about 2.8% of the valid taxa of some 680 living sponge genera known as a result of the recently completed major, collaborative work on global taxonomy (HOOPER, VAN SOEST, & DEBRENNE, 2002); the majority of living sponges lack a mineralized basal skeleton.

Also, in this first part of the present revised Volume 4 are general introductions to the fossil demosponge counterparts of the living taxa, contributed by WEST and WOOD on the chaetetid-type and post-Devonian stromatoporoid-like taxa. In these introductions, they mention the importance of recognizing spicules (or, at least, their pseudomorphs), as had been done earlier by KAŹMIERCZAK (1979), GRAY (1980), and REITNER (1991a) in Carboniferous–Cretaceous chaetetids and by WOOD (1987) for Mesozoic stromatoporoids. Traces of the secondarily entrapped or coated spicules (or spicule pseudomorphs) within their hypercalcified skeletons have been documented by West and Wood, based on their spicules and gross morphology. In addition, they identified in their fossil material evidence of aquiferous systems (for example, presence of astrorhizae on surfaces of chaetetids; see also West & Clark, 1983, fig. 3–4), and other morphological resemblances to extant taxa like *Acanthochaetetes, Merlia,* and *Ceratoporella* that ally these fossil groups to demosponges. Many of these fossil taxa were included previously in cnidarian-based groupings but are now revised and included in higher-level subdivisions of the poriferan class Demospongiae.

The well-illustrated systematic descriptions of extant hypercalcified, and fossil chaetetid- and post-Devonian stromatoporoid-type, demosponge genera are combined for the first time by West, Vacelet, Wood, Willenz, and Hartman in a classification of taxa spread across 8 different orders (2 uncertain) of the class Demospongiae. Included are 48 living and fossil genera (with addition of 5 fossil subgenera). Significantly, the chaetetid-type and stromatoporoid-like genera have separate distributions—that is, as different morphological grades they do not occur together in the same order—which suggests they have some taxonomic significance. On the one hand, chaetetids are distributed across 4 living orders—the Hadromerida, Poecilosclerida, Halichondrida, and possibly Chondrosida, and the stromatoporoid-type genera are presently included in quite different living orders, such as the Agelasida and Haplosclerida.

Another feature of these relationships is seen in the Upper Cretaceous chaetetid demosponge *Stromatoaxinella irregularis,* which Wood and Reitner (1988) have described as exhibiting tracts of style-like spicule pseudomorphs; they claim the species bears close affinities in its general skeletal organization and microstructure to the middle Mesozoic stromatoporoid-like genus *Dehornella*, on the one hand, and the living genus *Acanthochaetetes* on the other, and that this forms a kind of morphological continuum. However, currently these three genera have been assigned to three different demosponge orders—West and Wood have included *Stromatoaxinella* in order Halichondrida, Wood grouped *Dehornella* in the order Agelasida, and Vacelet, West, and Willenz placed *Acanthochaetetes* in the order Hadromerida—which raises the likelihood that this morphological trend represents one or more convergences owing to their polyphyletic origins.

EXTANT CALCAREA

Descriptions of the extant hypercalcified members of the class Calcarea are also presented by Vacelet in Volume 4. These complement earlier systematic descriptions of the mainly fossil (Mesozoic) hypercalcified genera belonging to the class, which were described by Finks and Rigby (2004d, p. 734–762) in Volume 3 of the revised *Treatise*, Part E (Porifera).

LISTS OF POST-DEVONIAN STROMATOPOROID-LIKE TAXA

A large number of nonspicular, post-Devonian, stromatoporoid-like genera, which could not be adequately determined or placed taxonomically in any coherent scheme of classification, were also compiled in an annotated list of 65 genera by Stearn and Stock. Unfortunately, no worker currently specializes in the study of these nonspicular post-Devonian forms. Some of these genera show astrorhizae and are confirmed as sponges, but not all genera exhibit astrorhizae and continue to have problematic relationships. Family affinities, where known, are mentioned, and a list of 15 excluded genera have also been included in Volume 4.

SPHINCTOZOANS, INOZOANS, AND DISJECTOPORIDS

A review of the sphinctozoans and inozoans is presented in the next section by Senowbari-Daryan and Rigby. It complements the systematic descriptions of these hypercalcified demosponge and calcarean groups by FINKS and RIGBY (2004d), incorporated in Volume 3 of the revised *Treatise,* Part E (Porifera). Senowbari-Daryan and Rigby have determined that the sphinctozoans and inozoans are markedly polyphyletic, given that the bulk of the sphinctozoan genera (about 160) occur in 3 demosponge orders: Agelasida (48.5%), Verticillitida (= Vaceletida) (37%), and Hadromerida (11%), and the remainder are calcareans of the order Sphaerocoeliida (3.5%).

In comparison, the inozoan genera (about 100) are represented by the demosponge order Agelasida (70%) and calcarean order Stellispongiida (30%). An additional few sphinctozoan genera are attributed to other poriferan classes, the Hexactinellida, Heteractinida, and the Archaeocyatha (e.g., cosinocyathine archaeocyaths show sphinctozoan-type chambers in early stages of ontogeny [DEBRENNE & WOOD, 1990; SENOWBARI-DARYAN & GARCIA-BELLIDO, 2002a]).

The sphinctozoan morphological grade apparently developed more commonly in sponge lineages than any of the other morphological types of hypercalcified sponges, and, in consequence, was probably the least taxonomically significant morphological type. Other aspects of sphinctozoan and inozoan morphology, their classification, patterns of water circulation, paleoecology, distribution in time and space, and their roles as contributors to reefs are discussed.

The living and fossil (Cretaceous–Tertiary) chambered, nonspiculate, aragonitic hypercalcified sponge *Vaceletia* PICKETT, 1982, is of particular interest as it was originally recognized as an archetypal sphinctozoan, though first allied to calcareans, then to demosponges (VACELET, 1977b, 1979b), and even mentioned as a sole survivor from archaeocyath stock (PICKETT, 1985b). More recently, it has been placed in the demosponge family Verticillitidae STEINMANN, 1882 (see VACELET, 2002b; and FINKS & RIGBY, 2004d). However, by applying molecular-sequencing procedures and other analyses to extant specimens of *Vaceletia,* WORHEIDE (2008) has been able to demonstrate that the taxon is monophyletic and has a precise placement within the extant, nonspiculate, keratose (bath sponge) members of order Dictyoceratida MINCHIN, 1900. The connection is perhaps not surprising, given that modern demosponges can build calcareous and keratose skeletons without spicules (VACELET, 1979b). Nevertheless, the dictyoceratids have only an organic-fiber spongin skeleton, with no trace of an aragonitic skeleton like *Vaceletia.* The fossil taxa that are included in the family Vaceletiidae REITNER & ENGESER, 1985, include only nonspiculate *Vaceletia.* However, within the broader grouping of order Verticillitida TERMIER & TERMIER (in TERMIER, TERMIER, & VACHARD, 1977) (= order Vaceletida of FINKS & RIGBY, 2004d, p. 691), some of these taxa show traces of monaxon spicules—e.g., *Colospongia* LAUBE, 1865, and *Subascosymplegma* DENG, 1981—and these are now excluded from a relationship with *Vaceletia.*

One other problematical group, family Disjectoporidae TORNQUIST, 1901, is described and illustrated by Stearn as comprising 11 Permian–Triassic genera that occur as encrusting forms in reef facies. These taxa have rodlike frameworks and resemble certain living hypercalcified sponges; they are possibly related to inozoan types, but their relationships within the phylum, classified as class and order Uncertain, remains obscure.

GLOSSARY OF TERMS

All authors contributed to the comprehensive glossary of terms. This glossary is applicable to all fossil and extant hypercalcified poriferans described herein (see latter part of Volume 4).

PALEOZOIC STROMATOPOROIDEA AND PULCHRILAMINIDA

The second, major part of this Treatise revision (see first part of Volume 5) is devoted to an introduction to and systematic descriptions of the extinct, Middle Ordovician–Devonian, nonspiculate class Stromatoporoidea *sensu* NICHOLSON & MURIE, 1878, by Stearn, Webby, Nestor, Kershaw, and Stock. The group comprises characteristically large, simple, hypercalcified skeletons of laminar, domical, bulbous, or less commonly, columnar and branching shapes. Internally the skeletal material exhibits repeated growth units, either in networks of pillars and laminae (or cyst plates), or as amalgamated elements; and evidence of aquiferous systems is commonly present. The general morphological forms of the Paleozoic (Mid-Ordovician to Devonian) skeleton may be interpreted to represent a grade of construction that includes a wide range of architectural types: all the known shapes of the Paleozoic skeletons, even columnar and branching growth forms.

Stromatoporoid-grade constructions also developed for a limited time during the early Cambrian in a very small group of porous archaeocyaths (order Kazachstanicyathida KONYUSHKOV, 1967). These constructions also formed during the Jurassic and Cretaceous when another group of spiculate stromatoporoid-grade demosponges appeared (WOOD, 1999, p. 229).

Attempts to establish an ontogenetic succession using the earliest stages of Paleozoic stromatoporoid growth have not been successful. The group is indubitably poriferan, and the nearest living forms are occurrences of hypercalcified demosponges, such as *Ceratoporella, Stromatospongia,* and *Astrosclera* of the family Astroscleriidae (order Agelasida) and *Calcifibrospongia* of the family Calcifibrospongiidae (order Haplosclerida). These extant forms show stellate astrorhizal patterns as surface depressions on upper surfaces where growth has been inhibited beneath exhalant water channel-ways, as originally explained by HARTMAN and GOREAU (1970, p. 224), but it remains very doubtful that these living taxa are directly related to Paleozoic or Mesozoic stromatoporoids. The modern forms are probably merely convergently similar to the ancient forms.

The Paleozoic stromatoporoid taxa have been described and classified using as many consistently preserved morphological characters in their hypercalcified skeletons as possible, though these tend to be limited to a comparatively few internal features and the microstructures. Nevertheless this has provided a workable framework for systematizing the taxa for use in determining such topics as stromatoporoid life history, paleoecology, paleobiogeography, and biostratigraphy.

The origins of the spiculate Mesozoic stromatoporoids remain obscure, but it seems most likely they developed independently of nonspiculate Paleozoic forms, possibly from a demosponge group that was producing siliceous spicules, though they may not have hitherto produced a hypercalcified skeleton.

The Paleozoic class Stromatoporoidea has an essential unity; despite significant imperfections in the stratigraphic record, the group comprises 7 orders and a total of 125 genera that clearly exhibit an early unidirectional evolutionary trend through late Middle to Late Ordovician time, with the group tentatively appearing to be monophyletic. The origins of the earliest order, the Labechiida, remains obscure, though it seems most likely to have evolved from a noncalcified demosponge ancestor during late Mid-Ordovician. Appearances of orders Clathrodictyida and Actinostromida followed, apparently in two separate lines of descent from the Labechiida, during the Late Ordovician. Then derivation of the two other orders occurred: the Stromatoporida from the Clathrodictyida early in the Silurian, and the Syringostromatida from the Actinostromatida in the Silurian (Wenlock). The enigmatic stemlike Amphiporida is another possible offshoot from the Stromatoporida, apparently also early in the Silurian. Representatives of most of these orders, except for the Actinostromatida, then persisted to the major extinction event at the end of Devonian. The Actinostromatida definitely became extinct a little earlier, probably at the end of the Frasnian, and the Syringostromatida only has a doubtful record after the Middle Devonian, and definitely also became extinct by the end of the Devonian.

Webby introduced a new order Pulchrilaminida WEBBY, 2012a, to accommodate the small problematical group (two or three genera) of Early to Mid-Ordovician (Dapingian) reef-building taxa. The group includes forms with large, half-meter diameters; hypercalcified skeletons composed of very thin, sheetlike latilaminae. Tiny (0.5 mm tall) erect, spinose rods, resembling diagenetically replaced (spar-filled) styles protrude above each successive latilamina into overlying thin layers of mud-rock. These structures vaguely resemble the palisade spicules of ectosomal surfaces of some living demosponges (like those in the genus *Suberites* NARDO, 1833, of the hadromerid family Suberitidae SCHMIDT, 1870; see VAN SOEST, 2002a, p. 240–243). The possibly spiculate pulchrilaminids are excluded from the nonspiculate, later Mid-Ordovician to Devonian stromatoporoids, in particular from a close association with the oldest representatives of the class Stromatoporoidea NICHOLSON & MURIE, 1878, namely, members of the order Labechiida KÜHN, 1927.

ARCHAEOCYATHA, RADIOCYATHS, AND CRIBRICYATHS

A comprehensive survey of the class Archaeocyatha BORNEMANN, 1884, is presented in the second part of this *Treatise,* Revised Volume 5, by Debrenne, Zhuravlev, and Kruse. This Early Cambrian group is highly diversified (with 307 genera described); it is nonspiculate and porous, exhibiting a wide variety of skeletal structures, as well as showing differences in the style of its ontogenetic development between the various skeletal groups. The classification is determined using all available data derived from the following three morphological attributes: (1) ontogenetic succession, following heterochronic principles in order to establish the taxonomic hierarchy; (2) functional analysis to allow discrimination between genotypic and phenotypic features; and (3) homologous variability limits that exist between taxa of equivalent levels. The total dataset provides the basis for a complex set of hierarchy-based keys across all levels (orders, suborders, superfamilies, families, and genera) and the recognition of the class Archaeocyatha as a monophyletic taxon (Pierre Kruse, personal communication, April 2008). In terms of hierarchy, the features that appear ontogenetically earlier have the higher taxonomic rank: orders are based on the architecture of the cup, suborders are represented by first-order intervallar structures, superfamilies are recognized from outer wall elements, families are determined using inner wall structures, and genera are based on certain variants of wall and intervallar structures.

The archaeocyaths are recognized as the first group of hypercalcified sponges to display a modular habit, apparently developing this tendency as a part of their colonization of more active reef habitats during the Early Cambrian (WOOD, ZHURAVLEV, & DEBRENNE, 1992). The modular habit arose within the aquiferous system of the sponge organism and was subdivided into multiple functional units. A single functional unit (FRY, 1979) is represented by a number of inhalant openings that lead water to a choanocyte layer and from which exhalant canals direct water away to a single exhalant opening (osculum). In the archaeocyaths, two types of sponges developed, one as a solitary cuplike (unioscular) form and the other exhibiting a modular (multioscular) habit. According to WOOD, ZHURAVLEV, and DEBRENNE (1992), modular is the advanced condition in sponges, whereas the solitary habit is the primitive state. Over 90% of living sponges are modular, whereas archaeocyaths were most commonly represented as a mix of solitary and modular types, with the proportion of modular forms increasing through the Early Cambrian and dominant over solitary types in biohermal settings (Wood, Zhuravlev, & Debrenne, 1992).

Archaeocyaths also exhibit a distinctive archaeocyathan grade of construction and are regarded taxonomically as representing an independent class-level taxon (clade) within the phylum Porifera. Currently, they are thought to have closer affinities to the class Demospongiae than to other living classes (Debrenne & Zhuravlev, 1994). The basic archaeocyathan architecture consists of a conical cup with porous outer and inner walls interconnected with radially arranged vertical plates (septa) and a central cavity; these may be either solitary (dominant) or exhibit a low-integration modular, branching form. A few may develop more complex modular types, such as the catenulate or pseudocerioid forms. Also, within the clade, a number of other distinctive grades of construction have been derived from the basic archaeocyathan morphological type. These comprise thalamid (= sphinctozoan), stromatoporoid, chaetetid, and syringoid architectures that each developed within one specific archaeocyath order or suborder: respectively, the order Capsulocyatha, the order Kazachstanicyathida, the suborder Dictyofavina, and the suborder Syringocnemina. Consequently, these particular grades of construction have real taxonomic significance in identifying the particular higher-level groups within the class Archaeocyatha. Whereas the thalamid architecture of the Capsulocyatha is developed only in solitary forms, the architectures represented in the other three higher-level groups are associated with both solitary and variably integrated modular forms.

Finally, there are two small sections that deal with minor, problematic, Early Cambrian groups: the Radiocyaths and related forms (8 genera), contributed by Kruse, Zhuravlev, and Debrenne; and the Cribricyaths and related forms (16 genera) presented by Zhuravlev and Kruse. Also Debrenne, Zhuravlev, and Kruse provide lists of the Archaeocyatha Nomina Dubia (40 genera); Archaeocyatha and Cribricyatha Nomina Nuda (20 genera); and a list of taxa not Archaeocyatha, Cribricyatha, or Radiocyatha (16 genera).

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In preparing these Revised Volumes 4 and 5 of the *Treatise,* Part E on the Porifera, I have been assisted by a number of specialists, virtually all of them invited in the early years of the project (late 1980s to early 1990s) by the previous *Treatise* Director and Editor, the late Roger L. Kaesler. At the outset, it was our intention only to survey the stromatoporoids, chaetetids, and related living hypercalcified sponge taxa (members of classes Demospongiae and Calcarea with spicules and hypercalcified calcareous basal skeletons), with a team comprising Jean Vacelet and the late Willard Hartman for the living forms, Ron West for the fossil chaetetids, Rachel Wood for the Mesozoic stromatoporoids, and Colin Stearn, Barry Webby, Heldur Nestor, Carl Stock, and Stephen Kershaw for the Paleozoic stromatoporoids. By 1995, however, it was considered desirable to widen the scope of the study to include all the main hypercalcified sponge groups. Consequently, Francoise Debrenne, Pierre Kruse, and Andrey Zhuravlev were added to the team to cover the archaeocyaths (*s.l.*), and Baba Senowbari-Daryan and the late J. Keith Rigby Sr. joined to contribute an introductory section on the sphinctozoan and inozoan architectures of the classes Demospongiae and Calcarea, since the Finks and Rigby (2004) of the revised *Treatise*, Part E (Porifera, vol. 3) treated only the systematic descriptions of these groups. Finally, Phillippe Willenz joined as an author early in 2005 to assist in the completion of the section on living hypercalcified sponges with Jean Vacelet and the late Willard Hartman. In my role as Cooordinating Author, I thank them for providing the high-quality, scholarly works that represent arguably the most comprehensive coverage of known ancient and modern hypercalcified sponges ever assembled. I appreciate their maintenance

of patience and faith in the project, their efforts in preparing digitized images of high quality, and perserverance in a long and, at times, thankless task of getting permissions to use copyrighted images. Ron West, Pierre Kruse, and Jean Vacelet, in particular, helped in coordination tasks and review of their sections of the *Treatise* work.

Roger Kaesler, in his role as Editor for more than a decade and a half, remained very supportive and encouraging through all stages of our *Treatise* work, monitoring closely the progress of preparation of our manuscripts and organization of illustrations, until his health began to fail in the latter part of 2005. He always responded in detail to the matters raised by me and other authors and invariably offered helpful advice as to how to solve a particular problem. He took a close personal interest in our work, and shared with us the view, perhaps encouraged by one or two of his departmental colleagues, that carbonate sedimentologists and others studying ancient reefs really needed to have access to such an authoritative, up-to-date *Treatise* volume on the problematical hypercalcified sponge groups. I am grateful to have had the opportunity to work with Roger and much enjoyed the close and cordial relationships we had for so long. Roger L. Kaesler retired in November 2006, and sadly passed away in the following August.

The manuscript and illustrative material was submitted to the *Treatise* office in parts through 2006 and 2007 and has since been processed through the various editorial stages with assistance of the *Treatise* staff. Bruce Lieberman, who acted as Interim Director for a short time in 2006, and then Paul Selden who commenced as new Director and Editor of the *Treatise* in January 2007, have facilitated this process. We are particularly appreciative to them, and to all other members of the Palaeontological Institute staff who have continued to support and help us, especially Jill Hardesty, who as Assistant Editor largely bore most of the responsibility for filing and maintaining our manuscript material after it was submitted. We offer a special thanks to her, for patiently answering our many queries relating to the project during this period through 2007 to 2008—all sorts of editorial matters and information about the work—and she has undertaken a large amount of editorial work in proofing the online chapters of individual sections from May 2009 to mid-2013.

Paul Selden has been largely responsible for an expansion of the Paleontological Institute web site and the development of excellent online facilities that have included the establishment of a new electronic journal called the *Treatise Online.* This latter has permitted us to publish the various sections of our compiled *Treatise* volume—a total of 38 individual chapters that commenced in 2009 and continued through 2010 to early 2013—in advance of this final publication of the consolidated, large volume: the hard copy, blue-covered compendium, which is the *Treatise on Invertebrate Paleontology,* Part E, Revised, Porifera, Volumes 4 and 5, Hypercalcified Porifera. Jill Hardesty, who became the Deputy Director of the Paleontological Institute and Assistant Editor of the *Treatise* near the end of 2009, was the driving force in getting these chapters into publication in the online series, and we thank her most sincerely for that, and all the other *Treatise* staff in Lawrence, Kansas, for their efforts on our behalf. The final bundled version of Hypercalcified Porifera in two *Treatise* volumes was published this year (early in 2015), bringing the long-standing work program of the authors to an end. We are grateful for the continued editorial support of Paul Selden, Jill Hardesty, Elizabeth Brosius, Denise Mayse, and other staff of the Paleontological Institute.

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[1] Willard Hartman, along with Thomas Goreau, confirmed in the early 1970s the presence of relict stocks of living hypercalcified sponges in reef-type habitats of the Caribbean and of the tropical Pacific. Important reinterpretations of problematic fossil groups emerged from these findings.

[2] J. Keith Rigby Sr., was a dedicated, enthusiastic, and highly productive researcher on fossil sponges. Over nearly six decades from the late 1950s, he published more than 140 peer-reviewed papers and monographs on fossil sponges, including descriptions of numerous new fossil assemblages and taxa from many parts of the world and through all periods of the Phanerozoic, from Cambrian to Quaternary. As a Coordinating Author, he completed the compilation of two *Treatise* volumes dealing with fossil sponges, published in 2003 and 2004.

EDITORIAL PREFACE

Paul A. Selden

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, Part E, Porifera, Revised, Hypercalcified Porifera, Volumes 4 and 5, continues this trend and has been prepared by a team of specialists, guided by Coordinating Author Barry D. Webby. Editorial matters specific to this volume are discussed near the end of this editorial preface.

ZOOLOGICAL NAMES

Questions about the proper use of zoological names arise continually, especially questions regarding both the acceptability of names and alterations of names that are allowed or even required. Regulations prepared by the International Commission on Zoological Nomenclature (ICZN) and published in 1999 in the *International Code of Zoological Nomenclature,* hereinafter referred to as the *Code,* provide procedures for answering such questions. The prime objective of the *Code* is to promote stability and universality in the use of the scientific names of animals, ensuring also that each generic name is distinct and unique, while avoiding unwarranted restrictions on freedom of thought and action of systematists. Priority of names is a basic principle of the *Code;* but, under specified conditions and by following prescribed procedures, priority may be set aside by the Commission. These procedures apply especially where slavish adherence to the principle of priority would hamper or even disrupt zoological nomenclature and the information it conveys.

The Commission, ever aware of the changing needs of systematists, revised the *Code* in 1999 to enhance further nomenclatorial stability, specifying that the revised *Code* should take effect at the start of 2000. Among other requirements, the revised *Code* is clear in Chapter 14 that the type genus of family-level taxa must be specified. In this volume we have continued the practice that has characterized most previous volumes of the *Treatise*, namely that the type genus of all family-level taxa is the first listed and diagnosed. In spite of the revisions, the nomenclatorial tasks that confront zoological taxonomists are formidable and have often justified the complaint that the study of zoology and paleontology is too often merely the study of names rather than the study of animals. It is incumbent upon all systematists, therefore, at the outset of their work to pay careful attention to the *Code* to enhance stability by minimizing the number of subsequent changes of names, too many of which are necessitated by insufficient attention to detail. To that end, several pages here are devoted to aspects of zoological nomenclature that are judged to have chief importance in relation to procedures adopted in the *Treatise,* especially in this volume. Terminology is explained, and examples are given of the style employed in the nomenclatorial parts of the systematic descriptions.

GROUPS OF TAXONOMIC CATEGORIES

Each taxon belongs to a category in the Linnaean hierarchical classification. The *Code* recognizes three groups of categories, a species-group, a genus-group, and a family-group. Taxa of lower rank than subspecies are excluded from the rules of zoological nomenclature, and those of higher rank than superfamily are not regulated by the *Code.* It is both natural and convenient to discuss nomenclatorial matters in general terms first and then to consider each of these three, recognized groups separately. Especially important is the provision that within each group the categories are coordinate, that is, equal in rank, whereas categories of different groups are not coordinate.

FORMS OF NAMES

All zoological names can be considered on the basis of their spelling. The first form of a name to be published is defined as the original spelling (*Code,* Article 32), and any form of the same name that is published later and is different from the original spelling is designated a subsequent spelling (*Code,* Article 33). Not every original or subsequent spelling is correct.

ORIGINAL SPELLINGS

If the first form of a name to be published is consistent and unambiguous, the original is defined as correct unless it contravenes some stipulation of the *Code* (Articles 11, 27 to 31, and 34) or unless the original publication contains clear evidence of an inadvertent error in the sense of the *Code,* or, among names belonging to the family-group, unless correction of the termination or the stem of the type genus is required. An original spelling that fails to meet these requirements is defined as incorrect.

If a name is spelled in more than one way in the original publication, the form adopted by the first reviser is accepted as the correct original spelling, provided that it complies with mandatory stipulations of the *Code* (Articles 11 and 24 to 34).

Incorrect original spellings are any that fail to satisfy requirements of the *Code,* represent an inadvertent error, or are one of multiple original spellings not adopted by a first reviser. These have no separate status in zoological nomenclature and, therefore, cannot enter into homonymy or be used as replacement names. They call for correction. For example, a name originally published with a diacritical mark, apostrophe, dieresis, or hyphen requires correction by deleting such features and uniting parts of the name originally separated by them, except that deletion of an umlaut from a vowel in a name derived from a German word or personal name unfortunately requires the insertion of *e* after the vowel. Where original spelling is judged to be incorrect solely because of inadequacies of the Greek or Latin scholarship of the author, nomenclatorial changes conflict with the primary purpose of zoological nomenclature as an information retrieval system. One looks forward with hope to further revisions of the *Code* wherein rules are emplaced that enhance stability rather than classical scholarship, thereby facilitating access to information.

SUBSEQUENT SPELLINGS

If a subsequent spelling differs from an original spelling in any way, even by the omission, addition, or alteration of a single letter, the subsequent spelling must be defined as a different name. Exceptions include such changes as an altered termination of adjectival specific names to agree in gender with associated generic names (an unfortunate impediment to stability and retrieval of information); changes of family-group names to denote assigned taxonomic rank; and corrections that eliminate originally used diacritical marks, hyphens, and the like.

Such changes are not regarded as spelling changes conceived to produce a different name. In some instances, however, species-group names having variable spellings are regarded as homonyms as specified in the *Code* (Article 58).

Altered subsequent spellings other than the exceptions noted may be either intentional or unintentional. If "demonstrably intentional" (*Code,* Article 33), the change is designated as an emendation. Emendations may be either justifiable or unjustifiable. Justifiable emendations are corrections of incorrect original spellings, and these take the authorship and date of the original spellings. Unjustifiable emendations are names having their own status in nomenclature, with author and date of their publication. They are junior, objective synonyms of the name in its original form.

Subsequent spellings, if unintentional, are defined as incorrect subsequent spellings. They have no status in nomenclature, do not enter into homonymy, and cannot be used as replacement names.

AVAILABLE AND UNAVAILABLE NAMES

Editorial prefaces of some previous volumes of the *Treatise* have discussed in appreciable detail the availability of the many kinds of zoological names that have been proposed under a variety of circumstances. Much of that information, while important, does not pertain to the present volume, in which authors have used fewer terms for such names. The reader is referred to the *Code* (Articles 10 to 20) for further details on availability of names. Here, suffice it to say that an available zoological name is any that conforms to all mandatory provisions of the *Code.* All zoological names that fail to comply with mandatory provisions of the *Code* are unavailable and have no status in zoological nomenclature. Both available and unavailable names are classifiable into groups that have been recognized in previous volumes of the *Treatise,* although not explicitly differentiated in the *Code.* Among names that are available, these groups include inviolate names, perfect names, imperfect names, vain names, transferred names, improved or corrected names, substitute names, and conserved names. Kinds of unavailable names include naked names (see *nomina nuda* below), denied names, impermissible names, null names, and forgotten names.

Nomina nuda include all names that fail to satisfy provisions stipulated in Article 11 of the *Code,* which states general requirements of availability. In addition, they include names published before 1931 that were unaccompanied by a description, definition, or indication (*Code,* Article 12) and names published after 1930 that (1) lacked an accompanying statement of characters that differentiate the taxon, (2) were without a definite bibliographic reference to such a statement, (3) were not proposed expressly as a replacement (*nomen novum*) of a preexisting available name (*Code,* Article 13.1), or (4) for genus-group names, were unaccompanied by definite fixation of a type species by original designation or indication (*Code,* Article 13.2). *Nomina nuda* have no status in nomenclature, and they are not correctable to establish original authorship and date.

VALID AND INVALID NAMES

Important considerations distinguish valid from available names on the one hand and invalid from unavailable names on the other. Whereas determination of availability is based entirely on objective considerations guided by articles of the *Code,* conclusions as to validity of zoological names may be partly subjective. A valid name is the correct one for a given taxon, which may have two or more available names but only a single correct, hence valid, name, which is also generally the oldest name that it has been given. Obviously, no valid name can also be an unavailable name, but invalid names may be either available or unavailable. It follows that any name for a given taxon other than the valid name, whether available or unavailable, is an invalid name.

One encounters a sort of nomenclatorial no-man's land in considering the status of such zoological names as *nomina dubia* (doubtful names), which may include both available and unavailable names. The unavailable ones can well be ignored, but names considered to be available contribute to uncertainty and instability in the systematic literature. These can ordinarily be removed only by appeal to the ICZN for special action. Because few systematists care to seek such remedy, such invalid but available names persist in the literature.

NAME CHANGES IN RELATION TO GROUPS OF TAXONOMIC CATEGORIES

SPECIES-GROUP NAMES

Detailed consideration of valid emendation of specific and subspecific names is unnecessary here, both because the topic is well understood and relatively inconsequential and because the *Treatise* deals with genus-group names and higher categories. When the form of adjectival specific names is changed to agree with the gender of a generic name in transferring a species from one genus to another, one need never label the changed name as *nomen correctum.* Similarly, transliteration of a letter accompanied by a diacritical mark in the manner now called for by the *Code,* as in changing originally *bröggeri* to *broeggeri,* or eliminating a hyphen, as in changing originally published *cornu-oryx* to *cornuoryx,* does not require the designation *nomen correctum.* Of course, in this age of computers and electronic databases, such changes of name, which are perfectly valid for the purposes of scholarship, run counter to the requirements of nomenclatorial stability upon which the preparation of massive, electronic databases is predicated.

GENUS-GROUP NAMES

Conditions warranting change of the originally published, valid form of generic and subgeneric names are sufficiently rare that lengthy discussion is unnecessary. Only elimination of diacritical marks and hyphens in some names in this category and replacement of homonyms seem to furnish basis for valid emendation. Many names that formerly were regarded as homonyms are no longer so regarded, because two names that differ only by a single letter or in original publication by the presence of a diacritical mark in one are now construed to be entirely distinct (but see *Code,* Article 58).

As has been pointed out above, difficulty typically arises when one tries to decide whether a change of spelling of a name by a subsequent author was intentional or unintentional, and the decision has to be made often arbitrarily.

FAMILY-GROUP NAMES

Family-Group Names: Authorship and Date

All family-group taxa having names based on the same type genus are attributed to the author who first published the name of any of these groups, whether tribe, subfamily, or family (superfamily being almost inevitably a later-conceived taxon). Accordingly, if a family is divided into subfamilies or a subfamily into tribes, the name of no such subfamily or tribe can antedate the family name. Moreover, every family containing differentiated subfamilies must have a nominate subfamily (*sensu stricto*), which is based on the same type genus as the family. Finally, the author and date set down for the nominate subfamily invariably are identical with those of the family, irrespective of whether the author of the family or some subsequent author introduced subdivisions.

Corrections in the form of family-group names do not affect authorship and date of the taxon concerned, but in the *Treatise,* recording the authorship and date of the correction is desirable, because it provides a pathway to follow the thinking of the systematists involved.

Family-Group Names: Use of *nomen translatum*

The *Code* (Article 29.2) specifies the suffixes for tribe (-ini), subfamily (-inae), family (-idae) and superfamily (-oidea), the formerly widely used ending (-acea) for superfamily having been disallowed. All these family-group categories are defined as coordinate (*Code*, Article 36.1): "A name established for a taxon at any rank in the family group is deemed to have been simultaneously established for nominal taxa at other ranks in the family group; all these taxa have the same type genus, and their names are formed from the stemof the name of the type genus (Art. 29.3] with appropriate change of suffix [Art. 34.1]. The name has the same authorship and date at every rank." Such changes of rank and concomitant changes of endings as elevation of a subfamily to family rank or of a family to superfamily rank, if introduced subsequent to designation of the original taxon or based on the same nominotypical genus, are *nomina translata*. In the *Treatise,* it is desirable to distinguish the valid alteration in the changed ending of each transferred family-group name by the term *nomen translatum,* abbreviated to *nom. transl.* Similarly for clarity, authors should record the author, date, and page of the alteration, as in the following example.

Family HEXAGENITIDAE
Lameere, 1917

[*nom. transl.* DEMOULIN, 1954, p. 566, *ex* Hexagenitinae LAMEERE, 1917, p. 74]

This is especially important for superfamilies, for the information of interest is the author who initially introduced a taxon rather than the author of the superfamily as defined by the *Code.* For example:

Superfamily AGNOSTOIDEA
M'Coy, 1849

[*nom. transl.* SHERGOLD, LAURIE, & SUN, 1990, p. 32, *ex* Agnostinae M'COY, 1849, p. 402]

The latter is merely the individual who first defined some lower-ranked, family-group taxon that contains the nominotypical genus of the superfamily. On the other hand, the publication that introduces the superfamily by *nomen translatum* is likely to furnish the information on taxonomic considerations that support definition of the taxon.

Family-Group Names: Use of *nomen correctum*

Valid name changes classed as *nomina correcta* do not depend on transfer from one category of the family group to another but most commonly involve correction of the stem of the nominotypical genus. In addition, they include somewhat arbitrarily chosen modifications of endings for names of tribes or superfamilies. Examples of the use of *nomen correctum* are the following.

Family STREPTELASMATIDAE
Nicholson, 1889

[*nom. correct.* WEDEKIND, 1927, p. 7, *pro* Streptelasmidae NICHOLSON in NICHOLSON & LYDEKKER, 1889, p. 297]

Family PALAEOSCORPIDAE
Lehmann, 1944

[*nom. correct.* PETRUNKEVITCH, 1955, p. 73, *pro* Palaeoscorpionidae LEHMANN, 1944, p. 177]

Family-Group Names: Replacements

Family-group names are formed by adding combinations of letters, which are prescribed for all family-group categories, to the stem of the name belonging to the nominotypical genus first chosen as type of the assemblage. The type genus need not be the first genus in the family to have been named and defined, but among all those included it must be the first published as name giver to a family-group taxon. Once fixed, the family-group name remains tied to the nominotypical genus even if the generic name is changed by reason of status as a junior homonym or junior synonym, either objective or subjective. Seemingly, the *Code* requires replacement of a family-group name only if the nominotypical genus is found to have been a junior homonym when it was proposed (*Code,* Article 39), in which case "... it must be replaced either by the next oldest available name from among its synonyms [Art. 23.3.5], including the names of its subordinate family-group taxa, or, if there is no such synonym, by a new name based on the valid name ... of the former type genus." Authorship and date attributed to the replacement family-group name are determined by first publication of the changed family-group name. Recommendation 40A of the *Code,* however, specifies that for subsequent application of the rule of priority, the family-group name "... should be cited with its original author and date (see Recommendation 22A.2.2), followed by the date of its priority as determined by this Article; the date of priority should be enclosed in parentheses." Many family-group names that have been in use for a long time are *nomina nuda,* since they fail to satisfy criteria of availability (*Code,* Article 11.7). These demand replacement by valid names.

The aim of family-group nomenclature is to yield the greatest possible stability and uniformity, just as in other zoological names. Both taxonomic experience and the *Code* (Article 40) indicate the wisdom of sustaining family-group names based on junior subjective synonyms if they have priority of publication, for opinions of the same worker may change from time to time. The retention of first-published, family-group names that are found to be based on junior objective synonyms, however, is less clearly desirable, especially if a replacement name derived from the senior objective synonym has been recognized very long and widely. Moreover, to displace a widely used, family-group name based on the senior objective synonym by disinterring a forgotten and virtually unused family-group name based on a junior objective synonym because the latter happens to have priority of publication is unsettling.

A family-group name may need to be replaced if the nominotypical genus is transferred to another family group. If so, the first-published of the generic names remaining in the family-group taxon is to be recognized in forming a replacement name.

SUPRAFAMILIAL TAXA: TAXA ABOVE FAMILY-GROUP

International rules of zoological nomenclature as given in the *Code* affect only lower-rank categories: subspecies to superfamily. Suprafamilial categories (suborder to kingdom) are either not mentioned or explicitly placed outside of the application of zoological rules. The *Copenhagen Decisions on Zoological Nomenclature* (1953, Articles 59 to 69) proposed adopting rules for naming suborders and higher taxa up to and including phylum, with provision for designating a type genus for each, in such manner as not to interfere with the taxonomic freedom of workers. Procedures were outlined for applying the rule of priority and rule of homonymy to suprafamilial taxa and for dealing with the names of such taxa and their authorship, with assigned dates, if they should be transferred on taxonomic grounds from one rank to another. The adoption of terminations of names, different for each category but uniform within each, was recommended.

The Colloquium on Zoological Nomenclature, which met in London during the week just before the 15th International Congress of Zoology convened in 1958, thoroughly discussed the proposals for regulating suprafamilial nomenclature, as well as many others advocated for inclusion in the new *Code* or recommended for exclusion from it. A decision that was supported by a wide majority of the participants in the colloquium was against the establishment of rules for naming taxa above family-group rank, mainly because it was judged that such regulation would unwisely tie the hands of taxonomists. For example, a class or order defined by an author at a given date, using chosen morphologic characters (*e.g.,* gills of bivalves), should not be allowed to freeze nomenclature, taking precedence over another class or order that is proposed later and distinguished by different characters (*e.g.,* hinge teeth of bivalves). Even the fixing of type genera for suprafamilial taxa would have little, if any, value, hindering taxonomic work rather than aiding it. Beyond mere tidying up, no basis for establishing such types and for naming these taxa has yet been provided.

The considerations just stated do not prevent the editors of the *Treatise* from making rules for dealing with suprafamilial groups of animals described and illustrated in this publication. Some uniformity is needed, especially for the guidance of *Treatise* authors. This policy should accord with recognized general practice among zoologists; but where general practice is indeterminate or nonexistent, our own procedure in suprafamilial nomenclature needs to be specified as clearly as possible. This pertains especially to decisions about names themselves, about citation of authors and dates, and about treatment of suprafamilial taxa that, on taxonomic grounds, are changed from their originally assigned rank. Accordingly, a few rules expressing *Treatise* policy are given here, some with examples of their application.

1. The name of any suprafamilial taxon must be a Latin or Latinized, uninominal noun of plural form or treated as such, with a capital initial letter and without diacritical mark, apostrophe, diaeresis, or hyphen. If a component consists of a numeral, numerical adjective, or adverb, this must be written in full.

2. Names of suprafamilial taxa may be constructed in almost any manner. A name may indicate morphological attributes (*e.g.,* Lamellibranchiata, Cyclostomata, Toxoglossa) or be based on the stem of an included genus (*e.g.,* Bellerophontina, Nautilida, Fungiina) or on arbitrary combinations of letters (*e.g.,* Yuania); none of these, however, can end in -idae or -inae, which terminations are reserved for family-group taxa. No suprafamilial name identical in form to that of a genus or to another published suprafamilial name should be employed (*e.g.,* order Decapoda LATREILLE, 1803, crustaceans, and order Decapoda LEACH, 1818, cephalopods; suborder Chonetoidea MUIR-WOOD, 1955, and genus *Chonetoidea* JONES, 1928). Worthy of notice is the classificatory and nomenclatorial distinction between suprafamilial and family-group taxa that, respectively, are named from the same type genus, since one is not considered to be transferable to the other (*e.g.,* suborder Bellerophontina ULRICH & SCOFIELD, 1897 is not coordinate with superfamily Bellerophontacea MCCOY, 1851 or family Bellerophontidae MCCOY, 1851).

3. The rules of priority and homonymy lack any force of international agreement as applied to suprafamilial names, yet in the interest of nomenclatorial stability and to avoid confusion these rules are widely applied by zoologists to taxa above the family-group level wherever they do not infringe on taxonomic freedom and long-established usage.

4. Authors who accept priority as a determinant in nomenclature of a suprafamilial taxon may change its assigned rank at will, with or without modifying the terminal letters of the name, but such changes cannot rationally be judged to alter the authorship and date of the taxon as published originally. A name revised from its previously published rank is a transferred name (*nomen translatum*), as illustrated in the following.

Order CORYNEXOCHIDA Kobayashi, 1935

[*nom. transl.* MOORE, 1959, p. 217, *ex* suborder Corynexochida KOBAYASHI, 1935, p. 81]

A name revised from its previously published form merely by adoption of a different termination without changing taxonomic rank is a *nomen correctum.*

Order DISPARIDA
Moore & Laudon, 1943

[*nom. correct.* MOORE in MOORE, LALICKER, & FISCHER, 1952, p. 613, *pro* order Disparata MOORE & LAUDON, 1943, p. 24]

A suprafamilial name revised from its previously published rank with accompanying change of termination, which signals the change of rank, is recorded as a *nomen translatum et correctum.*

Order HYBOCRINIDA
Jaekel, 1918

[*nom. transl. et correct.* MOORE in MOORE, LALICKER, & FISCHER, 1952, p. 613, *ex* suborder Hybocrinites JAEKEL, 1918, p. 90]

5. The authorship and date of nominate subordinate and supraordinate taxa among suprafamilial taxa are considered in the *Treatise* to be identical since each actually or potentially has the same type. Examples are given below.

Subclass ENDOCERATOIDEA
Teichert, 1933

[*nom. transl.* TEICHERT in TEICHERT & others, 1964, p. 128, *ex* order Endoceroidea TEICHERT, 1933, p. 214]

Order ENDOCERIDA
Teichert, 1933

[*nom. correct.* TEICHERT in TEICHERT & others, 1964, p. 165, *pro* order Endoceroidea TEICHERT, 1933, p. 214]

TAXONOMIC EMENDATION

Emendation has two distinct meanings as regards zoological nomenclature. These are alteration of a name itself in various ways for various reasons, as has been reviewed, and alteration of the taxonomic scope or concept for which a name is used. The *Code* (Article 33.1 and Glossary) concerns itself only with the first type of emendation, applying the term to intentional, either justified or unjustified changes of the original spelling of a name. The second type of emendation primarily concerns classification and inherently is not associated with change of name. Little attention generally has been paid to this distinction in spite of its significance.

Most zoologists, including paleontologists, who have emended zoological names refer to what they consider a material change in application of the name such as may be expressed by an importantly altered diagnosis of the assemblage covered by the name. The abbreviation *emend.* then must accompany the name with statement of the author and date of the emendation. On the other hand, many systematists think that publication of *emend.* with a zoological name is valueless because alteration of a taxonomic concept is introduced whenever a subspecies, species, genus, or other taxon is incorporated into or removed from a higher zoological taxon. Inevitably associated with such classificatory expansions and restrictions is some degree of emendation affecting diagnosis. Granting this, still it is true that now and then somewhat more extensive revisions are put forward, generally with a published statement of the reasons for changing the application of a name. To erect a signpost at such points of most significant change is worthwhile, both as an aid to subsequent workers in taking account of the altered nomenclatorial usage and to indicate where in the literature cogent discussion may be found. Authors of contributions to the *Treatise* are encouraged to include records of all especially noteworthy emendations of this nature, using the abbreviation *emend.* with the name to which it refers and citing the author, date, and page of the emendation. Examples from *Treatise* volumes follow.

Order ORTHIDA
Schuchert & Cooper, 1932

[*nom. transl. et correct.* MOORE in MOORE, LALICKER, & FISCHER, 1952, p. 220, *ex* suborder Orthoidea SCHUCHERT & COOPER, 1932, p. 43; *emend.,* WILLIAMS & WRIGHT, 1965, p. 299]

Subfamily ROVEACRININAE
Peck, 1943

[Roveacrininae PECK, 1943, p. 465; *emend.,* PECK in MOORE & TEICHERT, 1978, p. 921]

STYLE IN GENERIC DESCRIPTIONS

CITATION OF TYPE SPECIES

In the *Treatise,* the name of the type species of each genus and subgenus is given immediately following the generic name with its accompanying author, date, and page reference or after entries needed for definition of the name if it is involved in homonymy. The originally published combination of generic and trivial names of this species is cited, accompanied by an asterisk (*), with notation of the author, date, and page of original publication, except if the species was first published in the same paper and by the same author as that containing definition of the genus of which it is the type. In this instance, the initial letter of the generic name followed by the trivial name is given without repeating the name of the author and date. Examples of these two sorts of citations follow.

Orionastraea SMITH, 1917, p. 294 [**Sarcinula phillipsi* MCCOY, 1849, p. 125; OD].

Schoenophyllum SIMPSON, 1900, p. 214 [**S. aggregatum;* OD].

If the cited type species is a junior synonym of some other species, the name of this latter is given also, as follows.

Actinocyathus D'ORBIGNY, 1849, p. 12 [**Cyathophyllum crenulate* PHILLIPS, 1836, p. 202; M; =*Lonsdaleia floriformis* (MARTIN), 1809, pl. 43; validated by ICZN Opinion 419].

In some instances the type species is a junior homonym. If so, it is cited as shown in the following example.

Prionocyclus MEEK, 1871b, p. 298 [**Ammonites serratocarinatus* MEEK, 1871a, p. 429, *non* STOLICZKA, 1864, p. 57; =*Prionocyclus wyomingensis* MEEK, 1876, p. 452].

In the *Treatise,* the name of the type species is always given in the exact form it had in the original publication except that diacritical marks have been removed. Where other mandatory changes are required, these are introduced later in the text, typically in the description of a figure.

Fixation of Type Species Originally

It is desirable to record the manner of establishing the type species, whether by original designation (OD) or by subsequent designation (SD). The type species of a genus or subgenus, according to provisions of the *Code,* may be fixed in various ways in the original publication; or it may be fixed subsequently in ways specified by the *Code* (Article 68) and described in the next section. Type species fixed in the original publication include (1) *original designation* (in the *Treatise* indicated by OD) when the type species is explicitly stated or (before 1931) indicated by n. gen., n. sp. (or its equivalent) applied to a single species included in a new genus; (2) defined by use of *typus* or *typicus* for one of the species included in a new genus (adequately indicated in the *Treatise* by the specific name); (3) established by *monotypy* if a new genus or subgenus has only one originally included species (in the *Treatise* indicated as M); and (4) fixed by *tautonymy* if the genus-group name is identical to an included species name not indicated as the type.

Fixation of Type Species Subsequently

The type species of many genera are not determinable from the publication in which the generic name was introduced. Therefore, such genera can acquire a type species only by some manner of subsequent designation. Most commonly this is established by publishing a statement naming as type species one of the species originally included in the genus. In the *Treatise,* such fixation of the type species by subsequent designation in this manner is indicated by the letters SD accompanied by the name of the subsequent author (who may be the same person as the original author) and the publication date and page number of the subsequent designation. Some genera, as first described and named, included no mentioned species (for such genera established after 1930, see below); these necessarily lack a type species until a date subsequent to that of the original publication when one or more species is assigned to such a genus. If only a single species is thus assigned, it becomes automatically the type species. Of course, the first publication containing assignment of species to the genus that originally lacked any included species is the one concerned in fixation of the type species, and if this publication names two or more species as belonging to the genus but did not designate a type species, then a later SD designation is necessary. Examples of the use of SD as employed in the *Treatise* follow.

Hexagonaria GURICH, 1896, p. 171 [**Cyathophyllum hexagonum* GOLDFUSS, 1826, p. 61; SD LANG, SMITH, & THOMAS, 1940, p. 69].

Mesephemera HANDLIRSCH, 1906, p. 600 [**Tineites lithophilus* GERMAR, 1842, p. 88; SD CARPENTER, herein].

Another mode of fixing the type species of a genus is through action of the International Commission of Zoological Nomenclature using its plenary powers. Definition in this way may set aside application of the *Code* so as to arrive at a decision considered to be in the best interest of continuity and stability of zoological nomenclature. When made, it is binding and commonly is cited in the *Treatise* by the letters ICZN, accompanied by the date of announced decision and reference to the appropriate numbered opinion.

Subsequent designation of a type species is admissible only for genera established prior to 1931. A new genus-group name established after 1930 and not accompanied by fixation of a type species through original designation or original indication is invalid (*Code,* Article 13.3). Effort of a subsequent author to validate such a name by subsequent designation of a type species constitutes an original publication, making the name available under authorship and date of the subsequent author.

HOMONYMS

Most generic names are distinct from all others and are indicated without ambiguity by citing their originally published spelling accompanied by name of the author and date of first publication. If the same generic name has been applied to two or more distinct taxonomic units, however, it is necessary to differentiate such homonyms. This calls for distinction between junior homonyms and senior homonyms. Because a junior homonym is invalid, it must be replaced by some other name. For example, *Callophora* HALL, 1852, introduced for Paleozoic trepostomate bryozoans, is invalid because Gray in 1848 published the same name for Cretaceous–Holocene cheilostomate bryozoans. Bassler in 1911 introduced the new name *Hallophora* to replace Hall's homonym. The *Treatise* style of entry is given below.

Hallophora BASSLER, 1911, p. 325, *nom. nov. pro Callophora* HALL, 1852, p. 144, *non* GRAY, 1848.

In like manner, a replacement generic name that is needed may be introduced in the *Treatise* (even though first publication of generic names otherwise in this work is generally avoided). An exact bibliographic reference must be given for the replaced name as in the following example.

Mysterium DE LAUBENFELS, herein, *nom. nov. pro Mystrium* SCHRAMMEN, 1936, p. 183, *non* ROGER, 1862 [**Mystrium porosum* SCHRAMMEN, 1936, p. 183; OD].

Otherwise, no mention is made generally of the existence of a junior homonym.

Synonymous Homonyms

An author sometimes publishes a generic name in two or more papers of different date, each of which indicates that the name is new. This is a bothersome source of errors for later workers who are unaware that a supposed first publication that they have in hand is not actually the original one. Although the names were published separately, they are identical and therefore definable as homonyms; at the same time they are absolute synonyms. For the guidance of all concerned, it seems desirable to record such names as synonymous homonyms. In the *Treatise,* the junior of one of these is indicated by the abbreviation *jr. syn. hom.*

Not infrequently, identical family-group names are published as new names by different authors, the author of the name that was introduced last being ignorant of previous publication(s) by one or more other workers. In spite of differences in taxonomic concepts as indicated by diagnoses and grouping of genera and possibly in assigned rank, these family-group taxa, being based on the same type genus, are nomenclatorial homonyms. They are also synonyms. Wherever encountered, such synonymous homonyms are distinguished in the *Treatise* as in dealing with generic names.

A rare but special case of homonymy exists when identical family names are formed from generic names having the same stem but differing in their endings. An example is the family name Scutellidae Richter & Richter, 1925, based on *Scutellum* Pusch, 1833, a trilobite. This name is a junior homonym of Scutellidae Gray, 1825, based on the echinoid genus *Scutella* Lamarck, 1816. The name of the trilobite family was later changed to Scutelluidae (ICZN, Opinion 1004, 1974).

SYNONYMS

In the *Treatise,* citation of synonyms is given immediately after the record of the type species. If two or more synonyms of differing date are recognized, these are arranged in chronological order. Objective synonyms are indicated by accompanying designation *obj.,* others being understood to constitute subjective synonyms, of which the types are also indicated. Examples showing *Treatise* style in listing synonyms follow.

Mackenziephyllum Pedder, 1971, p. 48 [**M. insolitum;* OD] [=*Zonastraea* Tsyganko in Spasskiy, Kravtsov, & Tsyganko, 1971, p. 85, *nom. nud.;* =*Zonastraea* Tsyganko, 1972, p. 21 (type, *Z. graciosa,* OD)].

Kodonophyllum Wedekind, 1927, p. 34 [**Streptelasma Milne-Edwardsi* Dybowski, 1873, p. 409; OD; =*Madrepora truncata* Linne, 1758, p. 795, see Smith & Tremberth, 1929, p. 368] [=*Patrophontes* Lang & Smith, 1927, p. 456 (type, *Madrepora truncata* Linne, 1758, p. 795, OD); =*Codonophyllum* Lang, Smith, & Thomas, 1940, p. 39, obj.].

Some junior synonyms of either the objective or the subjective sort may be preferred over senior synonyms whenever uniformity and continuity of nomenclature are served by retaining a widely used but technically rejectable name for a genus. This requires action of the ICZN, which may use its plenary powers to set aside the unwanted name, validate the wanted one, and place the concerned names on appropriate official lists.

OTHER EDITORIAL MATTERS

BIOGEOGRAPHY

Purists, *Treatise* editors among them, would like nothing better than a stable world with a stable geography that makes possible a stable biogeographical classification. Global events of the past few years have shown how rapidly geography can change, and in all likelihood we have not seen the last of such change as new, so-called republics continue to spring up all over the globe. One expects confusion among readers in the future as they try to decipher such geographical terms as USSR, Yugoslavia, or Ceylon. Such confusion is unavoidable, as books must be completed and published at some real time. Libraries would be limited indeed if publication were always to be delayed until the political world had settled down. In addition, such terms as central Europe and western Europe are likely to mean different things to different people. Some imprecision is introduced by the use of all such terms, of course, but it is probably no greater than the imprecision that stems from the fact that the work of paleontology is not yet finished, and the geographical ranges of many genera are imperfectly known.

Other geographic terms can also have varying degrees of formality. In general, *Treatise* policy is to use adjectives rather than nouns to refer to directions. Thus we have used *southern* and *western* in place of *South* and *West* unless a term has been formally defined as a geographic entity (e.g., South America or West Virginia). Note that we have referred to western Texas rather than West Texas, which is said to be not a state but a state of mind.

NAMES OF AUTHORS: TRANSLATION AND TRANSLITERATION

Chinese scientists have become increasingly active in systematic paleontology in the past two decades. Chinese names cause anguish among English-language bibliographers for two reasons. First, no scheme exists for one-to-one transliteration of Chinese characters into roman letters. Thus, a Chinese author may change the roman-letter spelling of his name from one publication to another. For example, the name Chang, the most common family name in the world reportedly held by some one billion people, has been spelled more recently Zhang. The principal purpose of a bibliography is to provide the reader with entry into the literature. Quite arbitrarily, therefore, in the interest of information retrieval, the *Treatise* editorial staff has decided to retain the roman spelling that a Chinese author has used in each of his publications rather than attempting to adopt a common spelling of an author's name to be used in all citations of his work. It is entirely possible, therefore, that the publications of a Chinese author may be listed in more than one place under more than one name in the bibliography.

Second, most but by no means all Chinese list their family name first followed by given names. People with Chinese names who study in the West, however, often reverse the order, putting the family name last as is the Western custom. Thus, for example, Dr. Yi-Maw Chang, formerly of the staff of the Paleontological Institute, was Chang Yi-Maw when he lived in Taiwan. When he came to America, he became Yi-Maw Chang. In the *Treatise,* authors' names are used in the text and listed in the references as they appear in the source being cited.

Several systems exist for transliterating the Cyrillic alphabet into the roman alphabet. On the recommendation of skilled bibliographic librarians, we have adopted the American Library Association/Library of Congress romanization table for Russian and other languages using the Cyrillic alphabet.

MATTERS SPECIFIC TO THESE VOLUMES

Authorship entails both credit and responsibility. As the knowledge of paleontology grows and paleontologists become more specialized, preparation of *Treatise* volumes must necessarily involve larger and larger teams of researchers, each focusing on increasingly narrow aspects of the higher taxon under revision. In these two volumes, we have taken special pains to acknowledge authorship of small subsections. Readers citing the volume are encouraged to pay close attention to the actual authorship of a section or subsection.

Stratigraphic ranges of taxa listed in the systematic descriptions herein 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.

ACKNOWLEDGMENTS

The Paleontological Institute's Assistant Editor, Jill Hardesty, and Liz Brosius have faced admirably the formidable task of moving these volumes through the various stages of editing and into production. In this they have been ably assisted by other members of the editorial team, including Denise Mayse, Office

Manager, with her excellent attention to detail while checking the references and various other items, and Mike Cormack with his outstanding computer skills. Brittany Varnado, student assistant, helped with figure preparation and checking and formatting references.

This editorial preface and other, recent ones are extensive revisions of the prefaces prepared for previous *Treatise* volumes by former editors, including the late Raymond C. Moore, the late Curt Teichert, Richard A. Robison, and the late Roger L. Kaesler. I am indebted to them for preparing earlier prefaces and for the leadership they have provided in bringing the *Treatise* project to its present status.

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Paul A. Selden
Lawrence, Kansas
December 12, 2014

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 the revision of Part E (any provincial terms are presented in brackets in taxonomic descriptions). They are adapted from the International Stratigraphic Chart, compiled by the International Commission on Stratigraphy (ICS; ©2013).

- **Cenozoic Erathem**
  - **Quaternary System**
    - Holocene Series
    - Pleistocene Series
  - **Neogene System**
    - 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 Series
      - Gzhelian Stage
      - Kasimovian Stage
      - Moscovian Stage
      - Bashkirian Stage
    - Mississippian Series
      - Serpukhovian Stage
      - Visean Stage
      - Tournaisian Stage
  - **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
    - Series 3
    - Series 2
    - Terreneuvian Series

REPOSITORIES AND THEIR ABBREVIATIONS

Abbreviations and locations of museums and institutions holding type material, which are used throughout the systematic sections of Volumes 4 and 5, are listed below.

AM, AM.F, AM.FT: Australian Museum (incorporating former Sydney University Palaeontology type collection; see SUP), Sydney, New South Wales, Australia; note that type collections are catalogued using AM.F for specimens and AM.FT for thin sections

AMNH: American Museum of Natural History, New York, USA

BGU: Ministry of Natural Resources and Environmental Protection of Republic of Buryatia (formerly Buryatian Geological Survey), Ulan-Ude, Republic of Buryatia, Russia

BMNH: see NHM

BSP: Bayerische Staatssammlung für Paläontologie und historische Geologie, München, Germany

CE,: Departamento de Paleontología, Universidad Complutense de Madrid, Madrid, Spain

CIGMR: Chengdu Institute of Geology and Mineral Resources, Chengdu, China

CNIGR, TsNIGRm: Central Geological-Exploring Scientific-Research Museum named after F. N. Chernyshev of the All Russian Geological Institute (VSEGEI) of the Ministry of Natural Resources of the Russian Federation, St. Petersburg (formerly Leningrad), Russia; note that TsNIGRm is the newer transliteration

CORD-PZ: Universidad Nacional de Córdoba, Argentina

CSGM, SOAN, TsGM, TsSGM: Central Siberian Geological Museum of the United Institute of Geology, Geophysics, & Mineralogy (OIGGM), Siberian Branch, Russian Academy of Sciences, Akademgorodok, Novosibirsk, Russia; note that there are collections in other centers in Siberia where the SOAN (Siberian Branch of Academy of Sciences) has existed; TsSGM is the newer transliteration

CSGP: Instito Geologico e Minero, Geológicos de Portugal, Lisbon, Portugal

DPI: Geological Museum, Donetsk National Polytechnic University (formerly Donetsk Polytechnic Institute), Donetsk, Ukraine

DVGU: Committee of Natural Resources on the Khabarovsk Region (formerly Far East Territorial Geological Survey, PGO Dal'geologiya) of the Ministry of Natural Resources of the Russian Federation, Khabarovsk, Russia

FMNH: Field Museum of Natural History, Chicago (formerly Walker Museum, University of Chicago), USA

FSL (F.S.L.): Department of Earth Sciences, Faculté des Sciences de Lyon, Université Claude Bernard, Lyon I, Villeurbanne, France

GFCL: Faculté Libre des Sciences de Lille, Université catholique de Lille, France

GML: Geiseltalmuseum Martin Luther, University of Halle, Halle, Germany

GMU: Geological Museum of the State Committee of the Republic of Uzbekistan on Geology and Mineral Resources, Tashkent, Uzbekistan

GNS, IGNS: GNS Science (formerly the Institute of Geological and Nuclear Sciences, and New Zealand Geological Survey, Department of Scientific and Industrial Research), Lower Hutt, New Zealand

GSC: Geological Survey of Canada, Ottawa, Ontario, Canada

GSWA: Geological Survey of Western Australia, Perth, Western Australia, Australia

HBOI: Harbor Branch Oceanographic Institute at Florida Atlantic University, Fort Pierce, Florida, USA

HGT: Tunisian material in H. & G. Termier collection, Muséum National d'Histoire Naturelle, Paris, France; see MNHN

IG: Institute of Geology, Academia Sinica, Beijing, China

IGD: Institute of Geology, Dushanbe, Tadjikistan

IGPS: see TUM

IGNS: see GNS

IGTUT, IGTTU: Institute of Geology, Tallinn University of Technology, Tallinn, Estonia

IPB, PIUB, GPIBo: Institut für Paläontologie, Universität Bonn, Bonn, Germany

IPE: Institut für Paläontologie, Universität Erlangen, Erlangen, Germany; see RA, TTR

IPFUB: Institut für Paläontologie, Freie Universität, Berlin, Germany

IPUM: Instituto di Palaeontologia, Università di Modena, Modena, Italy

IRScNB, RBINSc: Institut Royal Sciences Naturelles Belgique, Brussels (including Lecompte and Willenz collections), Brussels, Belgium

KGU: Siberian Federal University (formerly Krasnoyarsk State University), Krasnoyarsk, Russia

KUMIP: Museum of Invertebrate Paleontology, University of Kansas, Lawrence, Kansas, USA

LGU: St. Petersburg State University, Museum in Faculty of Geology (formerly Leningrad State University), St. Petersburg, Russia

MCZ: Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA

MIGUP: Museum Instituto di Geologia, Università di Padova, Padova, Italy

MMF: Palaeontological Collection, Geological Survey of New South Wales (formerly Geological & Mining Museum), Londonderry, New South Wales, Australia

MNHB: Museum für Naturkunde der Humboldt-Universität zu Berlin, Geologisch-Paläontologisches Museum, Berlin, Germany

MNHN: Muséum National d'Histoire Naturelle, Paris, France

MUO: Miami University of Ohio, Miami, Ohio, USA

MV: see NMV

NHM: The Natural History Museum, London (formerly BMNH, British Museum, Natural History, London), London, United Kingdom

NIGP, NIGPAS: Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing, China

NMB: Naturhistorisches Museum zu Basel, Basel, Switzerland

NMV, MV: National Museum of Victoria, Melbourne, Victoria, Australia

NYSM: New York State Museum, Albany, USA

PGU: Committee of Natural Resources on the Primor'ye Region (formerly Primor'ye Territorial Geological Survey) of the Ministry of Natural Resources of the Russian Federation, Vladivostok, Russia

PIN: Palaeontological Institute, Russian Academy of Sciences, Moscow, Russia

PIUB: See IPB

PMO: Paleontologisk Museum, University of Oslo, Norway

PU, PUC: Princeton University Collections, Princeton, New Jersey, USA; note that a collection of archaeocyaths donated by the Bedfords were previously housed here, but now have been transferred to the USNM

PUM: Geology, Beijing (formerly Peking) University, Beijing, China

QMF: Queensland Museum, South Brisbane, Queensland, Australia (including the paleontological collections of the University of Queensland, UQF)

RA: Argentine Precordillera type and figured specimens in the Keller & Flügel collection are held in Erlangen; see IPE

RBINSc: see IRScNB

RIGMR: Laboratory of Palaeontology & Stratigraphy of Research Institute of Geology & Mineral Resources, Thanh Xuan, Ha Noi, Vietnam

RM, SCRM (Stearn collection): Redpath Museum, McGill University, Montreal, Canada

ROM: Royal Ontario Museum, Toronto, Ontario, Canada

SAM, SAM.P: South Australian Museum, Adelaide, South Australia, Australia

SAM(C): South African Museum, Cape Town, South Africa

SCRM: See RM

SGPIH: Geological-Paleontological Institute, Universität Hamburg, Hamburg, Germany

SMF, SM: Senckenberg Museum, Frankfurt am Main, Germany

SMNH: Naturhistorisk Riksmuseet, Stockholm, Sweden

SNIIGGiMS: Federal State Bureau "Siberian Scientific Research Institute of Geology, Geophysics & Mineral Resources" of the Russian Federation, Krasnyy Prospect, Novosibirsk, Russia; note that some of these collections have been transferred to CSGM (=TsSGM)

SOAN: Siberian Branch of Academy of Science; note that a number of divisions of this organization have maintained paleontological collections in Krasnoyarsk, Irkutsk, and Ulan-Ude, as well as Novosibirsk, Russia; some of the type material may also have been transferred to the CSGM (=TsSGM)

SUP: Palaeontological collections, University of Sydney, New South Wales, Australia; see AM

SRPMH: Roemer-Pelizaeus Museum, Hildesheim, Germany

SSPHG: Staatliches Sammlung für Paläontologie und Historische Geologie, München, Germany

TPI: Tomsk Polytechnic University, Tomsk, Russia (formerly Tomsk Polytechnic Institute)

TsNIGRA, TsNIGRm, TsNIGRM: see CNIGR

TsSGM: see CSGM

TTR: Turkish type specimens from Tilkideligi Tepe in Cremer collection are held in Erlangen; see IPE

TUM, IGPS: Tohoku University Museum, Sendai, Japan (formerly IGPS, Institute of Geology & Paleontology of Tohoku University)

UAM: University of Alaska Museum, Fairbanks, USA

UCMP: University of California, Museum of Paleontology, Berkeley, California, USA

UG: Universität Graz, Graz, Austria

UGM: Urals Geological Museum of the Urals State Mining University, Ekaterinburg (=Sverdlovsk), Russia

UHR: Hokkaido University, Sapporo, Japan

UM: Paläontologische Sammlung, Geologisch-Paläontologisches Institut, Universität Münster, Münster, Germany

UMMP: Paleontology Museum, University of Michigan, Ann Arbor, Michigan, USA

UQF: University of Queensland, Department of Geology, Brisbane, Queensland, Australia; paleontological collections have now been transferred to the Queensland Museum; see QMF

USNM: National Museum of National History, Smithsonian Institution, Washington, D.C., USA (formerly United States National Museum)

UTGD: University of Tasmania Geology Department, Hobart, Tasmania, Australia

UWA: University of Western Australia, Nedlands, Western Australia, Australia

VNIGRI: All-Union Scientific-Research Geological-Exploring Institute of the Ministry of Natural Resources of the Russian Federation, St Petersburg, Russia

VSEGEI: All-Russian Geological Institute of the Ministry of Natural Resources of the Russian Federation, Sredniy Prospect, St. Petersburg, Russia; note that relevant material has largely been incorporated into museum repositories such as CNIGR (more recently transliterated asTsNIGRm)

VU: Museum of Geology, Victoria University of Wellington, Wellington, New Zealand

XB: Palaeontological Collections of the Xi'an Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences, Xi'an, Shaanxi Province, China

YaFAN: Museum of Geology of the Institute of Geology of Diamonds and Precious Metals of the Yakutian Scientific Centre of the Siberian Branch of the Russian Academy of Sciences, Yakutsk, Republic of Sakha (Yakutia), Russia

YPM: Yale University, Peabody Museum of Natural History, New Haven, Connecticut, USA; stromatoporoid types of Galloway and St. Jean now housed in the Peabody Museum

ZPAL: Institute of Palaeobiology, Polish Academy of Sciences, Warsaw, Poland

ZSGGU: Closed Company "West Siberian State Geological Trust," PGO Zapsibgeologiya, Novokuznetsk, Kemerova Region, Russia

OUTLINE CLASSIFICATION AND RANGES OF TAXA OF THE HYPERCALCIFIED PORIFERA

BARRY D. WEBBY, Compiler

The outline classification presented below is of fossil and living hypercalcified sponges treated in these volumes. It summaries taxonomic relationships and presents stratigraphic ranges of these supragenic taxa, following best possible correlations. As far as possible, the ranges are are based on the International Stratigraphic Chart, compiled by the International Commission on Stratigraphy (ICS; COHEN & others, 2013).

The presentation is as unified as possible and comprises all the suprageneric divisions treated in these volumes, as well as a number of asterisked family groupings that were listed in the review-style section on chambered sphinctozoan and non-chambered inozoan hypercalcified sponges (see p. 387–395). These latter groups were described previously by FINKS and RIGBY (2004d, p. 585–764) in the *Treatise, Part E, Revised,* Volume 3, and they are shown in this listing as either sphinctozoan skeletal types (denoted by single asterisks) or inozoan types (with double asterisks). Also one family, the Maeandrostiidae, exhibits transitional features between the above-mentioned two skeletal types, and this is shown by a triple asterisk. The fossil orders Stellispongiida and Sphaerocoeliida are included with the Subclass Calcaronea following FINKS and RIGBY (2004d, p. 737–752), rather than in a grouping with subclass Calcinea as preferred by Senowbari-Daryan and Rigby (see p. 387, 391, 392, 394, 395).

In FINKS and RIGBY's (2004d) systematic descriptions on hypercalcified sponges, different morphological types can be distinguished, as follows: (1) inozoan-type morphologies in agelasid demosponges (p. 594–644) as well as in stellispongiid calcareans (p. 738–750); (2) sphinctozoan-type morphologies occurring in a range of agelasid, verticillitid, and hadromerid demosponge orders (p. 646–734) and the sphaerocoeliid calcareans (p. 750–752); and (3) both inozoan- and sphinctozoan-type morphologies developing apparently only in the agelasid demosponge family Maeandrostiidae (p. 644–646).

Largely as a consequence of the strong faunal provincialism, the archaeocyathan representatives have proved difficult to assign within formalized stratigraphic subdivisions of the Cambrian Period. At present only half of the proposed four global Series have been formally named, and five of the ten Stage divisions have not been properly ratified. The undefined subdivisions are presently associated with an interval spanning the "upper-lower" to "lower-middle" parts of the Cambrian, and this includes sequences with the most varied archaeocyathan assemblages. Consequently, Debrenne, Zhuravlev, and Kruse (see p. 909–912) have outlined a biostratigraphic scheme that employs the Siberian archaeocyathan zonal succession in conjunction with the regional stage nomenclature for Siberia. The four Cambrian regional stages are, in ascending order, the Tommotian, Atdabanian, Botomian and Toyonian, and these more or less equate with the largely unnamed "upper-lower" to "lower-middle" Cambrian interval—that is, through the upper part of the Terreneuvian Series (Stage 2 = Tommotian), to the undescribed Series 2, which comprises the Stage 3 (=Atdabanian to early Botomian) and Stage 4 (=late Botomian to Toyonian) interval. The regional units have been further subdivided using the archaeocyathan zonation and identified with four named Tommotian zones (Tom.1–4), four named Atdabanian zones (Atd.1–4), three (only the lowest one named) Botomian zones (Bot.1–3) and three (only the middle zone named) Toyonian, zones (Toy.1–3).

Note also that recent results of rDNA sequencing of the eponymous living genus *Vaceletia* of the family Vaceletiidae by WÖRHEIDE (2008) seems to confirm that this chambered genus is a keratose sponge, and that the group should be transferred to the demosponge Order Dictyoceratida MINCHIN, 1900, from its previous placement within the Order Verticillitida TERMIER & TERMIER in TERMIER, TERMIER, & VACHARD, 1977 (see discussion on p. 273–277).

- Phylum Porifera Grant, 1836. *?Cryogenian, Cambrian–Holocene.*
  - Class Demospongiae Sollas, 1885. *?Silurian, Middle Devonian–Holocene.*
    - Order Hadromerida Topsent, 1894. *?Silurian, Middle Devonian–Holocene.*
      - Family Acanthochaetetidae Fischer, 1970. *Upper Jurassic–Holocene.*
      - Family Suberitidae Schmidt, 1870. *?Silurian, Middle Devonian–Upper Cretaceous (Coniacian).*
      - Family Spirastrellidae Ridley & Dendy, 1886. *Lower Cretaceous (Albian).*
      - *Family Celyphiidae de Laubenfels, 1955. *Permian (Guadalupian)–Triassic.*
      - *Family Ceotinellidae Senowbari-Daryan in Flügel & others, 1978. *Triassic (Ladinian–Carnian).*
      - *Family Polysiphonidae Girty, 1909. *Permian (Guadalupian)–Triassic.*
    - Order Chondrosida Boury-Esnault & Lopes, 1985. *Lower Cretaceous (Albian).*
      - Family Chondrillidae Gray, 1872. *Lower Cretaceous (Albian).*
    - Order Poecilosclerida Topsent, 1928. *Lower Jurassic–Holocene.*
      - Family Merliidae Kirkpatrick, 1908. *Lower Jurassic–Holocene.*
    - Order Halichondrida Gray, 1867. *Triassic–Holocene.*
      - Family Uncertain. *Upper Triassic–Upper Cretaceous.*
    - Order Agelasida Hartman, 1980b. *Upper Permian–Holocene.*
      - Family Astroscleridae Lister, 1900. *Upper Permian–Holocene.*
      - Family Milleporellidae Yabe & Sugiyama 1935. *Upper Triassic–Eocene.*
      - Family Actinostromariidae Hudson, 1955c. *Upper Jurassic–Upper Cretaceous.*
      - Family Actinostromarianinidae Wood, 1987. *Upper Jurassic.*
      - Family Uncertain. *Triassic (Carnian–Norian)–Jurassic (lower Kimmeridgian).*
      - *Family Angullongiidae Webby & Rigby, 1985. *Upper Ordovician (Katian).*
      - *Family Phragmocoeliidae Ott, 1974. *Lower Devonian (Lochkovian)–Triassic (Carnian).*
      - *Family Intrasporeocoeliidae Fan & Zhang, 1985. *Permian (Guadalupian-Lopingian).*
      - *Family Cryptocoeliidae Steinmann, 1882. *Silurian (Ludlow)–upper Triassic.*
      - *Family Palermocoeliidae Senowbari-Daryan, 1990. *upper Triassic.*
      - *Family Thaumastocoeliidae Ott, 1967. *Upper Ordovician–Triassic (Norian).*
      - *Family Amphorithalamiidae Senowbari-Daryan & Rigby, 1988. *Permian (Lopingian).*
      - *Family Polyedridae Termier & Termier in Termier & others, 1977. *Permian (?Arkinskian–Lopingian).*
      - *Family Aphrosalpingidae Myagkova, 1955. *Upper Ordovician, Silurian (Ludlow) Carboniferous (Pennsylvanian, Permian (Lopingian), Triassic.*
      - *Family Glomocystospongiidae Rigby, Fan, & Zhang, 1989. *Permian (Lopingian).*
      - *Family Sebargasiidae de Laubenfels, 1955. *?Ordovician, Carboniferous–Triassic.*
      - *Family Olangocoeliidae Bechstadt & Brandner, 1970. *middle Triassic.*
      - *Family Cliefdenellidae Webby, 1969. *Upper Ordovician (Katian).*
      - *Family Guadalupiidae Girty, 1908. *Carboniferous–Triassic (Norian).*
      - *Family Tabasiidae Senowbari-Daryan, 2005. *Triassic.*
      - **Family Catenispongiidae Finks, 1995. *Permian (Artinskian)–Triassic.*
      - **Family Virgolidae Termier & Termier in Termier & others, 1977. *Permian (Kungurian), Triassic.*
      - **Family Sphaeropontiidae Rigby & Senowbari-Daryan, 1996. *Permian (Lopingian).*
      - **Family Exotubispongiidae Rigby & Senowbari-Daryan, 1996. *Permian (Lopingian).*
      - **Family Sestrostomellidae de Laubenfels, 1955. *Triassic–Lower Cretaceous.*
      - **Family Pharetrospongiidae de Laubenfels, 1955. *Triassic (Carnian)–Cretaceous.*
      - **Family Auriculospongiidae Termier & Termier in Termier & others, 1977. *Permian (Asselian, Guadalupian–Lopingian).*
      - **Family Stellispongiellidae Wu, 1991. *Permian (Guadalupian)–Triassic.*
      - **Family Preperonidellidae Finks & Rigby, 2004c. *Upper Ordovician–upper Triassic.*
      - **Family Fissispongiidae Finks & Rigby, 2004c. *Devonian (Eifelian)–Permian (Roadian, or early Guadalupian).*
      - ***Family Maeandrostiidae Finks, 1971. *Carboniferous (middle Pennsylvanian)–Triassic.*
    - Order Haplosclerida Topsent, 1928. *Upper Carboniferous–Holocene.*
      - Family Calcifibrospongiidae Hartman, 1979. *Holocene.*
      - Family Euzkadiellidae Reitner, 1987a. *Lower Cretaceous.*
      - Family Newellidae Wood, Reitner, & West 1989. *Upper Carboniferous (middle Pennsylvanian).*
    - Order Dictyoceratida Minchin, 1900. *?Cretaceous, Eocene–Holocene.*
      - Family Vaceletiidae Reitner & Engeser, 1985. *?Cretaceous, Eocene–Holocene.*
    - Order Verticillitida Steinmann, 1882. *?lower Cambrian, Cretaceous, ?Cenozoic.*
      - *Family Solenolmiidae Engeser, 1986. *lower Cambrian–Triassic, ?Jurassic.*
      - *Family Colospongiidae Senowbari-Daryan, 1990. *lower Cambrian–Triassic.*
      - *Family Gigantothalamiddae Senowbari-Daryan, 1994. *upper Triassic (Norian).*
      - *Family Tebagathalamiidae Senowbari-Daryan & Rigby, 1988. *Permian–upper Triassic.*
      - *Family Annaecoeliidae Senowbari-Daryan, 1978. *upper Triassic.*
      - *Family Cheilosporitiidae Fischer, 1962. *Triassic (Carnian–Rhaetian).*

*Family Salzburgiidae Senowbari-Daryan & Schafer, 1979. *Permian–Triassic (Rhaetian).*
*Family Cribrothalamiidae Senowbari-Daryan, 1990. *Triassic (Norian–Rhaetian).*
*Family Verticillitidae Steinmann, 1882. *Permian (Guadalupian)–Upper Cretaceous, Paleogene (Eocene).*
Order Uncertain.
Family Burgundiidae Dehorne, 1920. *Upper Jurassic–Lower Cretaceous.*
Family Uncertain. *Upper Triassic, Jurassic, ?Lower Cretaceous, Miocene.*

Class Calcarea Bowerbank, 1864. *?Cambrian, ?Carboniferous ?Permian, ?Jurassic, Cretaceous–Holocene.*
Subclass Calcinea Bidder, 1898. *Holocene.*
Order Murrayonida Vacelet, 1981. *Holocene.*
Family Murrayonidae Dendy & Row, 1913. *Holocene.*
Family Paramurrayonidae Vacelet, 1967a. *Holocene.*
Subclass Calcaronea Bidder, 1898. *?Jurassic, Cretaceous–Holocene.*
Order Lithonida Vacelet, 1981. *?Jurassic, Cretaceous–Holocene.*
Family Minchinellidae Dendy & Row, 1913. *?Jurassic, Cretaceous–Holocene.*
Order Stellispongiida Finks & Rigby, 2004c. *Permian–Holocene.*
**Family Stellispongiidae de Laubenfels, 1955. *Permian–Neogene (Miocene).*
Order Sphaerocoeliida Vacelet, 1979b. *Permian–Cretaceous (Cenomanian).*
*Family Sphaerocoeliidae Steinmann, 1882 *Permian–Cretaceous (Cenomanian).*
Order Baerida Borojevic, Boury-Esnault & Vacelet, 2000. *Pleistocene–Holocene.*
Family Petrobionidae Borojevic, 1979. *Pleistocene–Holocene.*
Family Lepidoleuconidae, Vacelet 1967a. *Holocene.*

Class and Order Uncertain (?Demospongiae or ?Calcarea).
Family Disjectoporidae Tornquist, 1901. *Permian–Triassic.*

Class Heteractinida Hinde, 1887. *lower Cambrian–Permian.*
Order Octactinellida Hinde, 1887. *lower Cambrian–Permian.*
?*Family Nuchidae Pickett, 2002. upper lower–middle Cambrian.

Class Stromatoporoidea Nicholson & Murie, 1878. *Middle Ordovician (Darriwilian)–Lower Carboniferous (Serpukhovian), ?Triassic.*
Order Labechiida Kühn, 1927. *Middle Ordovician (Darriwilian)–Upper Devonian, ?Triassic.*
Family Rosenellidae Yavorsky in Khalfina & Yavorsky, 1973. *Middle Ordovician (Darriwilian)–Upper Devonian.*
Family Labechiidae Nicholson, 1879b. *Middle Ordovician (Darriwilian)–Upper Devonian.*
Family Stromatoceriidae Bogoyavlenskaya, 1969b. *Upper Ordovician (Sandbian–Katian).*
Family Platiferostromatidae Khalfina & Yavorsky, 1973. *Silurian (Llandovery)–Upper Devonian (Famennian).*
Family Stylostromatidae Webby, 1993. *Middle Ordovician (Darrwilian)–Upper Devonian (Famennian).*
Family Aulaceratidae Kühn, 1927. *Middle Ordovician (Darriwilian)–Upper Devonian (Famennian).*
Family Lophiostromatidae Nestor, 1966a. *Middle Ordovician (Darriwilian)–Upper Devonian (Frasnian), ?Triassic.*
Order Clathrodictyida Bogoyavlenskaya, 1969b. *Upper Ordovician (Katian)–Lower Carboniferous (Serpukhovian).*
Family Clathrodictyidae Kühn, 1939a. *Upper Ordovician (Katian)–Lower Carboniferous (Serpukhovian).*
Family Actinodictyidae Khalfina & Yavorsky, 1973. *Upper Ordovician (Katian)–Lower Devonian (Emsian).*
Family Gerronostromatidae Bogoyavlenskaya, 1969b. *Silurian (Llandovery)–Upper Devonian (upper Famennian).*
Family Tienodictyidae Bogoyavlenskaya, 1965c. *Silurian (Llandovery)–Upper Devonian (Frasnian).*
Family Anostylostromatidae Nestor, 2011. Silurian (Ludlow)–Upper Devonian (upper Famennian).
Family Atelodictyidae Khalfina, 1968a. *Lower Devonian–Upper Devonian (upper Famennian).*
Order Actinostromatida Bogoyavlenskaya, 1969b. *Upper Ordovician (Katian)–Upper Devonian (Frasnian).*
Family Actinostromatidae Nicholson, 1886a. *Lower Silurian (Llandovery)–Upper Devonian (Frasnian).*
Family Pseudolabechiidae Bogoyavlenskaya, 1969a. *Lower Silurian (Llandovery)–Upper Silurian (Pridoli).*
Family Plumataliniidae Bogoyavlenskaya, 1969b. *Upper Ordovician (Katian).*
Family Actinostromellidae Nestor, 1966a. *Middle Silurian (Wenlock)–Lower Devonian (Lochkovian).*
Family Densastromatidae Bogoyavlenskaya, 1974. *Lower Silurian (Llandovery)–Lower Devonian (Lochkovian).*
Order Stromatoporellida Stearn, 1980. *Silurian (Pridoli)–Upper Devonian (Famennian).*
Family Stromatoporellidae Lecompte, 1951 in Lecompte, 1951–1952. *Silurian (Wenlock)–Devonian (Frasnian, ?upper Famennian).*
Family Trupetostromatidae Germovsek, 1954. *Silurian (Pridoli)–Upper Devonian (Famennian).*
Family Idiostromatidae Nicholson, 1886a. *Middle Devonian (Eifelian)–Upper Devonian (Frasnian).*
Order Stromatoporida Stearn, 1980. *Silurian (upper Llandovery)–Upper Devonian (Frasnian).*
Family Stromatoporidae, Winchell, 1867. *Silurian (upper Llandovery)–Upper Devonian (Frasnian).*
Family Ferestromatoporidae Khromykh, 1969. *Lower Devonian (?Emsian), Middle-Upper Devonian (Frasnian).*
Family Syringostromellidae Stearn, 1980. *Silurian (upper Llandovery–Upper Devonian (Frasnian).*

Order Syringostromatida Bogoyavlenskaya, 1969b. *Silurian (Wenlock)–Middle Devonian (Givetian), Upper Devonian (?Famennian).*
Family Coenostromatidae Waagen & Wentzel, 1887. Silurian *(Pridoli)–Upper Devonian (Frasnian).*
Family Parallelostromatidae Bogoyavlenskaya, 1984. Silurian *(Wenlock)–Middle Devonian (Givetian), Upper Devonian (?Frasnian).*
Family Stachyoditidae Khromykh, 1967. *Lower Devonian (?Lochkovian), Middle Devonian (Eifelian)–Upper Devonian (Frasnian, ?Famennian).*
Order Amphiporida Rukhin, 1938. *?middle Silurian, upper Silurian (Ludlow)–Upper Devonian (Famennian).*
Family Amphiporidae Rukhin, 1938. *?middle Silurian, upper Silurian (Ludlow)–Upper Devonian (Famennian).*
Order and Family Uncertain. *Upper Ordovician (Katian), middle Silurian–Upper Devonian (upper Famennian).*

Class Uncertain
Order Pulchrilaminida Webby, 2012a. *Lower Ordovician (upper Tremadocian)–Middle Ordovician (lower Darriwilian).*
Family Pulchrilaminidae Webby, 1993. *Lower Ordovician (upper Tremadocian–Middle Ordovician (lower Darriwilian).*

Class Archaeocyatha Bornemann, 1884. *Cambrian (Terreneuvian–Furongian).*
Order Monocyathida Okulitch, 1935b. *lower Cambrian (Tom.1–Bot.3).*
Family Monocyathidae R. Bedford & W. R. Bedford, 1934. *lower Cambrian (Tom.1–Bot.3).*
Family Palaeoconulariidae Chudinova 1959. *lower Cambrian (Atd.4–Bot.3).*
Family Tumuliolynthidae Rozanov in Rozanov & Missarzhevskiy, 1966. *lower Cambrian (Tom.2–Bot.3).*
Family Sajanolynthidae Rozanov in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.1).*
Family Globosocyathidae Okuneva, 1969. *lower Cambrian (Atd.2–Bot.1).*
Family Favilynthidae Debrenne, 1989. *lower Cambrian (Atd.1–Bot.3).*
Order Ajacicyathida R. Bedford & J. Bedford, 1939. *lower Cambrian (Tom.1–Toy.3).*
Suborder Dokidocyathina Vologdin, 1957. *lower Cambrian (Tom. 2–Bot.3).*
Superfamily Dokidocyathoidea R. Bedford & W. R. Bedford, 1936. *lower Cambrian (Tom.2–Bot.3).*
Family Dokidocyathidae R. Bedford & W. R. Bedford, 1936. *lower Cambrian (Tom. 2–Bot.3)*
Family Dokidocyathellidae Debrenne, 1964. *lower Cambrian (Atd.2–Bot.1).*
Family Cordobicyathidae Perejón, 1975a. *lower Cambrian (Atd.2).*
Superfamily Kidrjasocyathoidea Rozanov in Zhuraveleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Atd.2–Bot.1).*
Family Kidrjasocyathidae Rozanov in Zhuraveleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Atd.2–Bot.1).*
Superfamily Kaltatocyathoidea Rozanov in Zhuraveleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Atd.1–Bot.1).*
Family Kaltatocyathidae Rozanov in Zhuraveleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Atd.1–Bot.1).*
Superfamily Papillocyathoidea Rozanov in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.4–Bot.1).*
Family Papillocyathidae Rozanov in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.4–Bot.1).*
Superfamily Soanicyathoidea Rozanov in Zhuraveleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Atd.2–Bot.1).*
Family Soanicyathidae Rozanov in Zhuraveleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Atd.2–Bot.1).*
Family Zhuravlevaecyathidae Rozanov in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.1).*
Superfamily Kymbecyathoidea Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.4–Bot.3).*
Family Kymbecyathidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.4–Bot.3).*
Suborder Ajacicyathina R. Bedford & J. Bedford, 1939. *lower Cambrian (Tom.1–Toy.3).*
Superfamily Bronchocyathoidea R. Bedford & J. Bedford, 1936. *lower Cambrian (Tom.1–Toy.2).*
Family Ajacicyathidae R. Bedford & J Bedford, 1939. *lower Cambrian (Tom.1–Toy.2).*
Family Densocyathidae Vologdin, 1937b. *lower Cambrian (Atd.1–Bot.3).*
Family Bronchocyathidae R. Bedford & J. Bedford, 1936. *lower Cambrian (Atd.1–Bot.3).*
Family Ethmocyathidae Debrenne, 1969a. *lower Cambrian (Atd.1–Bot.3).*
Family Sajanocyathidae Vologdin, 1956. *lower Cambrian (Atd.1–Toy.2).*
Family Bipallicyathidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.2).*
Superfamily Pretiosocyathoidea Rozanov, 1969. *lower Cambrian (Atd.1–Bot.2).*
Family Robertocyathidae Rozanov, 1969. *lower Cambrian (Atd.2–Bot.1).*
Family Pretiosocyathidae Rozanov, 1969. *lower Cambrian (Atd.1–Bot.1).*

Superfamily Erbocyathoidea Vologdin & Zhuravleva in Vologdin, 1956. *lower Cambrian (Atd.1–Toy.3).*
  Family Erbocyathidae Vologdin & Zhuravleva in Vologdin, 1956. *lower Cambrian (Atd.1–Tot.3).*
  Family Peregrinicyathidae Zhuravleva in Zhuravleva & others, 1967. *lower Cambrian (Bot.1-Bot.2).*
  Family Vologdinocyathidae Yaroshevich, 1957. *lower Cambrian (Bot.1–Toy. 2).*
  Family Tegerocyathidae Krasnopeeva, 1972. *lower Cambrian (Bot.1–Toy.3).*
Superfamily Tumulocyathoidea Krasnopeeva, 1953. *lower Cambrian (Tom.2–Bot.3).*
  Family Tumulocyathidae Krasnopeeva, 1953. *lower Cambrian (Tom.2–Bot.3).*
  Family Sanarkocyathidae, Hill, 1972. *lower Cambrian (Atd.3–Bot.1).*
  Family Geocyathidae Debrenne, 1964. *lower Cambrian (Atd.1–Bot.1).*
  Family Konjuschkovicyathidae Debrenne & Zhuravlev, 2000. *lower Cambrian (Bot.1–Bot.3).*
Superfamily Lenocyathoidea Zhuravleva in Vologdin, 1956. *lower Cambrian (Atd.1–Bot.1).*
  Family Torosocyathidae Debrenne, Zhuravlev, & Kruse, 2002. *lower Cambrian (Atd.1–Bot.1).*
  Family Japhanicyathidae Rozanov in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.2–Bot.1).*
  Family Lenocyathidae Zhuravleva in Vologdin, 1956. *lower Cambrian (Atd.2–Bot.1).*
Superfamily Annulocyathoidea Krasnopeeva, 1953. *lower Cambrian (Tom.2–Bot.3).*
  Family Tumulifungiidae Rozanov in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Tom.2–Bot.3).*
  Family Annulocyathidae Krasnopeeva, 1953. *lower Cambrian (Atd.2–Bot.3).*
  Family Jakutocarinidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.1–Bot.3).*
  Family Gagarinicyathidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.3–Bot.1).*
Superfamily Ethmophylloidea Okulitch, 1937b. *lower Cambrian (Atd.1–Toy.1).*
  Family Fallocyathidae Rozanov, 1969. *lower Cambrian (Bot.1–Bot.2).*
  Family Gloriosocyathidae Rozanov, 1969. *lower Cambrian (Atd.1–Bot.1).*
  Family Kijacyathidae Zhuravleva in Repina & others, 1964. *lower Cambrian (Atd.2–Bot.3).*
  Family Carinacyathidae Krasnopeeva, 1953. *lower Cambrian (Atd.1–Bot.3).*
  Family Ethmophyllidae Okulitch, 1937b. *lower Cambrian (Atd.4–Toy.1).*
Superfamily Tercyathoidea Vologdin in Simon, 1939. *lower Cambrian (Atd.4–Toy.1).*
  Family Piamaecyathellidae Rozanov, 1974. *lower Cambrian (Bot.2).*
  Family Botomocyathidae Zhuravleva, 1955b. *lower Cambrian (Atd.4–Bot.3).*
  Family Olgaecyathidae Borodina, 1974. *lower Cambrian (Bot.2).*
  Family Tercyathidae Vologdin, 1939. *lower Cambrian (Bot.1–Toy.1).*
Superfamily Sigmocyathoidea Krasnopeeva, 1953. *lower Cambrian (Bot.3).*
  Family Sigmocyathidae Krasnopeeva, 1953. *lower Cambrian (Bot.3).*
  Family Wrighticyathidae Kruse, 1978. *lower Cambrian (Bot.3).*
Suborder Erismacoscinina Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Tom.2–Bot.3).*
Superfamily Salairocyathoidea Zhuravleva in Vologdin, 1956. *lower Cambrian (Tom.2–Bot.3).*
  Family Asterocyathidae Vologdin, 1956. *lower Cambrian (Tom.2–Bot.3).*
  Family Rudanulidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.1–Bot.3).*
  Family Salairocyathidae Zhuravleva in Vologdin, 1956. *lower Cambrian (Atd.2–Bot.1).*
  Family Crassicoscinidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1988. *lower Cambrian (Atd.4–Bot.1).*
Superfamily Kasyricyathoidea Zhuravleva in Musatov & others, 1961. *lower Cambrian (Atd.1–Bot.3).*
  Family Agyrekocyathidae Konyushkov, 1967. *lower Cambrian (Atd.1–Bot.1).*
  Family Xestecyathidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.3).*
  Family Kasyricyathidae Zhuravleva in Musatov & others, 1961. *lower Cambrian (Bot.1).*
  Family Membranacyathidae Debrenne, Zhuravlev, & Kruse, 2002. *lower Cambrian (Atd.1–Atd.2).*
Superfamily Polycoscinoidea Debrenne, 1964. *lower Cambrian (Atd.3–Bot.3).*
  Family Anaptyctocyathidae Debrenne, 1970a. *lower Cambrian (Atd.4–Bot.3).*
  Family Polycoscinidae Debrenne, 1964. *lower Cambrian (Atd.3–Bot.3).*
  Family Veronicacyathidae Debrenne, Zhuravlev, & Kruse, 2002. *lower Cambrian (Atd.4–Bot.3).*
  Family Zonacoscinidae Debrenne, 1971. *lower Cambrian (Bot.1).*
Superfamily Ethmocoscinoidea Zhuravleva, 1957. *lower Cambrian (Atd.2–Bot.3).*
  Family Tumulocoscinidae Zhuravleva, 1960b. *lower Cambrian (Atd.2–Bot.1).*
  Family Ethmocoscinidae Zhuravleva, 1957. *lower Cambrian (Bot.3).*
Superfamily Coscinoptyctoidea Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.1–Bot.3).*
  Family Geyericoscinidae Debrenne & Zhuravlev, 2000. *lower Cambrian (Atd.1–Bot.1).*
  Family Coscinoptyctidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.3).*

Family Jebileticoscinidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.1).*
Superfamily Sigmocoscinoidea R. Bedford & J. Bedford, 1939. *lower Cambrian (Bot.1–Bot.3).*
Family Sylviacoscinidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.1–Bot.3).*
Family Sigmocoscinidae R. Bedford & J. Bedford, 1939. *lower Cambrian (Bot.3).*
Superfamily Porocoscinoidea Debrenne, 1964. *lower Cambrian (Atd.1–Bot.3).*
Family Rozanovicyathidae Korshunov in Zhuravleva, Korshunov, & Rozanov, 1969. *lower Cambrian (Bot.1).*
Family Tatijanaecyathidae Korshunov, 1976. *lower Cambrian (Bot.1).*
Family Porocoscinidae Debrenne, 1964. *lower Cambrian (Atd. 3–Bot.3).*
Superfamily Mootwingeecyathoidea Kruse, 1982. *lower Cambrian (Bot.3).*
Family Mootwingeecyathidae Kruse, 1982. *lower Cambrian (Bot.3).*
Order Putapacyathida Vologdin, 1961. *lower Cambrian (Bot.1–Bot.3).*
Superfamily Alphacyathoidea R. Bedford & J. Bedford, 1939. *lower Cambrian (Bot.1–Bot.3).*
Family Alphacyathidae R. Bedford & J. Bedford, 1939. *lower Cambrian (Bot.1–Bot.3).*
Superfamily Putapacyathoidea R. Bedford & J. Bedford, 1936. *lower Cambrian (Bot.1–Bot.3).*
Family Putapacyathidae R. Bedford & J. Bedford, 1936. *lower Cambrian (Bot.3).*
Superfamily Hupecyathoidea Debrenne, Rozanov, & Zhuravlev, 1990. *lower Cambrian (Atd.4).*
Family Hupecyathidae Debrenne, Rozanov, & Zhuravlev, 1990. *lower Cambrian (Atd.4).*
Superfamily Chabakovicyathoidea Rozanov in Debrenne, Zhuravlev, & Kruse, 2002. *lower Cambrian (Bot.1).*
Family Chabakovicyathidae Rozanov in Debrenne, Zhuravlev, & Kruse, 2002. *lower Cambrian (Bot.1).*
Order Capsulocyathida Zhuravleva in Zhuravleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Tom.1–Bot.3).*
Suborder Capsulocyathina Zhuravleva in Zhuravleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Tom.1–Bot.3).*
Family Cryptoporocyathidae Zhuravleva, 1960b. *lower Cambrian (Tom.1–Bot.3).*
Family Uralocyathellidae Zhuravleva in Zhuravleva, Konyushkov, & Rozanov, 1964. *lower Cambrian (Bot.1).*
Family Tylocyathidae Zhuravlev, 1988. *lower Cambrian (Tom.4–Bot.3).*
Family Fransuasaecyathidae Debrenne, 1964. *lower Cambrian (Atd.1–Bot.1).*
Family Tubericyathidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.1).*
Suborder Coscinocyathina Zhuravleva, 1949. *lower Cambrian (Atd.1–Bot.3).*
Superfamily Coscinocyathoidea Taylor, 1910. *lower Cambrian (Atd.2–Bot.3).*
Family Coscinocyathidae Taylor, 1910. *lower Cambrian (Atd.2–Bot.3).*
Family Mawsonicoscinidae Debrenne & Kruse, 1986. *lower Cambrian (Bot.3).*
Family Coscinocyathellidae Zhuravleva in Vologdin, 1956. *lower Cambrian (Bot.1–Bot.3).*
Superfamily Calyptocoscinoidea Debrenne, 1964. *lower Cambrian (Atd.1–Bot.1).*
Family Calyptocoscinidae Debrenne, 1964. *lower Cambrian (Bot.1).*
Family Tomocyathidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Atd.1–Atd. 3).*
Superfamily Alataucyathoidea Zhuravleva, 1955b. *lower Cambrian (Atd.1–Atd.2).*
Family Alataucyathidae Zhuravleva, 1955b. *lower Cambrian (Atd.1–Atd.2).*
Superfamily Clathricoscinoidea Rozanov in Repina & others, 1964. *lower Cambrian (Bot.1–Toy.1).*
Family Clathricoscinidae Rozanov in Repina & others, 1964. *lower Cambrian (Bot.1–Toy.1).*
Family Lanicyathidae Debrenne, Rozanov, & Zhuravlev in Debrenne, Zhuravlev, & Rozanov, 1989. *lower Cambrian (Bot.1).*
Order Archaeocyathida Okulitch, 1935b. *lower Cambrian (Tom.1–Toy.3), middle Cambrian, upper Cambrian (Furongian).*
Suborder Loculicyathina Zhuravleva, 1954. *lower Cambrian (Tom.1–Bot.3), upper Cambrian (Furongian).*
Superfamily Loculicyathoidea Zhuravleva, 1954. *lower Cambrian (Tom.1–Bot.3), upper Cambrian (Furongian).*
Family Loculicyathidae Zhuravleva, 1954. *lower Cambrian (Tom.1–Bot.3), upper Cambrian (Furongian).*
Family Eremitacyathidae Debrenne, 1992. *lower Cambrian (Atd.2).*
Superfamily Sakhacyathoidea Debrenne & Zhuravlev, 1990. *lower Cambrian (Tom.2–Atd.2).*
Family Sakhacyathidae Debrenne & Zhuravlev, 1990. *lower Cambrian (Tom. 2–Atd.2).*
Superfamily Chankacyathoidea Yakovlev, 1959. *lower Cambrian (Atd.4–Bot.3).*
Family Chankacyathidae Yakovlev, 1959. *lower Cambrian (Bot.1–Bot.3).*
Family Tchojacyathidae Debrenne & Zhuravlev, 1992b. *lower Cambrian (Atd.4).*
Suborder Anthomorphina Okulitch, 1935b. *lower Cambrian (Bot.1).*
Superfamily Anthomorphoidea Okulitch, 1935b. *lower Cambrian (Bot.1).*
Family Anthomorphidae Okulitch, 1935b. *lower Cambrian (Bot.1).*
Family Shiveligocyathidae Fonin, 1983. *lower Cambrian (Bot.1).*
Suborder Archaeocyathina Okulitch, 1935b. *lower Cambrian (Tom. 2–Toy. 3), middle Cambrian.*
Superfamily Dictyocyathoidea Taylor, 1910. *lower Cambrian (Tom. 2–Toy.1), middle Cambrian.*
Family Dictyocyathidae Taylor, 1910. *lower Cambrian (Tom. 2–Toy.1), middle Cambrian.*
Family Claruscoscinidae Debrenne & Zhuravlev, 1992b. *lower Cambrian (Bot.1–Toy 1).*
Family Pycnoidocoscinidae Debrenne, 1974a. *lower Cambrian (Bot.3).*

Superfamily Archaeocyathoidea Hinde, 1889. *lower Cambrian (Atd.1–Toy. 3).*
Family Archaeopharetridae R. Bedford & W. R. Bedford, 1936. *lower Cambrian (Atd.1–Bot.3).*
Family Archaeocyathidae Hinde, 1889. *lower Cambrian (?Atd.4, Bot.2–Toy. 3).*
Family Archaeosyconidae Zhuravleva, 1954. *lower Cambrian (Bot.1–Bot.3).*
Superfamily Metacyathoidea R. Bedford & W. R. Bedford, 1934. *lower Cambrian (Tom. 2–Bot.3).*
Family Copleicyathidae R. Bedford & J. Bedford, 1937. *lower Cambrian (Tom. 2–Bot.3).*
Family Jugalicyathidae Gravestock, 1984. *lower Cambrian (Atd.4–Bot.2).*
Family Metacyathidae R. Bedford & W. R. Bedford, 1934. *lower Cambrian (Atd.4–Bot.3).*
Superfamily Naimarkcyathoidea Wrona & Zhuravlev, 1996. *lower Cambrian (Bot.3).*
Family Naimarkcyathidae Wrona & Zhuravlev, 1996. *lower Cambrian (Bot.3).*
Superfamily Warriootacyathoidea Debrenne & Zhuravlev, 1992b. *lower Cambrian (Atd. 3–Atd.4).*
Family Warriootacyathidae Debrenne & Zhuravlev, 1992b. *lower Cambrian (Atd.3–Atd.4).*
Superfamily Beltanacyathoidea Debrenne, 1974a. *lower Cambrian (Atd. 3–Bot.3).*
Family Maiandrocyathidae Debrenne, 1974a. *lower Cambrian (Bot.3).*
Family Beltanacyathidae Debrenne, 1974a. *lower Cambrian (Atd. 3–Atd. 4).*
Superfamily Tabellaecyathoidea Fonin, 1963. *lower Cambrian (Bot.2–Bot.3).*
Family Tabellaecyathidae Fonin, 1963. *lower Cambrian (Bot.2-Bot.3).*
Suborder Dictyofavina Debrenne, 1991. *lower Cambrian (Atd.1–Bot.2).*
Superfamily Usloncyathoidea Fonin in Vologdin & Fonin, 1966. *lower Cambrian (Atd.1–Bot.2).*
Family Usloncyathidae Fonin in Vologdin & Fonin, 1966. *lower Cambrian (Atd.1–Bot.2).*
Superfamily Keriocyathoidea Debrenne & Gangloff in Debrenne & Zhuravelev, 1992a. *lower Cambrian (Bot.1–Bot.2).*
Family Keriocyathidae Debrenne & Gangloff in Debrenne & Zhuravelev, 1992a. *lower Cambrian (Bot.1–Bot.2).*
Superfamily Gatagacyathoidea Debrenne & Zhuravlev, 1992a. *lower Cambrian (Bot.2).*
Family Gatagacyathidae Debrenne & Zhuravlev, 1992a. *lower Cambrian (Bot.2).*
Suborder Syringocnemina Okulitch, 1935b. *lower Cambrian (Atd.4–Bot.3).*
Superfamily Auliscocyathoidea Debrenne & Zhuravlev, 1992b. *lower Cambrian (Atd.4–Bot.3).*
Family Auliscocyathidae Debrenne & Zhuravlev, 1992b. *lower Cambrian (Atd.4–Bot.3).*
Superfamily Syringocnemoidea Taylor, 1910. *lower Cambrian (Bot.1-Bot.3).*
Family Tuvacnemidae Debrenne & Zhuravlev 1990. *lower Cambrian (Bot.1–Bot.3).*
Family Syringocnemidae Taylor, 1910. *lower Cambrian (Bot.1–Bot.3).*
Superfamily Kruseicnemoidea Debrenne & Zhuravlev, 1990. *lower Cambrian (Bot.3).*
Family Kruseicnemoidae Debrenne & Zhuravlev, 1990. *lower Cambrian (Bot.3).*
Superfamily Fragilicyathoidea Belyaeva in Belyaeva & others, 1975. *lower Cambrian (Bot.1).*
Family Fragilicyathidae Belyaeva in Belyaeva & others, 1975. *lower Cambrian (Bot.1).*
Order Kazachstanicyathida Konyushkov, 1967. *lower Cambrian (Bot.1–Bot.3).*
Suborder Kazachstanicyathina Konyushkov, 1967. *lower Cambrian (Bot.1–Bot.3).*
Family Korovinellidae Khalfina, 1960a. *lower Cambrian (Bot.1–Bot.3).*
Suborder Altaicyathina Debrenne, 1991. *lower Cambrian (Bot.1–Bot.2).*
Family Altaicyathidae Debrenne & Zhuravlev 1992b. *lower Cambrian (Bot.1- Bot.2)*
Archaeocyatha *Nomina Dubia*
?Class Radiocyatha Debrenne, H. Termier & G. Termier, 1970. *lower Cambrian (Tom. 3–Toy. 2).*
Family Hetairacyathidae R. Bedford & J Bedford, 1937. *lower Cambrian (Tom. 3–Toy. 2).*
Family Uranosphaeridae R. Bedford & J. Bedford, 1936. *lower Cambrian (Bot.1–Bot.3).*
Class Uncertain (probably not allied to Archaeocyatha or Radiocyatha)
Order Acanthinocyathida R. Bedford & W. R. Bedford 1936 *lower Cambrian (Atd.1–Bot.3).*
Family Acanthinocyathidae R. Bedford & W. R. Bedford, 1936. *lower Cambrian (Atd.1–Bot.3).*
Class Cribricyatha Vologdin, 1961 *lower Cambrian (Tom. 2–Bot.3).*
Order Vologdinophyllida Radugin, 1964. *lower Cambrian (Tom.2- Bot.1).*
Superfamily Vologdinophylloidea Radugin, 1964. *lower Cambrian (Tom. 2–Bot.1).*
Family Vologdinophyllidae Ragugin, 1964. *lower Cambrian (Atd.1).*
Family Leibaellidae Jankauskas, 1965. *lower Cambrian (Tom. 2–Bot.1).*
Superfamily Akademiophylloidea Radguin, 1964. *lower Cambrian (Atd.1–Bot.1).*
Family Akademiophyllidae Radugin, 1964. *lower Cambrian (Atd.1–Bot.1).*
Family Striatocyathidae Vologdin & Jankauskas, 1968. *lower Cambrian (Atd.1–Bot.1).*
Order Cribricyathida Vologdin, 1961. *lower Cambrian (Atd.1–Bot.3).*
Superfamily Conoidocyathoidea Vologdin, 1964a. *lower Cambrian (Atd.1–Bot.3).*
Family Concoidocyathidae Vologdin, 1964a. *lower Cambrian (Atd.1–Bot.3).*
Superfamily Pyxidocyathoidea Vologdin, 1964a. *lower Cambrian (Atd.1–Bot.3).*
Family Pyxidocyathidae Vologdin, 1964a. *lower Cambrian (Atd.1–Bot.3).*
Phylum Uncertain (Cribricyath-like Taxa). *lower Cambrian (Atd.1–Bot.3).*
Family Boyarinovicyathidae Zhuravleva in Zhuravleva & others, 1997b. *lower Cambrian (Bot.3).*
Family Uncertain. *lower Cambrian (Atd.1).*