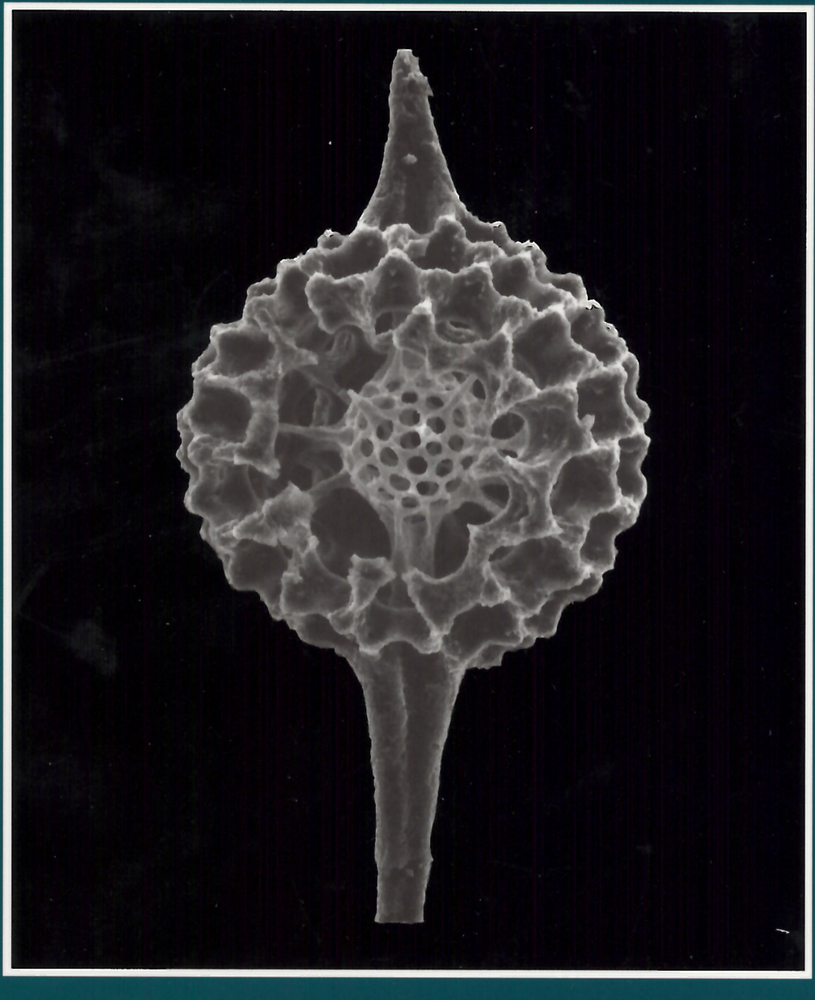
GEOLOGICAL SURVEY OF CANADA
BULLETIN 496

BIOCHRONOLOGY AND PALEONTOLOGY OF LOWER JURASSIC (HETTANGIAN AND SINEMURIAN) RADIOLARIANS, QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA

E.S. Carter, P.A. Whalen, and J. Guex



1998

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BIOCHRONOLOGY AND PALEONTOLOGY OF LOWER JURASSIC (HETTANGIAN AND SINEMURIAN) RADIOLARIANS, QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA

Elizabeth S. Carter, Patricia A. Whalen, and Jean Guex

1998

Catalogue No. M42-496/1998E
ISBN 0-660-17524-X

Available in Canada from
Geological Survey of Canada offices:

601 Booth Street
Ottawa, Ontario K1A 0E8

3303-33rd Street N.W.
Calgary, Alberta T2L 2A7

101-605 Robson Street
Vancouver, B.C. V6B 5J3

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Price subject to change without notice

Cover illustration

Pantanellium tanuense Pessagno and Blome. This distinctive and abundant radiolarian species signals the base of the Hettangian (Lower Jurassic) in Queen Charlotte Islands, British Columbia. GSC 99430 from 87-CNA-KUD-2 (Kunga Island).

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Original manuscript submitted: 1995-11
Final version approved for publication: 1996-02

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BIOCHRONOLOGY AND PALEONTOLOGY OF LOWER JURASSIC (HETTANGIAN AND SINEMURIAN) RADIOLARIANS, QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA

Abstract

Rich, well preserved assemblages of Hettangian and Sinemurian Radiolaria have been recovered from limestone concretions in the Sandilands Formation, Queen Charlotte Islands. Collections from stratigraphic sections at Kennecott Point (northwest Graham Island) and Kunga Island provide the main framework for this study while others from lesser exposed outcrops supplement data for certain intervals. Ammonites collected in close association with most radiolarian samples provide excellent biostratigraphic control.

A new radioarian zonation, defined by Unitary Associations (UA; Guex, 1977), is proposed for the Hettangian and Sinemurian. A database recording the appearance of 119 species in 95 superposed horizons or samples of 15 sections was used to establish 25 successive Unitary Associations. Unitary Associations were grouped into seven biochronozones: five Unitary Associations Zones (UAZ) and two Interval Zones (IZ), with each zone defined by its coexisting species pairs and by the totality of characteristic species.

The sequence of co-occurring ammonites indicates that the Canoptum merum *Zone (IZ) is earliest Hettangian; the* Protokatroma aquila *Zone (IZ) is late early Hettangian; the* Pantanellium browni *Zone (UAZ) is mid- to late Hettangian; the* Crucella hettangica *Zone (UAZ) is latest Hettangian to earliest Sinemurian; the* Parahsuum simplum *Zone (UAZ) is early Sinemurian; the* Canutus rockfishensis-Wrangellium thurstonense *Zone (UAZ) is early late Sinemurian; and the* Jacus? sandspitensis *Zone (UAZ) is late Sinemurian.*

Hettangian and Sinemurian Radiolaria are Tethyan in affinity and compare well with assemblages from Bavaria, the Mediterranean area, Japan, and New Zealand.

*One radiolarian subfamily (Charlotteinae), fourteen genera (*Amuria, Beatricea, Charlottea, Danubea, Empirea, Foremania, Protokatroma, Solidea, Sophia, Teesium, Thurstonia, Tozerium, Trexus, *and* Udalia*), and sixty-eight species are described as new.*

Résumé

Plusieurs riches assemblages de radiolaires bien préservés de l'Hettangien et du Sinémurien ont été extraits de concrétions calcaires contenues dans la Formation de Sandilands, dans les îles de la Reine-Charlotte. Des récoltes effectuées dans les coupes stratigraphiques de la pointe Kennecott (nord-ouest de l'île Graham) et de l'île Kunga permettent de définir le cadre principal de la présente étude. D'autres récoltes effectuées dans des affleurements moins bien exposés ont fourni des données complémentaires pour certains intervalles stratigraphiques. Des ammonites intimement associées aux échantillons de radiolaires assurent un excellent contrôle biochronologique à la présente étude.

Une nouvelle zonation basée sur les associations unitaires (AU; Guex, 1977) est proposée pour l'Hettangien et le Sinémurien. Une base de données recensant la présence ou l'absence de 119 espèces de radiolaires dans une succession verticale de 95 horizons, ou échantillons, répartis dans 15 coupes stratigraphiques a permis de construire une séquence de 25 associations unitaires. Ces associations unitaires ont été regroupées en sept biochronozones. Cinq d'entre elles sont des zones d'associations unitaires (ZAU) au sens strict et les trois autres sont des zones d'intervalle (ZI), chacune de ces zones étant définie par des paires d'espèces en relation de coexistence et par l'ensemble des espèces caractéristiques.

La séquence des ammonites associées aux faunes de radiolaires nous permettent d'établir que la Zone à Canoptum merum (ZI) est de l'Hettangien basal; la Zone à Protokatroma aquila(ZI) est assignable au sommet de l'Hettangien inférieur; la Zone à Pantanellium browni (ZAU) est de l'Hettangien moyen à supérieur; la Zone à Crucella hettangica (ZAU) s'étend de l'Hettangien sommital au Sinémurien basal; la Zone à Parashuum simplum (ZAU) est du Sinémurien inférieur; la Zone à Canutus rockfishensis-Wrangellium thurstonense (ZAU) correspond à la base du Sinémurien supérieur; et la Zone à Jacus (?) sandspitensis (ZAU) est assignable au Sinémurien supérieur.

Les radiolaires de l'Hettangien et du Sinémurien ont des affinités téthysiennes et ils sont comparables à ceux que l'on connaît en Bavière, dans la région méditerranéenne, au Japon et en Nouvelle-Zélande.

Une nouvelle sous-famille (Charlotteinae), quatorze nouveaux genres (Amuria, Beatricea, Charlottea, Danubea, Empirea, Foremania, Protokatroma, Solidea, Sophia, Teesium, Thurstonia, Tozerium, Trexus et Udalia) et soixante-huit nouvelles espèces de radiolaires sont décrits ici.

SUMMARY

Lower Jurassic radiolarians (Hettangian and Sinemurian) are present in continuous sequences of the Sandilands Formation, Queen Charlotte Islands. The formation is Rhaetian to earliest Pliensbachian in age. Limestone samples collected from stratigraphic sections at Kennecott Point (Graham Island) and Kunga Island have yielded rich assemblages of excellently preserved radiolarians; collections from lesser exposed outcrops in Skidegate Inlet and Tasu Sound supplement the data for certain intervals. The sections at Kennecott Point and Kunga Island conformably overlie Rhaetian beds of the Sandilands Formation whose radiolarian faunas have been reported previously (Carter, 1993).

Radiolarian assemblages are dated by using closely associated suites of ammonites which provide excellent biostratigraphic control. The sequence of ammonites indicates that the Hettangian and Sinemurian stages are likely complete in Queen Charlotte Islands. Ammonites are referred to North American ammonite assemblages for the Hettangian (Tipper and Guex, 1994) and Sinemurian (Pálfy et al., 1994).

This report documents the gradual rebuilding of the Hettangian and Sinemurian fauna following the near complete extinction of Radiolaria at the end of the Triassic (Carter 1994b; Tipper et al., 1994). Few genera survive the boundary, and even fewer species. Earliest Hettangian faunas are dominated by spumellarians and diversity is very low, but increases markedly by the end of the stage as new genera and species appear. The fauna becomes more diverse in the Sinemurian and nassellarians (especially multicyrtids) become increasingly dominant. Over one hundred and fifty species have been examined for this study and many demonstrate restricted biostratigraphic ranges. One new radiolarian subfamily

SOMMAIRE

Des radiolaires du Jurassique inférieur (Hettangien et Sinémurien) sont présents dans les séquences continues de la Formation de Sandilands, dans les îles de la Reine-Charlotte. Cette formation couvre un intervalle allant du Rhétien au Pliensbachien basal. Des échantillons de calcaire récoltés dans les coupes de la pointe Kennecott (île Graham) et de l'île Kunga ont livré de riches assemblages de radiolaires extrêmement bien préservés. Des récoltes effectuées dans des affleurements moins bien exposés de la baie Skidegate et de la baie Tasu ont fourni des informations complémentaires pour certains intervalles stratigraphiques. Les coupes de la pointe Kennecott et de l'île Kunga reposent en concordance sur les couches rhétiennes de la Formation de Sandilands dont les faunes de radiolaires ont été décrites récemment (Carter, 1993).

Les assemblages de radiolaires sont datés grâce aux séquences d'ammonites qui leur sont associées et qui assurent un excellent contrôle biochronologique. Ces faunes d'ammonites indiquent que les étages Hettangien et Sinémurien sont approximativement complets dans les îles de la Reine-Charlotte. Les ammonites sont rattachées aux assemblages nord-américains d'ammonites de l'Hettangien (Tipper et Guex, 1994) et du Sinémurien (Pálfy et al., 1994).

Le présent rapport documente la reconstitution graduelle des faunes de radiolaires de l'Hettangien et du Sinémurien à la suite de la quasi-extinction du Trias terminal (Carter 1994b; Tipper et al., 1994). Peu de genres, et encore moins d'espèces, ont survécu au passage de cette limite. Les faunes de l'Hettangien basal sont dominées par des spumellaires et montrent une très faible diversité mais celle-ci augmente de façon importante au sommet de cet étage avec l'apparition de nouveaux genres et d'espèces. La faune devient plus diversifiée dans le Sinémurien et les nassellaires (en particulier les multicyrtides) deviennent progressivement les formes dominantes. Plus de cent cinquante espèces ont été examinées dans le cadre de la présente étude et plusieurs d'entre elles montrent des extensions stratigraphiques restreintes. Une nouvelle

(Charlotteinae), fourteen genera, and sixty-eight species are described in Part II of this report and many other species are recorded informally.

Detailed and well dated, local zonations are essential to the development of a global biostratigraphy. New radiolarian zonation, defined by Unitary Associations (UA; Guex, 1977), is proposed for Hettangian and Sinemurian strata of the Sandilands Formation, Queen Charlotte Islands. One hundred and nineteen species from ninety-five stratigraphic horizons compose the Unitary Associations database for this study. Zonation consists of 25 vertically ordered UA divided into seven zones: five Unitary Associations zones (UAZ) and two Interval zones (IZ). These zones are described for local use in the Queen Charlotte Islands but it is probable that further testing in other areas of the world will prove them to be of more regional value. The following is a synopsis of the proposed radiolarian zones and their age based on the sequence of co-occurring ammonites.

Canoptum merum Zone (IZ). Zone defined by the interval separating the first appearance of *Canoptum merum* and the first appearance of *Protokatroma aquila*. This zone is earliest Hettangian, approximately equivalent to the *Psiloceras* Assemblage of Tipper and Guex (1994).

Protokatroma aquila Zone (IZ). Zone defined by the interval separating the first appearance of *Protokatroma aquila* and the first appearance of *Pantanellium browni*. This zone is late early Hettangian, approximately equivalent to the *Euphyllites* Assemblage of Tipper and Guex (1994).

Pantanellium browni Zone (UAZ). Zone defined by the coexistence of *Pantanellium browni* and Spumellarian indet A. This zone is mid- to late Hettangian, approximately equivalent to the *Franziceras* Assemblage of Tipper and Guex (1994).

Crucella hettangica Zone (UAZ). Zone defined by the coexistence of *Saitoum triumphense, Ectonocorys*? sp., *Laxtorum hemingense*, *Trexus dodgensis, Nitrader montegufonensis, Beatricea christovalensis, Crucella hettangica* and *Pantanellium tanuense, Paronaella ravensis*, and *Relanus reefensis*. This zone is latest Hettangian to earliest Sinemurian, approximately equivalent to the Canadensis Zone.

Parahsuum simplum Zone (UAZ). Zone defined by the coexistence of *Parahsuum simplum, Archaeocenosphaera laseekensis, Bipedis elizabethae,*

sous-famille (Charlotteinae), quatorze nouveaux genres et soixante-huit nouvelles espèces sont décrits dans la deuxième partie de ce rapport et plusieurs autres espèces sont décrites de façon informelle.

Des zonations locales détaillées et bien étalonnées dans le temps sont essentielles à l'élaboration d'une biostratigraphie à l'échelle globale. Une nouvelle zonation des radiolaires basée sur les associations unitaires (AU; Guex 1977) est proposée ici pour l'Hettangien et le Sinémurien de la Formation de Sandilands, dans les îles de la Reine-Charlotte. Cent dix-neuf espèces provenant de quatre-vingt-quinze horizons stratigraphiques forment la base de données de à partir de laquelle ont été établies les associations unitaires présentées ici. La zonation définie dans la présente étude est constituée d'une succession verticale de 25 associations unitaires réparties en sept zones, dont cinq sont des zones d'associations unitaires (ZAU) et les deux autres, des zones d'intervalle (ZI). Ces zones ont été définies pour servir à un usage local dans les îles de la Reine-Charlotte, mais il est probable que des travaux ultérieurs effectués dans d'autres régions du monde montreront que ces zones ont une valeur plus régionale. Ci-dessous, apparaît un synopsis des zones de radiolaires définies dans la présente étude auxquelles ont été attribués des âges relatifs basés sur les séquences d'ammonites trouvées dans les mêmes couches.

La Zone à *Canoptum merum* (ZI) est définie par l'intervalle qui sépare la première apparition de *Canoptum merum* de la première apparition de *Protokatroma aquila*. Cette zone, de l'Hettangien basal, est équivalente à l'Assemblage à *Psiloceras* de Tipper et Guex (1994).

La Zone à *Protokatroma aquila* (ZI) est définie par l'intervalle qui sépare la première apparition de *Protokatroma aquila* de celle de *Pantanellium browni*. Cette zone se situe au sommet de l'Hettangien inférieur et correspond approximativement à l'Assemblage à *Euphyllites* de Tipper et Guex (1994).

La Zone à *Pantanellium browni* (ZAU) est définie par la coexistence de *Pantanellium browni* et du Spumellaire indét. A. Cette zone est de l'Hettangien moyen à supérieur et est approximativement équivalente à l'Assemblage à *Franziceras* de Tipper et Guex (1994).

La Zone à *Crucella hettangica* (ZAU) est définie par la coexistence de *Saitoum triumphense*, de *Ectonocorys*? sp., de *Laxtorum hemingense*, de *Trexus dodgensis*, de *Nitrader montegufonensis*, de *Beatricea christovalensis*, de *Crucella hettangica*, de *Pantanellium tanuense*, de *Paronaella ravensis* et de *Relanus reefensis*. Elle s'étend de l'Hettangien sommital au Sinémurien basal et correspond approximativement à la Zone à Canadensis.

La Zone à *Parahsuum simplum* (ZAU) est définie par la coexistence de *Parahsuum simplum*, de *Archaeocenosphaera laseekensis*, de *Bipedis elizabethae*, de *Tozerium nascens*, de

Tozerium nascens, Thurstonia timberensis, and *Bipedis hiberniaensis*. This zone is early Sinemurian, approximately equivalent to the *Arnouldi* Assemblage of Pálfy et al. (1994).

Canutus rockfishensis-Wrangellium thurstonense Zone (UAZ). Zone defined by the coexistence of *Canutus rockfishensis, Wrangellium thurstonense,* and *Sophia palfyi*. This zone is early late Sinemurian, approximately equivalent to the *Varians* Assemblage of Pálfy et al. (1994).

Jacus? *sandspitensis* Zone (UAZ). Zone defined by the occurrence of the index species and by *Paronaella* cf. *corpulenta* De Wever. This zone is late Sinemurian, approximately equivalent to the *Harbledownense* Assemblage of Pálfy et al. (1994).

Hettangian and Sinemurian Radiolaria are Tethyan in affinity and compare well with assemblages from Bavaria, the Mediterranean area, Japan, and New Zealand. Correlation of new radiolarian zones with zonations in Japan and eastern Russia is quite good for the Sinemurian (especially the upper part), but very little comparison exists for the Hettangian. This is because well dated Hettangian radiolarians are rare in other areas of the world and very few taxa have been described or figured.

This report presents substantial new information on the biostratigraphy and taxonomy of Hettangian and Sinemurian radiolarians. It provides a important tool for scientists working on the Lower Jurassic of the Pacific Rim, especially those whose interests span the Triassic-Jurassic boundary.

Thurstonia timberensis et de *Bipedis hiberniaensis*. Elle se situe au Sinémurien inférieur et est approximativement équivalente à l'Assemblage à *Arnouldi* de Pálfy et al. (1994).

La Zone à *Canutus rockfishensis-Wrangellium thurstonense* (ZAU) est définie par la coexistence de *Canutus rockfishensis*, de *Wrangellium thurstonense* et de *Sophia palfyi*. Elle remonte au Sinémurien supérieur et est approximativement équivalente à l'Assemblage à Varians de Pálfy et al. (1994).

La Zone à *Jacus*? *sandspitensis* (ZAU) est définie par la présence de l'espèce index et de *Paronaella* cf. *copulenta* De Wever. Cette zone est du Sinémurien sommital et est approximativement équivalente à l'Assemblage à *Harbledownense* de Pálfy et al. (1994).

Les radiolaires hettangiens et sinémuriens ont des affinités téthysiennes et ils sont comparables aux assemblages décrits en Bavière, dans la région méditerranéenne, au Japon et en Nouvelle-Zélande. La corrélation des zones de radiolaires définies ici avec celles établies au Japon et dans l'est de la Russie est assez bonne pour le Sinémurien (plus particulièrement dans sa partie supérieure) mais la corrélation avec l'Hettangien de ces régions est très délicate. Ceci est dû au fait que les radiolaires bien datés de l'Hettangien sont rares dans les autres régions du monde où très peu de taxons ont été décrits ou figurés.

Ce rapport présente des informations nouvelles et substantielles sur la biostratigraphie et la taxonomie des radiolaires de l'Hettangien et du Sinémurien. Il apporte un outil important aux scientifiques qui travaillent sur le Jurassique inférieur de la province pacifique, et plus particulièrement à ceux qui s'intéressent à l'intervalle qui chevauche la limite Trias-Jurassique.

PART I. LITHOSTRATIGRAPHY AND BIOSTRATIGRAPHY

(E.S. Carter, P.A. Whalen, and J. Guex)

INTRODUCTION

The rich fossil beds of the Queen Charlotte Islands have been known to paleontologists since the islands were first investigated by G.M. Dawson of the Geological Survey of Canada in the late nineteenth century. For many years only the macrofauna was studied (Whiteaves, 1884, 1890; McLearn, 1932, 1949; Hall and Westermann, 1980; Smith et al., 1988; Tipper and Guex, 1994; Pálfy et al., 1994). The biostratigraphic importance of this archipelago has increased with the finding of abundant well preserved Triassic, Jurassic, and Cretaceous Radiolaria (Pessagno and Blome, 1980; Pessagno and Whalen, 1982; Blome, 1984; Carter et al., 1988, 1989; Carter, 1991, 1993, 1994b; Carter and Jakobs, 1991, Tipper et al., 1991; Haggart and Carter, 1993). The excellent preservation of these faunas, whose age can be precisely determined from closely associated ammonites and/or conodonts and foraminifers, makes them especially suitable for constructing integrated biochronological zonations and detailed taxonomic studies.

Hettangian and Sinemurian radiolarians were first studied in the late 1970s by E.A. Pessagno, P.A. Whalen, and C.D. Blome at the type section of the Kunga Formation (Sutherland Brown, 1968; = Sandilands Formation of Cameron and Tipper, 1985; Desrochers and Orchard, 1991) on the north shore of Kunga Island. Collections in the upper part of the sequence are associated with Sinemurian ammonites. Older collections from studies by Pessagno and others were presumed Hettangian based on their stratigraphic position and morphological differences in the Radiolaria. This work resulted in the taxonomic description of many new families, genera, and species (Pessagno and Blome, 1980; Pessagno and Whalen, 1982; Pessagno et al., 1986, Pessagno and Yang in Pessagno et al., 1989), and provided the basis for a preliminary radiolarian zonation for the Hettangian and Sinemurian of North America (Pessagno et al., 1987).

The Geological Survey of Canada (GSC) began radiolarian studies of the Sandilands Formation in the mid-1980s. Sinemurian faunas were collected in the Skidegate Inlet area by E.S. Carter in 1984-1985, and the following year Carter and M.J. Orchard (GSC) collected the Sandilands Formation on the north shore of Kunga Island (= type section of the Kunga Formation). In 1987, H.W. Tipper (GSC) and Carter began ammonite and radiolarian investigations of the Sandilands Formation at Kennecott Point on northwest Graham Island. Successive visits to this locality through 1990 refined the stratigraphy and augmented fossil collections. Over the same period of time, Carter collected Rhaetian (= upper upper Norian sensu Tozer, 1979) and Hettangian faunas on the southeast shore of Kunga Island (Carter, 1990, 1993; Carter and Galbrun, 1990) and made additional collections (mostly Hettangian) on the north shore of the island (Tipper et al., 1991). The results of all GSC biostratigraphic studies of the Upper Triassic-Lower Jurassic Kunga Group are contained on the paleontological database of Orchard et al. (1991).

The purpose of this study is: (1) to develop a detailed radiolarian zonation for the Hettangian and Sinemurian that refines the preliminary zonation of Pessagno et al. (1987); (2) to integrate new radiolarian zones with ammonite assemblages for the Hettangian (Tipper and Guex, 1994) and Sinemurian (Pálfy et al., 1994) of western North America; (3) to document the distribution and range of Queen Charlotte Islands' Radiolaria as completely as possible; and (4) to describe new taxa.

The Unitary Association (UA) method developed by J. Guex (1977, 1991) was used to integrate the large radiolarian database into a biochronological framework. This concept has been applied recently to Rhaetian radiolarians in the lower part of the Sandilands Formation, Queen Charlotte Islands (Carter, 1993), and is used here to develop a new zonation for the Hettangian and Sinemurian in the upper part of the formation.

Radiolarian information presented in "Part I. Lithostratigraphy and Biostratigraphy" is derived from Carter's work in Queen Charlotte Islands sponsored by the Geological Survey of Canada, and from P.A. Whalen's (1985) Ph.D. studies at the University of Texas at Dallas. J. Guex developed the new radiolarian zonation using the computer program BioGraph (Savary and Guex, 1991). Whalen and Carter compiled the systematic paleontology (Part II).

This paper uses Rhaetian as the uppermost stage of the Triassic. This follows the proposal of Dagys (1988) which was presented at the Symposium on Triassic Stratigraphy in Lausanne, Switzerland, October, 1991 and is now being considered by the International Subcommission of Triassic Stratigraphy. The Rhaetian stage sensu Dagys is approximately equivalent to the Amoenum and Crickmayi ammonoid zones of Tozer (1979) in North America. The upper Norian substage as used here is restricted to the Cordilleranus ammonoid zone of Tozer (1979).

Previous work

The first studies of Hettangian and Sinemurian radiolarians were conducted in the late 1970s by Emile A. Pessagno Jr. and his students on collections made from Sutherland Brown's black argillite member of the Kunga Formation (= Sandilands Formation) at the type section on the north shore of Kunga Island, Queen Charlotte Islands. This work resulted in the taxonomic description of several new radiolarian families and many new genera and species (Pessagno and Blome, 1980; Pessagno and Whalen, 1982; Pessagno et al., 1986), and provided the basis for a preliminary zonation for the Hettangian and Sinemurian of North America (Pessagno et al., 1987). At that time, knowledge of Sinemurian ammonites co-occurring with these faunas was minimal, and no ammonites indicating the Hettangian stage had been found on Kunga Island. Lacking precise dating, the Sinemurian stage was loosely divided into an upper Zone 03, and a lower Zone 04; radiolarians lower in the sequence were presumed Hettangian and assigned to Zone 05, the basal zone of the Jurassic. In subsequent investigations of the Family Xiphostylidae, Pessagno and Yang (in Pessagno et al., 1989) described the genus *Archaeocenosphaera* and the species *Archaeocenosphaera laseekensis* Pessagno and Yang. This species is from upper Hettangian strata on the north side of Kunga Island and is abundant in all Hettangian collections from Queen Charlotte Islands.

Following Carter's initial studies of radiolarians at Kennecott Point, Kunga Island, and Tasu Sound (Lomgon Bay and Wilson Bay) in 1986-1988, a brief account of Hettangian and Sinemurian faunas was included in a paper on the Lower Jurassic formations of Queen Charlotte Islands (Tipper et al., 1991). By this time Hettangian and Sinemurian ammonites were under study by H.W. Tipper (GSC) and J. Pálfy (then at the University of British Columbia), respectively, and more precise ages became available for the illustrated radiolarian taxa. More recently, evolutionary studies of Triassic-Jurassic boundary faunas have been explored (Carter, 1994a, b) and further taxonomic description of Queen Charlotte Islands Radiolaria has begun (Cordey and Carter, 1996).

Taxonomic studies of Liassic (Lower Jurassic) faunas in the Mediterranean area began with Pessagno and Poisson (1981) who described upper Pliensbachian taxa from Gümüslü, Turkey. The first major taxonomic work was conducted by Patrick De Wever (1981a, b, 1982) who described an exquisitely preserved fauna of new Hagiastridae, Pantanellidae, Parasaturnalidae, Patulibracchiidae, Spongodiscidae, Sponguridae, and Nassellaria also from the upper Pliensbachian (Domerian) of the Western Taurides at Gümüslü. Although the biostratigraphy of these forms was not examined, De Wever created a useful, well illustrated reference for future taxonomic comparison of the faunas. The genera *Ares, Bipedis, Cuniculiformis, Ectonocorys, Jacus, Saitoum, Thetis*, and even some of De Wever's species (e.g. *Cuniculiformis plinius, Paronaella* sp. cf. *P. corpulenta*) are found in Queen Charlotte Islands.

In the "Passé Jaspeuse" Formation, Budva Basin (External Dinarides) of coastal Montenegro, Gorican (1994) found *Pantanellium tanuense* Pessagno and Whalen and identified species of *Canoptum, Droltus, Praeorbiculiformella*, and *Pseudoeucyrtis* near the base of the sequence at Gornja Lastva and Bar. Based on our present findings, these taxa are typical of the Hettangian. Samples a little higher in the formation at Petrovac and Bar contain *Canoptum, Droltus, Gorgansium gongyloideum, Katroma, Parahsuum ovale, P. simplum, Paronaella*, and *Wrangellium* which in our view are likely Sinemurian. Gorican's highest samples at Gornja Lastva Petrovac, Canj, and Bar contain *Bagotum* and *Gigi*. Comparison with faunas of Queen Charlotte Islands suggests these samples are more likely Pliensbachian.

In northern Europe, Kozur and Mostler (1990) described new taxa from sample L1 in the lower part of the Kirchstein Limestone at Lenggries/Isar (Northern Calcareous Alps), Bavaria. The occurrence of *Schlotheimia angulata* (Schlotheim) at this level indicates a late Hettangian age. Many new Saturnaliacea were described along with species of *Canoptum, Crucella, Droltus, Gorgansium, Parahsuum, Relanus*, and a few other forms having affinities to the new subfamily Charlotteinae described herein.

In the Waipapa terrane, New Zealand, Aita (in Spörli and Aita, 1988) figured a mixed fauna of uppermost Triassic and Lower Jurassic Tethyan radiolarians from the red chert of Kawakawa Bay near Auckland. Lower Jurassic taxa include *Pantanellium* sp. cf. *P. haidaense* Pessagno and Blome, *Pseudocrucella* (= *Crucella hettangica* Kozur and Mostler herein), *Cuniculiformis plinius* De Wever, and several species of *Droltus* similar to forms present in Queen Charlotte Islands. Aita and Spörli (1992) indicate this fauna is probably upper Sinemurian to lower Pliensbachian. Further references to this fauna and to its use in solving complexities of terrane accretion in New Zealand, are found in Spörli et al. (1989).

Since the late 1970s, the Japanese have been extremely active in radiolarian biostratigraphy, and numerous radiolarian zonal schemes for the Lower Jurassic have been proposed (some are illustrated in Fig. 21). In the earliest of these, Yao et al. (1980a) established three successive radiolarian assemblages of Middle Triassic to Early Jurassic age from continuous sequences of chert in the Inuyama area, central Japan. The upper assemblage, the *Dictyomitrella* sp. C - *Archaeodictyomitra* sp. A Assemblage is Early Jurassic. In 1982, Yao described *Archaeodictyomitra* sp. A as *Parahsuum simplum*, and this species became the name bearer for the lowest zone of the Jurassic in subsequent zonation by Yao et al. (1982). This zone is now widely used by Japanese workers for various time intervals in the Lower Jurassic (see below) and the species *Parahsuum simplum* Yao is recognized around the world.

Kishida and Sugano (1982) established five assemblage zones for Triassic strata from the Chichibu Belt in the Kuchi and Oita Prefecture, Japan. The uppermost of these, the *Pantanellium* sp. B - *Gorgansium* sp. A Assemblage-zone, was originally believed to be Rhaetian in age. In their studies of the Ueno-mura area of the Chichibu Belt, Kishida and Hisada (1985, 1986) renamed this the *Bagotum psuedoerraticum* Assemblage, designated it the lowest Jurassic unit, and subdivided it into a lower *Katroma elliptica* subassemblage and upper *Wrangellium* s.s. subassemblage. Previously, Igo and Nishimura (1984) examined strata in the Kuzuu area of the Ashio Belt and established the *Parahsuum simplum* - *Gigi* sp. Assemblage for Lower Jurassic strata.

At about the same time, Nishizono et al. (1982), Sato and Nishizono (1983), and Nishizono and Murata (1983) established the "*Archaeodictyomitra*" sp. *A-Triassocampe* sp. A Zone for Lower Jurassic strata in the Kuma area of the Chichibu Belt, Kyushu. Subsequently, Sato et al. (1986) established the *Parahsuum* sp. A Zone for approximately equivalent strata in the same area. Yoshida (1986) examined a Late Triassic to Early Jurassic bedded chert sequence in Kagamigahara City, Gifu Prefecture, central Japan, and subdivided it into seven radiolarian zones, with the uppermost zone, the *Parahsuum* Zone, designated as Lower Jurassic. This zone is characterized by *Parahsuum simplum* Yao, *Parahsuum* sp. A, and the *Syringocapsa* group. Yoshida further notes that these species are very similar to species defining the *Parahsuum simplum* Zone of Yao (1982). In the Kanto region of the Chichibu Belt, Sashida and Igo (1986) and Sashida et al. (1986) established the *Parahsuum simplum* Assemblage for the lower part of the Lower Jurassic. Later, Sashida (1988) established the *Parahsuum simplum* Zone for coeval strata in the Itsukaichi area of the Chichibu Belt. This zone is characterized by the occurrence of species of *Bipedis, Canoptum, Jacus*, and *Katroma*.

In 1986, Matsuoka and Yao proposed a new radiolarian zonation for the Jurassic of Japan establishing three interval zones for the Lower Jurassic; the *Parahsuum* sp. C (=*Parahsuum* ovale Hori and Yao 1988) Zone, the *Archicapsa pachyderma* Zone, and the *Laxtorum* (?) *jurassicum* Zone. The *Parahsuum* sp. C Zone is defined by the first appearance of *Parahsuum simplum*, and the *Archicapsa pachyderma* Zone by the first appearance of *Archicapsa pachyderma*. They indicate that the *Parahsuum* sp. C Zone is roughly equivalent to the *Parahsuum simplum* Zone of Yao et al. (1982), and that species of *Parahsuum, Canoptum, Katroma*, and *Bipedis* are abundant in this interval. More recently, Hori (1990) divided the *Parahsuum simplum* Assemblage-zone into four subassemblages (I through IV): I – *Parahsuum* aff. *longiconicum*; II – *Katroma kurusuensis*; III – *Eucyrtidiellum* (?) sp. C group; and IV – *Trillus elkhornensis*.

In northeast China, Yang and Mizutani (1991) discussed the geology and biostratigraphy of the Nadanhada terrane comparing it to the Mino terrane of Japan. Yang presented a preliminary revision of the Parasaturnalidae and described new parasaturnalid taxa of latest Triassic and Early Jurassic age. The precise dating of these chert faunas is not well explained but the forms figured as upper Norian compare well with some Rhaetian taxa of Queen Charlotte Islands (Carter, 1993). Those assigned to the Hettangian are identical morphologically to some saturnalids discussed herein (see “Systematic Paleontology”).

In the Russian Far East (shores of the Okhotsk Sea, Amur and Khabarovsk regions, central Sikhote-Alin), Tikhomirova (1988) proposed four radiolarian assemblages for the Lower Jurassic. The oldest of these, R:1, is not discussed here owing to the indeterminate nature of the fauna. Assemblages R:2 (beds with *Katroma* (?) cf. *bicornis*) and R:3 (beds with *Bagotum modestum* and *Droltus hecatensis*) are likely uppermost Sinemurian to Pliensbachian in our estimation, and the uppermost assemblage, R:4 (beds with *Unuma typicus*), is probably late Early Jurassic to early Middle Jurassic as indicated by the author. Vishnevskaya (1988) also proposed a twelve-fold zonation for the Hettangian to Albian Tethyan and Pacific margin of Russia. The lowest of these assemblages, the *Parahsuum simplum* assemblage, represents the combined Hettangian and Sinemurian stages. Also in the Russian Far East, Oleinik (1993) proposed seven radiolarian assemblages for the Jurassic Pribrezhnaya structural-formation Zone, Primorye (South Sikhote-Alin). The lowest of these, the *Canoptum dixoni* Assemblage, is said to be late Sinemurian to early Pliensbachian.

Acknowledgments

E.S. Carter’s work is part of a joint biostratigraphic study of Upper Triassic and Lower Jurassic faunas of the Kunga Group conducted by the Geological Survey of Canada. H.W. Tipper, J. Guex, and J. Pálfy have been instrumental in defining the ammonite biostratigraphy for the Queen Charlotte Islands, and discussions with all three have been essential to the greater understanding of Lower Jurassic biostratigraphy. G.K. Jakobs is thanked for collecting Hettangian ammonites from hard, black rock on the north and southeast shores of Kunga Island. Without these ammonites to date our collections, the biochronology of Hettangian radiolarians would be poorly known. Fieldwork for E.S Carter was supported by the Queen Charlotte Islands Frontier Geoscience Program under the leadership of R.I. Thompson (and later J.W. Haggart). Research was supported under GSC contract 23254-1-0221/01-XSB. M.J. Johns (Pacific Geoscience Centre, Sidney, B.C.) and P. Krauss (GSC, Vancouver, B.C.) helped with photography of Carter’s specimens; Tonia Williams (GSC, Vancouver, B.C.) drafted most of the figures.

P.A. Whalen’s work has been supported by grants from the National Science Foundation (EAR 7812934) and the Geological Society of America Penrose Foundation, and by funding from the Atlantic Richfield Company, the Exxon Production Research Company, and the Mobil Oil Corporation. The following people provided valuable assistance during the course of this project and they are thanked by the authors: Emile A. Pessagno, Jr., P.A. Whalen’s advisor at the University of Texas at Dallas, for his continual guidance throughout her graduate studies; Walter Six (formerly at UTD) for his assistance with the scanning electron microscope; Charles Blome (USGS, Denver) for his valuable field assistance in the Queen Charlotte Islands; and Howard Tipper (GSC) for his identification and dating of ammonites from the Sandilands Formation.

J. Guex’s research is subsidized by Swiss NSF, Grant 21.27464.89.

We further thank Paulian Dumitrica, Emile Pessagno, and J.W. (Jim) Haggart (GSC) for their thorough review of the manuscript and many helpful suggestions.

THE SANDILANDS FORMATION

Lithostratigraphy

The Sandilands Formation (Cameron and Tipper, 1985; Desrocher and Orchard, 1991; = black limestone member of the Kunga Formation of Sutherland Brown, 1968) is widely distributed in Queen Charlotte Islands (Table 1). The type area was designated as Sandilands Island (Cameron and Tipper, 1985, p. 12) where the formation is dated by ammonites as Sinemurian. More complete reference sections for older (Rhaetian and Hettangian) parts of the formation are located at Kennecott Point and Kunga Island. Additional sequences of the Sandilands Formation are known from Burnaby Island (Sutherland Brown, 1968), southern Kunghit Island (southeast Luxana Bay), northern Huxley Island, eastern Louise Island south of Vertical Point,

Table 1. Table of Upper Triassic and Lower Jurassic formations in Queen Charlotte Islands.

Age		Stratigraphic units		Thickness (m)	Ammonoid zones / assmb.	Conodont zones	Radiolarian zones / subzones		
Lower Jurassic	Toarcian	Maude Group	Phantom Creek	26 ±	Yakounensis		1A2	1A	Assmb. 3-5
					Hillebrandti				
					Crassicosta				Assmb. 2
			Whiteaves	up to 70	Planulata		01B	01	
			Fannin	up to 113	Kanense				
	Pliensbachian				Carlottense		01A		Assmb. 1
					Kunae				
					Freboldi			02	
					Whiteavesi				
			Ghost Creek	up to 68.5	Imlayi				
	Sinemurian	Kunga Group	Sandilands	~500	Tetraspidoceras assemb.			03	This study
					Harbledownense assmb.				
					Varians assmb.				
					Arnouldi assmb.			04	
					Coroniceras assmb.				
	Hettangian				Canadensis			05	
					Doetzkirchneri assmb.				
					Franziceras assmb.				
					Euphyllites assmb.				
					Psiloceras assmb.				
Upper Triassic	Rhaetian				Crickmayi	Posthernsteini	G. Tozeri		
					Amoenum	Bidentata	P. Moniliformis		
	Norian		Peril	~350	Cordilleranus		B. Deweveri		
					Columbianus IV	Serrulata	P. Silberlingi		
					Columbianus III	Postera	Capnoodle zone	L. Paucum	
					Columbianus II	Elongata			
					Columbianus I	Spiculata			
					Rutherfordi	Multidentata		X. Striata	
					Magnus	Triangularis			
					Dawsoni	Quadrata		J. Novum	
					Kerri	Primitus			
	Carnian				Macrolobatus	Communisti			
					Welleri	Nodosus			
			Sadler	up to 200	Dilleri	Polygnathiformis			
		Karmutsen		4300 m ± basalt pillow lavas					

and at numerous localities around Skidegate Inlet, Cumshewa Inlet, and on central Graham Island (Desrochers and Orchard, 1991). Localities and sections utilized in this study are shown on Figure 1A and 1B. The formation consists predominantly of thinly bedded, dark grey siliceous siltstone; minor tuffaceous sandstone and shale; and rare limestone beds, lenses, and concretions. It conformably overlies the upper member (*Monotis* coquina) of the Peril Formation and underlies the massive shale beds of the Ghost Creek Formation (Cameron and Tipper, 1985; see Table 1). The formation is believed to contain Triassic-Jurassic boundary strata at both Kennecott Point and Kunga Island (Tipper and Carter, 1990; Tipper et al., 1994).

The Sandilands Formation is Late Triassic (upper Norian? Rhaetian) to Early Jurassic (latest Sinemurian to earliest Pliensbachian) based on ammonoid, conodont, and radiolarian faunas (Carter et al., 1989; Carter, 1990, 1993; Orchard, 1991; Tipper et al., 1991, 1994) (see Table 1). Preliminary information on Hettangian and Sinemurian ammonites has been published by Tipper and Guex (1994) and Pálfy et al. (1994), respectively, and more detailed studies by these authors are underway.

According to Cameron and Tipper (1985), the Sandilands Formation appears to have been deposited in a relatively deep back-arc basin remote from the source of fine volcanic detritus. Although the precise provenance is problematic, they suggest a volcanic terrane probably to the west or southwest of the basin.

Kennecott Point

The Sandilands Formation at Kennecott Point (northwest Graham Island) is exposed at low tide on a wide wave-swept bench. It begins directly above the resistant *Monotis* coquina of the Peril Formation where the stratigraphic contact marks the change from carbonate to clastic sedimentation. The sequence contains some small discontinuities, but most are easily traced and no obvious gaps have been noted.

Triassic ammonoids and conodonts, Jurassic ammonites, and a continuous succession of radiolarians throughout indicate the sequence probably spans the entire Rhaetian, Hettangian, and earliest Sinemurian, including the Triassic-Jurassic boundary. The formation is composed of thinly bedded siltstone with minor sandstone, limestone, and shale, and abundant limestone lenses and concretions (Carter, 1993). It is lighter in colour, sandier, less tuffaceous, and has not undergone the extensive siliceous alteration more characteristic of the Sandilands Formation at localities further south in Queen Charlotte Islands.

The Lower Jurassic part of the Sandilands Formation at Kennecott Point is illustrated in sections 9 (KPD) and 10 (KPB) (for location see maps, Fig. 1E). Section 9 (Fig. 2) begins in siltstone beds containing Rhaetian ammonoids, conodonts, and radiolarians (Carter, 1993). Above this fossiliferous interval, between 6-20 m, the beds become more sandy and tuffaceous, limestones are absent, and no macro- or microfaunas have been recovered. The transition from Triassic to Jurassic undoubtedly occurs somewhere within this unfossiliferous interval. Immediately above this level, three low-diversity radiolarian assemblages (samples 90-CNA-KPD-4, 90-CNA-KPD-5, and 90-TD-11A; see Appendix 1) contain earliest Jurassic faunas that totally lack Rhaetian affinities (Carter, 1994b). A slight lithological discordance (Fig. 3) is present above sample 90-TD-11A, and immediately above this, the lower Hettangian ammonite *Psiloceras* aff. *primocostatum* Hillebrandt was found together with radiolarian sample 88-CNA-KPD-4A. The upper part of the section is mostly shale, interbedded finely laminated siltstone and sandstone, and coarser sandstone. Across a fault and boulder field, this coarsening upward sequence is further apparent in the base of section 10 (Fig. 2). This section was measured and collected for radiolarians and ammonites over four field seasons (1987-1990) by E.S. Carter and H.W. Tipper respectively; the section illustrated here is a composite derived from this work. Section 10 is sandy in the lower part but higher up is composed mostly of laminated siltstone with minor shale and sandstone and abundant limestone lenses and concretions (Fig. 4).

Kunga Island

Extensive exposures of the Sandilands Formation fringe the north and southeast shores of Kunga Island. These rocks were originally described by Sutherland Brown (1968) as the upper black argillite member of the Kunga Formation with the type section for all three members of the formation located on the north shore of Kunga Island. Of all Sandilands localities examined by the Geological Survey of Canada since 1986, it is still likely that the most complete exposures of the formation are at Kunga Island.

On the north shore of the island the topmost *Monotis* coquina of the Peril Formation is overlain (above an undulating contact) by a short sequence of calcite-veined argillaceous beds. These beds probably belong to the Sandilands Formation, but no fossils have been recovered and age is uncertain. Further up section (beyond a covered interval), a lengthy exposure of disrupted and repeated Sandilands Formation strata contains ammonites of late Hettangian to late Sinemurian age (H.W. Tipper, pers. comm., 1994; Pálfy et al., 1994).

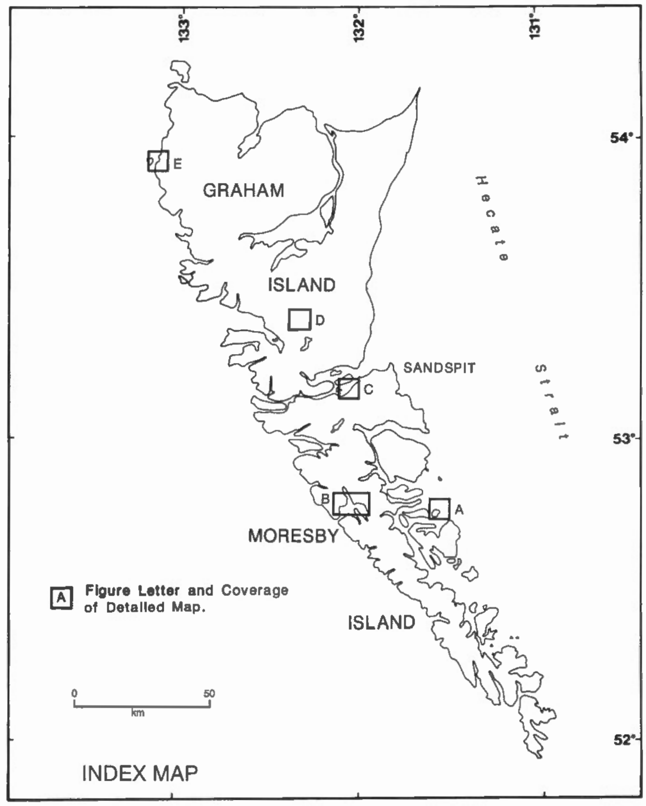
On the southeast shore of Kunga Island the upper member (*Monotis* coquina) of the Peril Formation is disconformably overlain by a complete sequence of Rhaetian strata (see Carter, 1993, Fig. 3 and 5). These strata are conformably overlain by beds containing lowest Hettangian radiolarians (Carter, 1993; Tipper et al., 1994), and based on new information lower and middle to upper Hettangian ammonites (H.W. Tipper, pers. comm., 1998) and radiolarians. Across a small bay and extending to the eastern tip of the island, the entire Sinemurian sequence is present (Pálfy, 1991); these rocks located on the southeast shore were not sampled for radiolarians.

Southeast shore

The lower to middle Hettangian part of the Sandilands Formation is best exposed on the southeast side of Kunga Island in sections 1 (SKUD) and 2 (SKUE) (Fig. 1A and 5). These rocks are located well above shoreline in steeply dipping to nearly vertical overturned beds consisting of hard, black, thinly bedded siltstone, occasional thick sandstone (up to 50 cm thickness), minor limestone and shale, and abundant limestone concretions and lenses (Fig. 6). In both sections, distinctive beds made up of very large laminated sandstone concretions, informally known as the "eyeglass beds" (Fig. 7), are illustrated as beds A and B. These beds allow precise correlation between section 1 and section 2. Section 1 comprises the upper part of SKUD and illustrates the transition from topmost Rhaetian to Hettangian (for a complete description of the lower (Rhaetian) part of the section see Carter, 1993). The lowest sample (89-CNA-SKUD-25) contains rare conodonts and a diverse radiolarian fauna belonging to the *Globolaxtorum tozeri* Zone (Carter, 1993). Sample 89-CNA-SKUD-339, 2-3 m above, has yielded a low diversity earliest Jurassic radiolarian fauna that totally lacks affinities to the Rhaetian. Section 2 (SKUE) lies parallel to section 1 northeast across a high knoll. The lower part contains latest Rhaetian conodonts and radiolarians, the upper part early Hettangian ammonites and radiolarians, but the sequence is faulted in the interval between Triassic and Jurassic.

North shore

A complete sequence of upper Hettangian and Sinemurian strata is exposed on the north side of Kunga Island. This is the original type section of the Kunga Formation of Sutherland Brown (1968) who reported a thickness of 497 m and first recognized radiolarians in these rocks. The



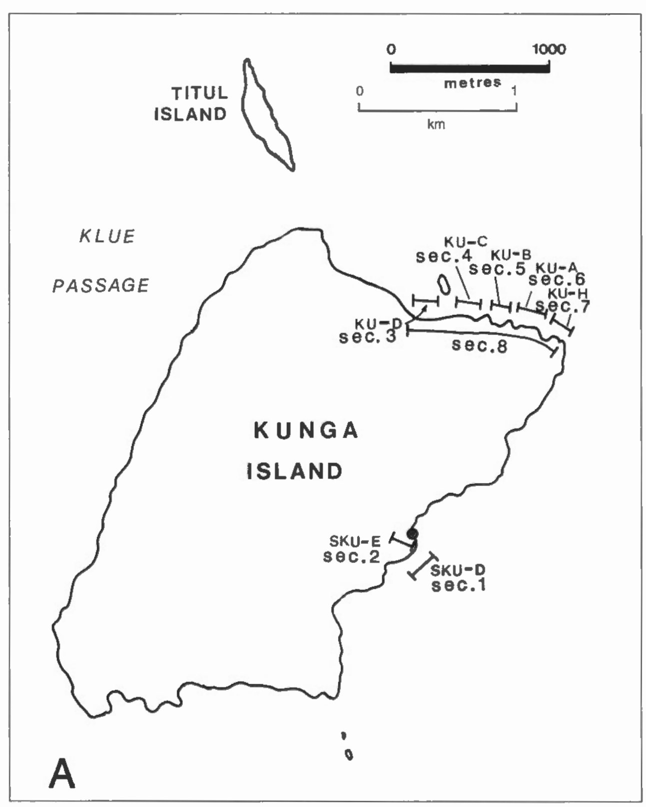
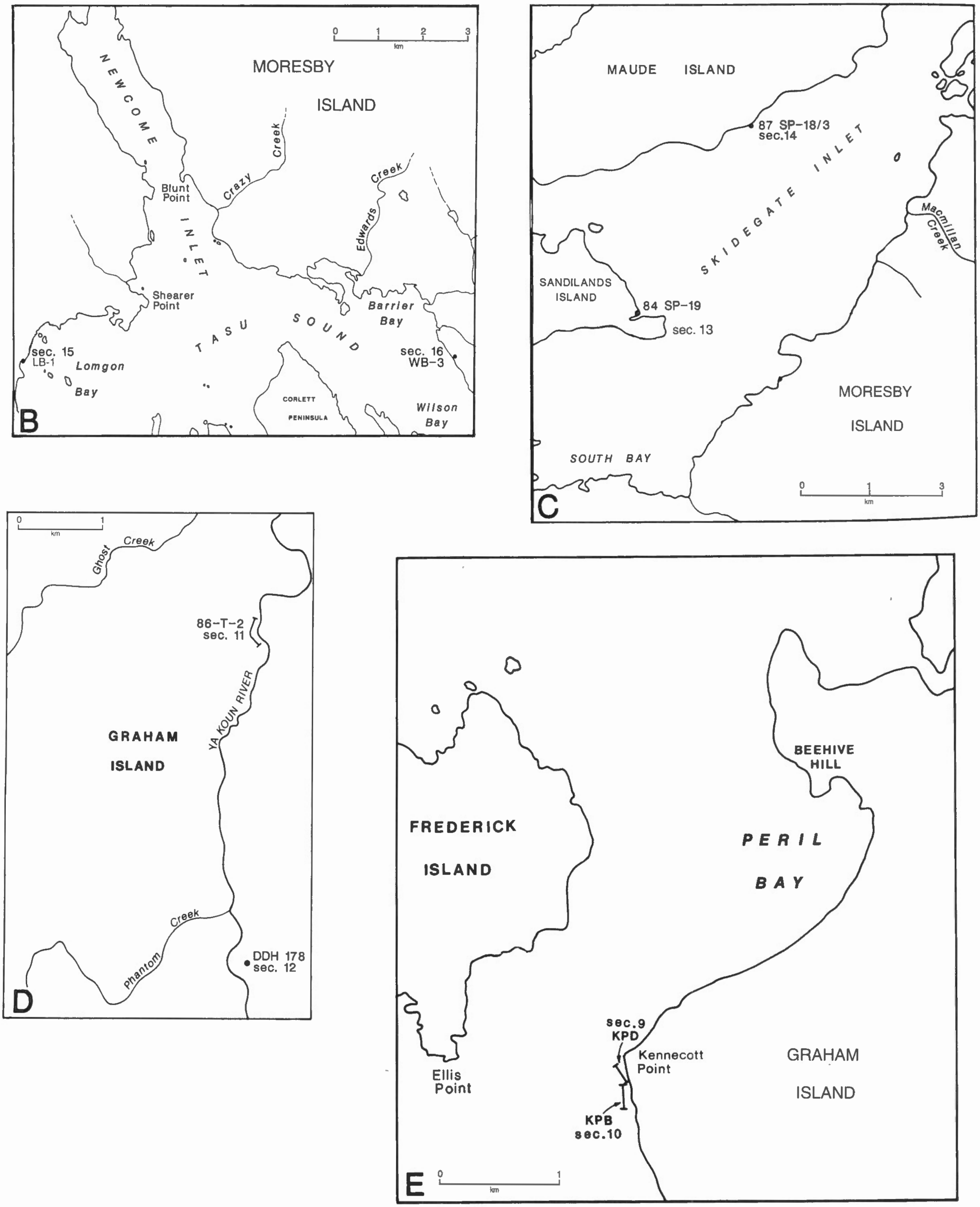


Figure 1.

Locality index map of Queen Charlotte Islands showing coverage of detailed maps A-E (maps adapted from Orchard et al., 1991); inset maps show position of radiolarian-bearing sections analyzed in this study. ***A)*** *Kunga Island;* ***B)*** *Lomgon Bay and Wilson Bay, Tasu Sound;* ***C)*** *Maude Island and Sandilands Island, Skidegate Inlet;* ***D)*** *Yakoun River, Graham Island;* ***E)*** *Kennecott Point, Graham Island.*


B
MORESBY
ISLAND
NEWCOME
INLET
Crazy Creek
Edwards Creek
Blunt Point
Shearer Point
TASU SOUND
Barrier Bay
sec. 15
LB-1
Lomgon Bay
sec. 16
WB-3
CORLETT PENINSULA
Wilson Bay
0 1 2 3
km
C
MAUDE ISLAND
87 SP-18/3
sec.14
SKIDEGATE INLET
Macmillan Creek
SANDILANDS ISLAND
84 SP-19
sec. 13
MORESBY
ISLAND
SOUTH BAY
0 1 3
km
D
0 1
km
Ghost Creek
86-T-2
sec. 11
YA KOUN RIVER
GRAHAM
ISLAND
Phantom Creek
DDH 178
sec. 12
E
FREDERICK
ISLAND
BEEHIVE
HILL
PERIL
BAY
sec.9
KPD
Kennecott
Point
Ellis
Point
GRAHAM
ISLAND
KPB
sec.10
0 1
km

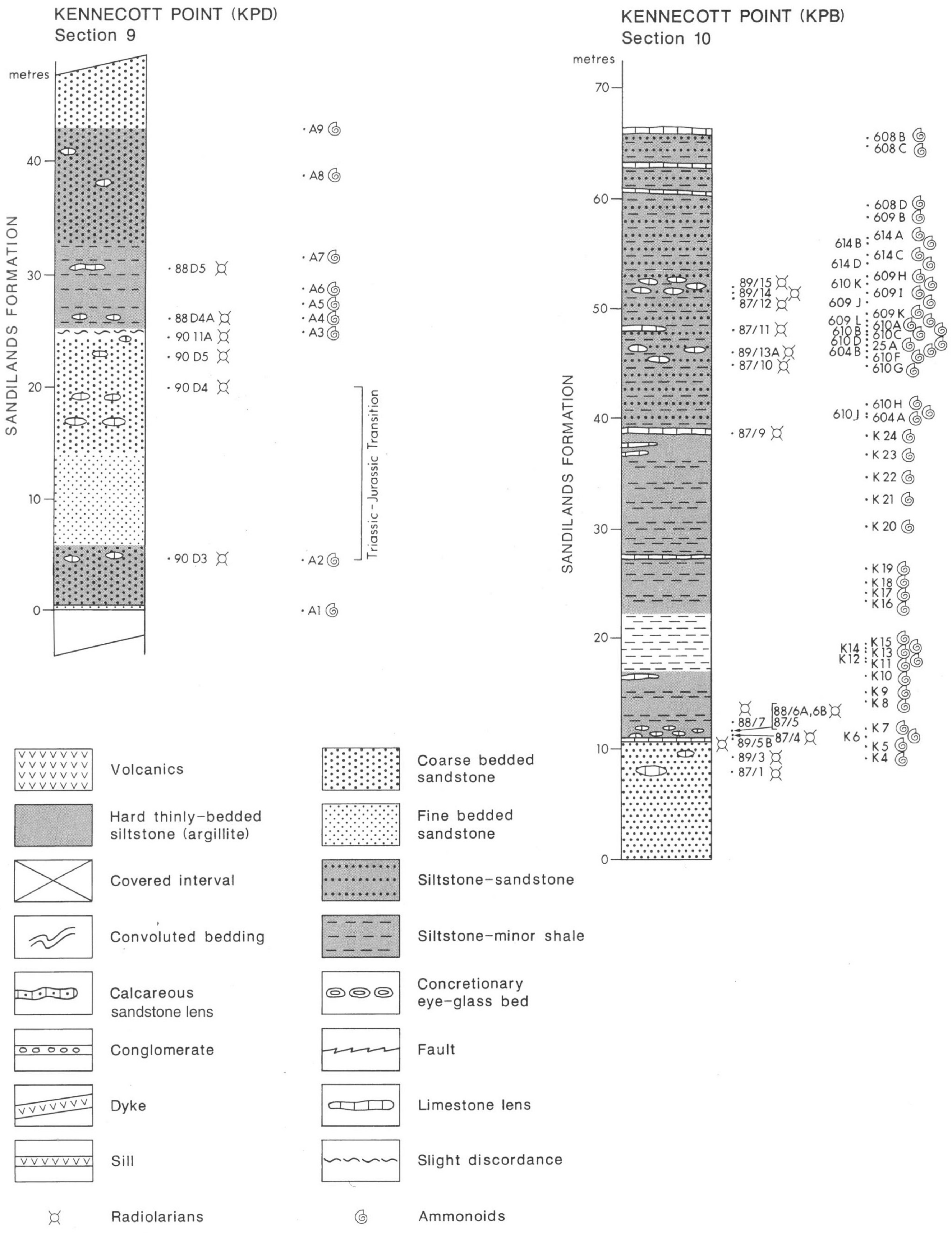

KENNECOTT POINT (KPD)
Section 9
metres
40
30
20
10
0
SANDILANDS FORMATION
· 88D5
· 88D4A
· 90 11A
· 90 D5
· 90 D4
· 90 D3
· A9
· A8
· A7
· A6
· A5
· A4
· A3
· A2
· A1
Triassic - Jurassic Transition
KENNECOTT POINT (KPB)
Section 10
metres
70
60
50
40
30
20
10
0
SANDILANDS FORMATION
· 89/15
· 89/14
· 87/12
· 87/11
· 89/13A
· 87/10
· 87/9
88/6A,6B
· 88/7
87/5
87/4
89/5B
· 89/3
· 87/1
· 608 B
· 608 C
· 608 D
· 609 B
614 B
· 614 A
614 D
· 614 C
610 K
· 609 H
609 J
· 609 I
609 L
610 B
610 D
604 B
· 609 K
610A
610C
25 A
610 F
610 G
610 J
· 610 H
604 A
· K 24
· K 23
· K 22
· K 21
· K 20
· K 19
· K 18
· K 17
· K 16
K14
K12
K 15
K 13
K 11
· K 10
· K 9
· K 8
K6
· K 7
· K 5
· K 4
Volcanics
Hard thinly-bedded siltstone (argillite)
Covered interval
Convoluted bedding
Calcareous sandstone lens
Conglomerate
Dyke
Sill
Radiolarians
Coarse bedded sandstone
Fine bedded sandstone
Siltstone-sandstone
Siltstone-minor shale
Concretionary eye-glass bed
Fault
Limestone lens
Slight discordance
Ammonoids

Figure 2.

Section 9 (KPD) and section 10 (KPB), Kennecott Point. The stratigraphic position of productive radiolarian samples and macrofossil collections is indicated to the right of the column. See Appendix 1 for detailed sample locality information and Appendix 2 for ammonite identifications.

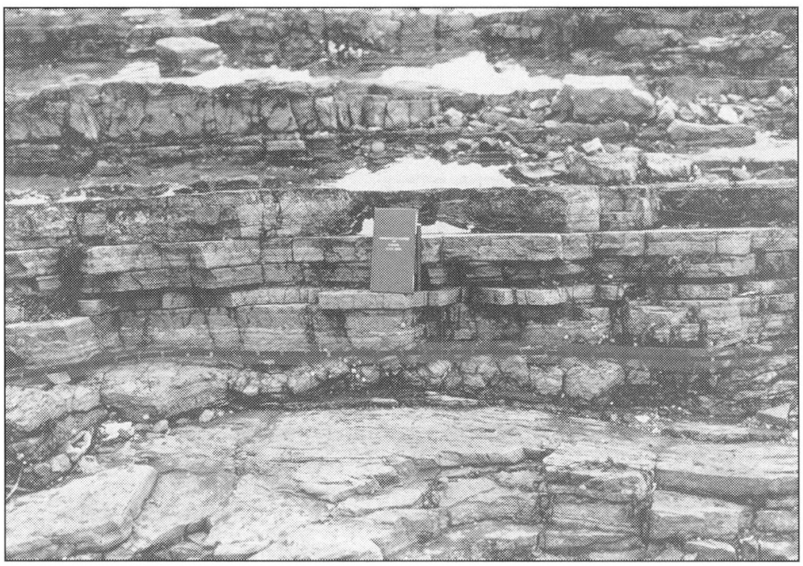


Figure 3.

Basal contact of Jurassic siltstone resting on undulating surface of youngest Triassic rocks at Kennecott Point (section 9, KPD). Photograph by H.W. Tipper. GSC 1996-170A

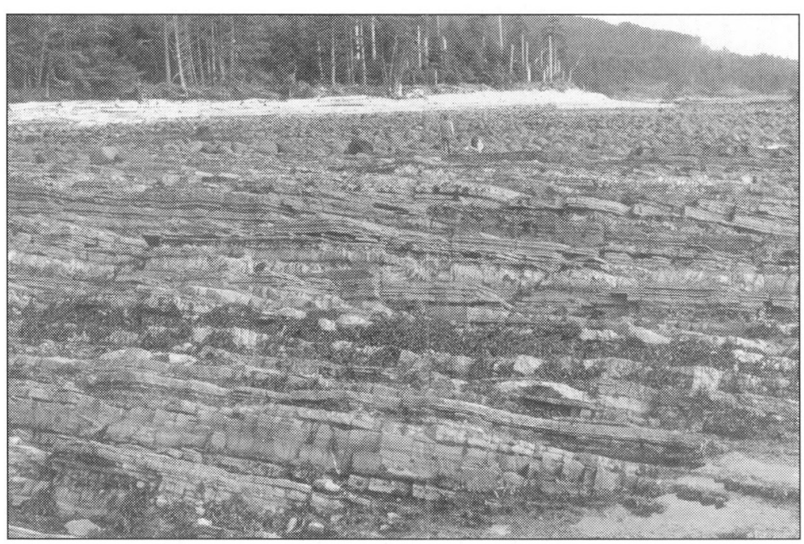


Figure 4.

Middle to upper Hettangian strata containing ammonites of the Franziceras and Doetzkirchneri assemblages, respectively. Kennecott Point (section 10, KPB). Photograph by H.W. Tipper. GSC 1996-170B

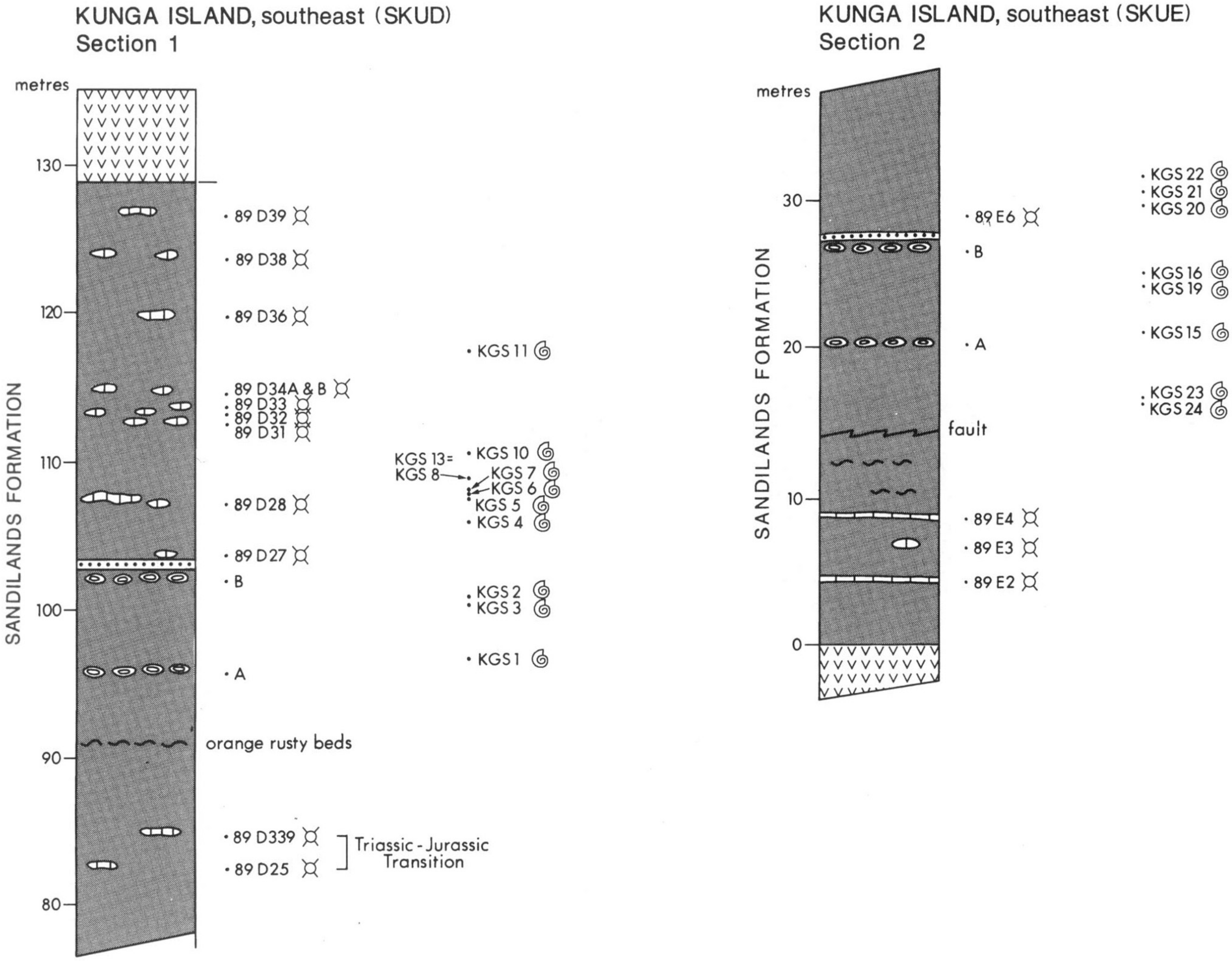


Figure 5. Section 1 (SKUD) and section 2 (SKUE), Kunga Island, southeast side. The stratigraphic position of productive radiolarian samples and macrofossil collections is indicated to the right of the column; for legend see Figure 2. See Appendix 1 for detailed sample locality information and Appendix 2 for ammonite identifications.

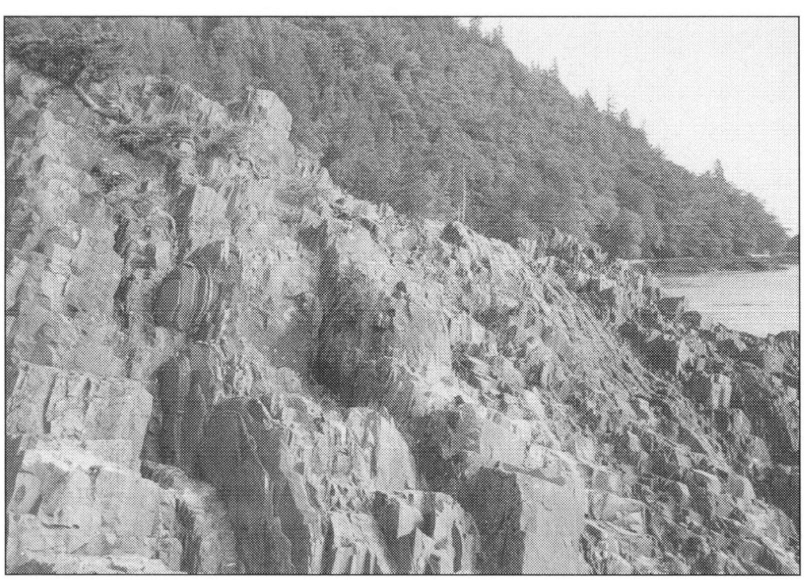


Figure 6.

Steeply dipping, slightly overturned middle Hettangian beds in the upper part of section 1 (SKUD), Kunga Island, southeast side. Uppermost level of the distinctive concretionary "eyeglass beds" can be seen left of centre. Thick sandstone bed to right is 50 cm thick. Photograph by E.S. Carter. GSC 1996-170C

Figure 7.

Closeup of the "eyeglass beds", section 1 (SKUD), Kunga Island, southeast side. Note the banded, concretionary nature of these beds. Photograph by E.S. Carter. GSC 1996-170D

section was subsequently visited by E.A. Pessagno, P.A. Whalen, and C.D. Blome (University of Texas at Dallas), who measured and collected in the summers of 1977, 1979, and 1980. The section (section 8, Fig. 8) was measured in feet (later converted to metres) using a Jacob staff and Brunton compass. The north shore of the island was first visited by M.J. Orchard (Geological Survey of Canada) and E.S Carter in 1986. Considering the faulted/disrupted nature of these Sandilands Formation strata, these workers chose to measure/collect the section where discrete uninterrupted units could be discerned, and ignored the disrupted sequences in between. Thus, in this report, five superpositional sections, section 3 (KUD) (Fig. 9), section 4 (KUC) and section 5 (KUB) (Fig. 10), section 6 (KUA) and section 7 (KUH) (Fig. 11), beginning at the base of the Hettangian sequence and spanning the entire exposure southeastward (see map Fig. 1A), comprise the Jurassic part of the Sandilands Formation on the north side of Kunga Island. These five sections together are approximately equivalent to section 8.

The rocks comprise a long, monotonous sequence of hard, dense, dark grey to black, flaggy, siliceous siltstone or 'argillite' with some calcareous sandstone and shale and abundant limestone concretions. Basal beds (section 3, KUD, Fig. 12) are composed of flaggy, fractured, dark grey, 3-10 cm thick, siliceous siltstone with some weathered laminations, occasional 3-5 cm thick calcareous sandstone beds, and buff-weathering limestone concretions. Convoluted bedding is apparent in several intervals where laminated limestone/sandstone complexes similar to the 'eyeglass beds' in sections 1 and 2 are recognized, but these are not distinct enough to provide stratigraphic correlation with sections on the south side of the island. Section 3 (KUD), is late Hettangian to early Sinemurian based on contained ammonites (Fig. 13).

Overlying sections, section 4 (KUC), section 5 (KUB), section 6 (KUA), and section 7 (KUH), represent repeated intervals of coeval upper Sinemurian strata. All are composed of thinly bedded siltstone, minor calcareous sandstone lenses and thin waxy green shale layers, and limestone concretions (Fig. 14). The concretions are normally flattened parallel to bedding and frequently contain well preserved radiolarians (Fig. 15). The highest section (section 7, KUH) extends almost to the southeast tip of the island where it is juxtaposed against volcanic strata of the Middle Jurassic Yakoun Group. This four-fold repetition of the upper Sinemurian interval is the major factor contributing to the vast thickness of Sandilands strata on Kunga Island and has an important bearing on the radiolarian zonation presented in the "Radiolarian Biochronology" section of this paper.

Central Graham Island

The Jurassic part of the Sandilands Formation is recognized on central Graham Island mainly along the shores of the Yakoun River, on the high bluffs east of the river, at roadcuts and rock quarries, and in cores drilled by Intercoastal Resources in 1978. Most these rocks are upper Sinemurian. On Graham Island and in Skidegate Inlet, the Sandilands Formation is composed of thinly bedded, hard dark grey to black siliceous siltstone interbedded with minor beds of grey siliceous tuff, lithic sandstone derived mainly from tuffs, green to grey-green shale, fine volcanic breccia with clasts to 2.5 cm, and thin laminations of black shale or siltstone (Cameron and Tipper, 1985). These rocks generally display a prominent thin banded appearance with alternations of black, white, or grey and are typical of Sandilands Formation strata in central Queen Charlotte Islands.

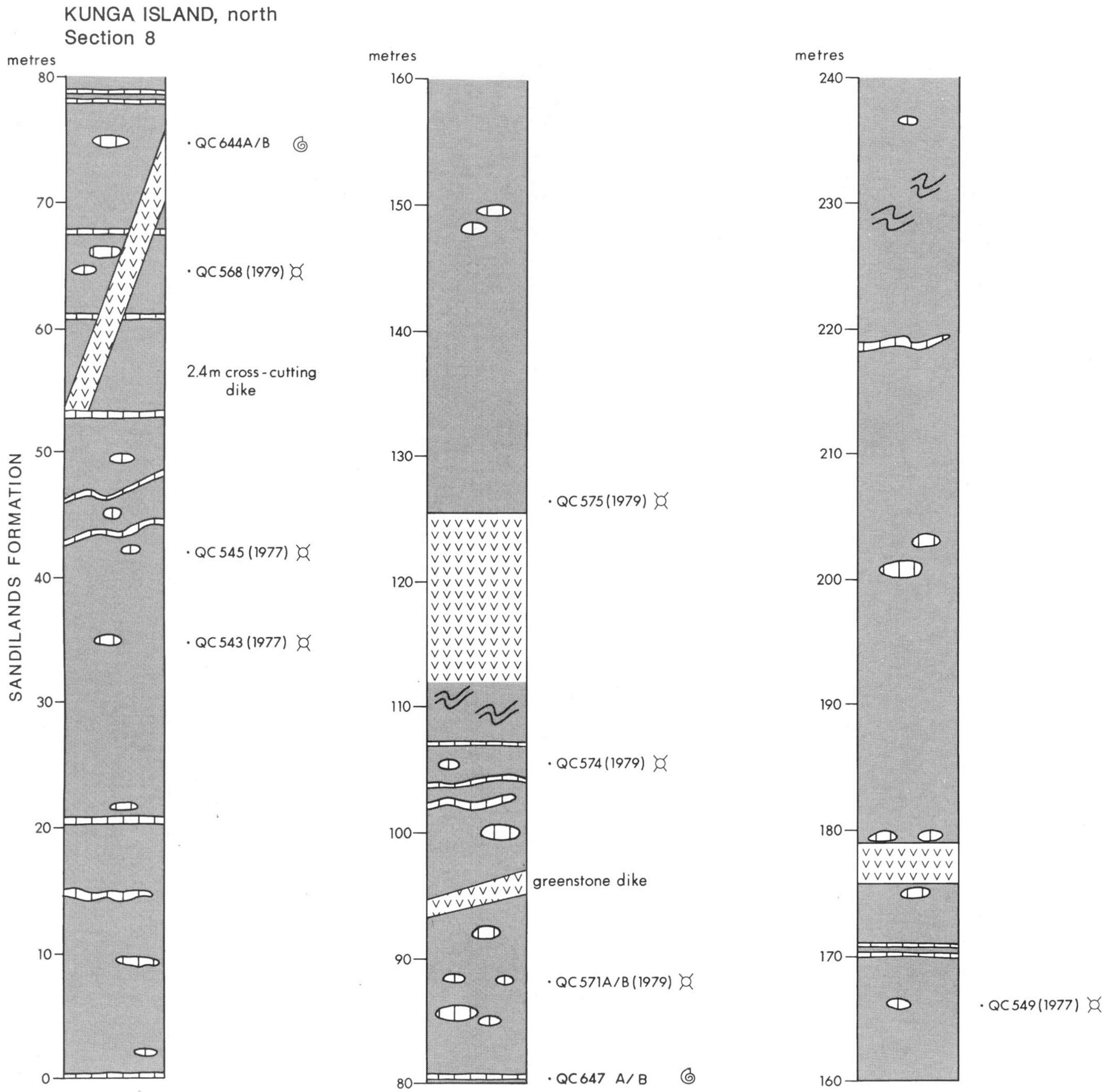


Figure 8. *Section 8, of Pessagno, Whalen, and Blome (1977-1980), Kunga Island, north side. The stratigraphic position of productive radiolarian samples and ammonite samples collected is shown to the right of the column; for legend see Figure 2. See Appendix 1 for detailed sample locality information and Appendix 2 for ammonite identifications.*

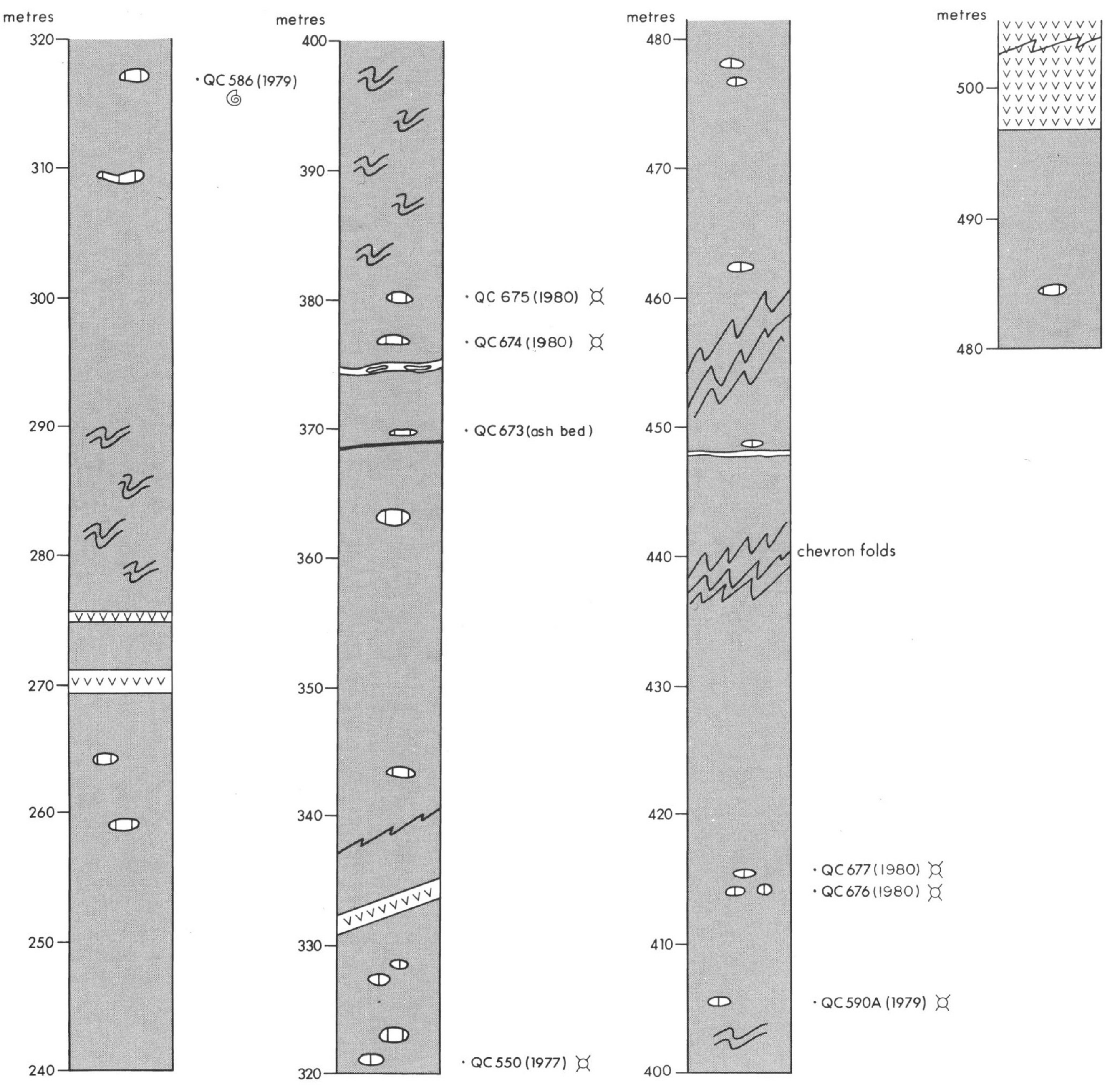
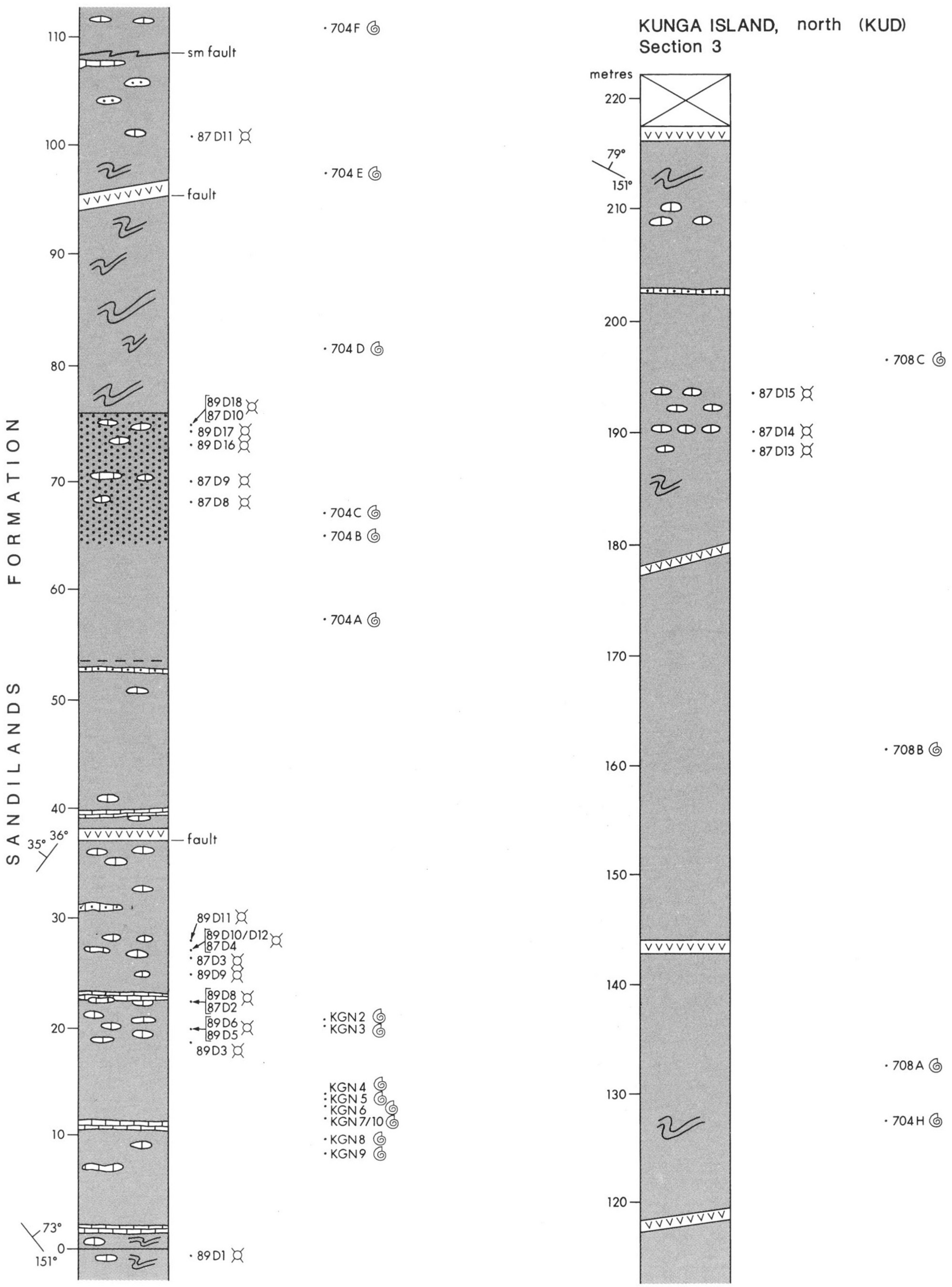


Figure 8. (cont.)


SANDILANDS FORMATION
sm fault
fault
fault
· 704F
· 87 D11
· 704 E
· 704 D
89 D18
87 D10
89 D17
89 D16
87 D9
87 D8
· 704C
· 704 B
· 704A
89 D11
89 D10/D12
87 D4
87 D3
89 D9
89 D8
87 D2
89 D6
89 D5
89 D3
KGN 2
KGN 3
KGN 4
KGN 5
KGN 6
KGN 7/10
KGN 8
KGN 9
· 89 D1
KUNGA ISLAND, north (KUD)
Section 3
metres
· 708 C
· 87 D15
· 87 D14
· 87 D13
· 708 B
· 708 A
· 704 H

Yakoun River area

Three limestone samples (section 11, see map Fig. 1D) were collected by B.E.B. Cameron in 1986 in a transit along the west side of the Yakoun River, south of the junction with Ghost Creek (see Appendix 1). These recessive Sandilands Formation beds are exposed only during summer at low water. Cameron taped the sequence and noted the lithology, but the section was not measured stratigraphically. Ammonites collected in close association with the radiolarian samples have been identified as *Paltechioceras* sp. and belong to the upper Sinemurian *Harbledownense* Assemblage of Pálfy et al. (1994).

Three diamond drill-cores were obtained by Cameron and Tipper from Intercoastal Resources. These cores were drilled in potential source rocks of the Sandilands Formation and overlying Ghost Creek Formation in 1978-1979. Subsequently, the limestones in each core were processed for radiolarians at GSC facilities at Sidney, B.C. Two samples from Corehole I-178 (stratigraphic section 2 of Cameron and Tipper, 1985) are included here as section 12 (see map, Fig. 1D).

Skidegate Inlet

Sandilands Island

Cameron and Tipper (1985) designated a typical exposure on the southeast side of Sandilands Island as the type area for the Sandilands Formation. Unfortunately only the upper part of the formation is exposed here, and it displays the typical banded appearance commonly found elsewhere in Skidegate Inlet and central Graham Island. This exposure was visited in 1984 by E.S. Carter who collected 15 superpositional samples for radiolarians (see Figure 1C). Three productive samples (84-CNA-SP-19/1, 8, and 12) are included here as section 13.

Maude Island

The upper part of the Sandilands Formation is partly exposed on the south shore of Maude Island beginning about 130 m west of Fannin Bay and continuing westward (see Fig. 1C). These strata are strongly folded and faulted, but a fairly coherent interval of about 30 m is exposed at the base of stratigraphic section 8 of Cameron and Tipper (1985). The rocks are composed of hard, partly tuffaceous, argillaceous siltstone with rare thin, waxy, green shale interbeds. The sequence grades to dark grey silty shale in the upper part where it is overlain by the massive shale beds of the Ghost Creek Formation. Several samples were collected at this Sandilands locality, but the only productive one (87-CNA-SP-18/3) is included here as section 14.

Tasu Sound

Lomgon Bay

Sandilands Formation strata are variably exposed along the shoreline of Lomgon Bay, northern Tasu Inlet (Fig. 1B). Several samples were collected in 1988 from beds containing arietitid ammonites. Sample 88-OF-LB-1 is represented by section 15.

Wilson Bay

At Wilson Bay, southeastern Tasu Inlet, steeply dipping Sandilands strata are exposed along a cliff face on the western shore of the bay (Fig. 1B) immediately above a logging road. Some prominent green sandy shale beds are interbedded with the siltstone, and the lithology is generally very similar to the north shore of Kunga Island. Three samples were collected in 1988; the top one (88-OF-WB-3) yielded radiolarians and is included here as section 16.

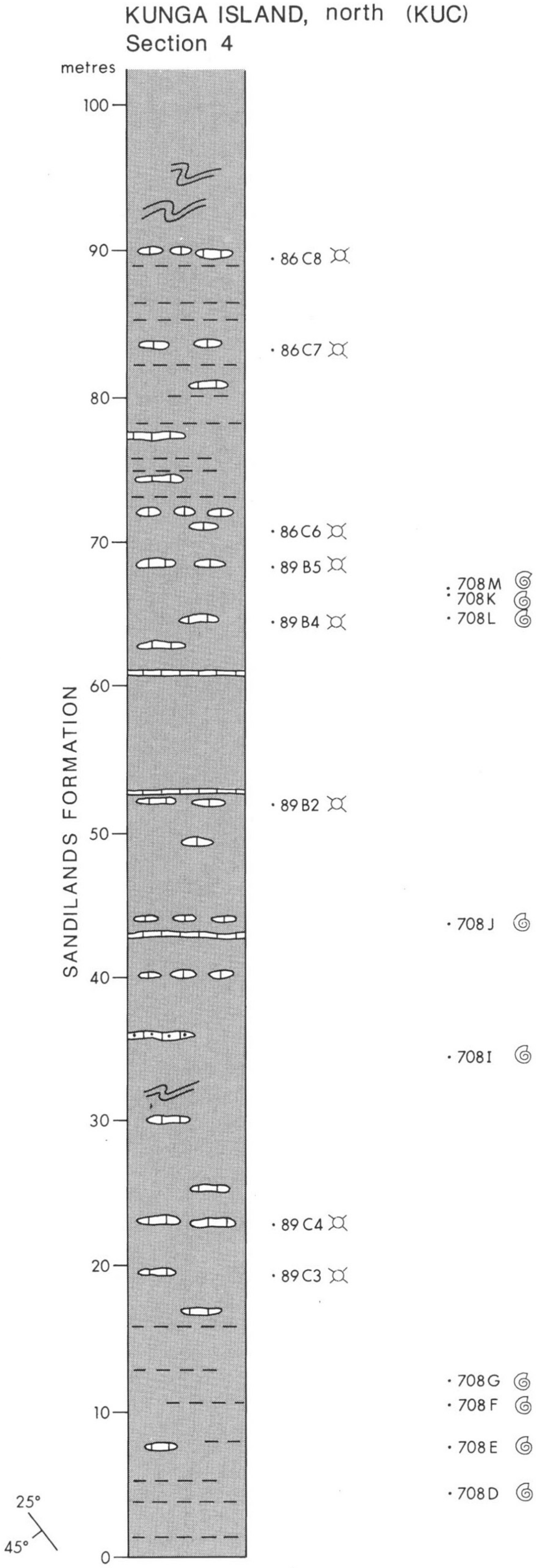
INDEPENDENT FOSSIL DATING

Ammonoids

Queen Charlotte Islands radiolarian material is dated by associated ammonite faunas. The first ammonites were collected by G.M. Dawson in the late 1870s and studied by Whiteaves (1883, 1884, 1890). Many authors have subsequently contributed to the study of these faunas (McLearn, 1929, 1932, 1949; Frebold, 1967; Smith and Tipper, 1986, Smith et al., 1988), and the field is still active. The faunas in this study are referred to North American Ammonite Assemblages for the Hettangian (Tipper and Guex, 1994) and the Sinemurian (Pálfy et al., 1994). Hettangian ammonites at Kennecott Point were identified by H.W. Tipper and J. Guex; H.W. Tipper identified specimens from the north and southeast sides of Kunga Island; most Sinemurian ammonites from Kennecott Point and Kunga Island were identified by J. Pálfy; Triassic ammonoids at Kennecott Point were identified by E.T. Tozer. Appendix 2 contains detailed identifications for all ammonoids in this study.

Figure 9.

Section 3 (KUD), Kunga Island, north side. The stratigraphic position of productive radiolarian samples and macrofossil collections is indicated to the right of the column; for legend see Figure 2. See Appendix 1 for detailed sample locality information and Appendix 2 for ammonite identifications.



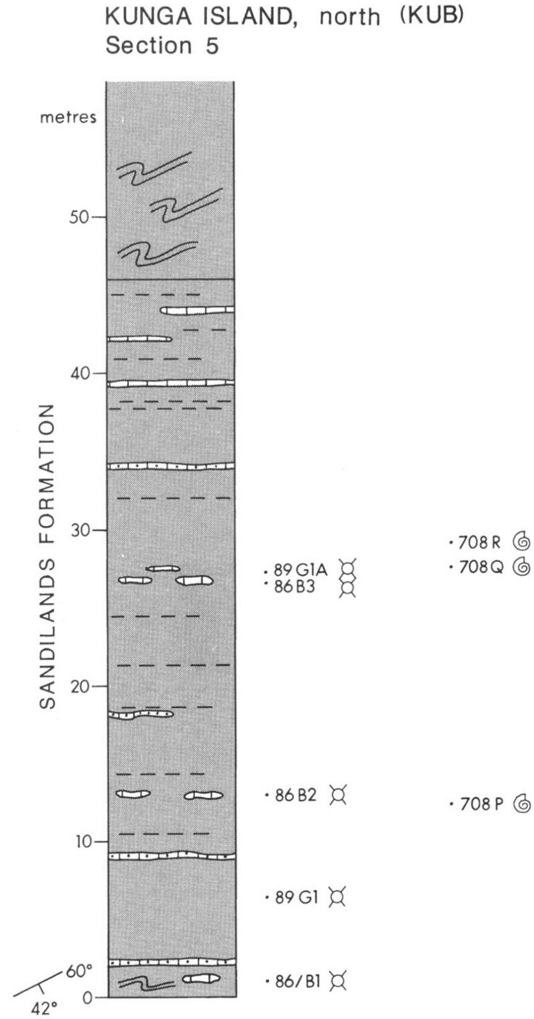


Figure 10.

Section 4 (KUC) and section 5 (KUB), Kunga Island, north side. The stratigraphic position of productive radiolarian samples and macrofossil collections is indicated to the right of the column; for legend see Figure 2. See Appendix 1 for detailed sample locality information and Appendix 2 for ammonite identifications.

Kennecott Point

The Sandilands Formation at Kennecott Point spans the topmost upper Norian, Rhaetian, Hettangian, and lowest Sinemurian. *Choristoceras nobile* Mojsisovics and *C. rhaeticum* Guembel are present near the base of section 9 (KPD) (Fig. 2) (at datum and 4.8 m, respectively) and are indicative of the Crickmayi Zone, the uppermost ammonoid zone of the Triassic. Higher in the section, the first ammonite indicating the Hettangian is *Psiloceras* aff. *primocostatum* Hillebrandt (= Planorbis Zone of NW Europe) which occurs at 25.1 m. However, radiolarian samples collected at 20 m (90-CNA-KPD-4), 22.8 m (90-CNA-KPD-5), and 24.3 m (90-TD-11A) have yielded low diversity, primitive faunas that are probably earliest Hettangian as they bear no resemblance to the distinctive Rhaetian faunas described by Carter (1993). Tipper et al. (1994) believe that the Triassic-Jurassic boundary occurs in the unfossiliferous transitional interval between 4.8 m and 20 m. In the upper part of the section, ammonites identified as *Psiloceras* cf. *polymorphum*, *Psiloceras* aff. *plicatulum*?, *Psiloceras* sp., and *Paradasyceras* aff. *veromoense* indicate a very early Hettangian age; these faunas are older than the lowest occurring ammonites in section 10 (KPB).

Section 10 (KPB, Fig. 2) was collected intensively for ammonites by H.W. Tipper during the summers of 1987-1990. The faunal succession spans the upper lower Hettangian to lower Sinemurian without break. Based on studies of these faunas, Tipper and Guex (1994) proposed four preliminary assemblages (with approximate age boundaries) for the Hettangian of North America: the *Psiloceras*, *Euphyllites*, *Franziceras*, and *Doetzkirchneri* assemblages (see Table 1). Further studies are needed to refine the age of these assemblages and provide correlation with other faunas from western North America. Ammonites in the basal 10 m of section 10 belong to the *Euphyllites* Assemblage (upper lower to middle Hettangian); the

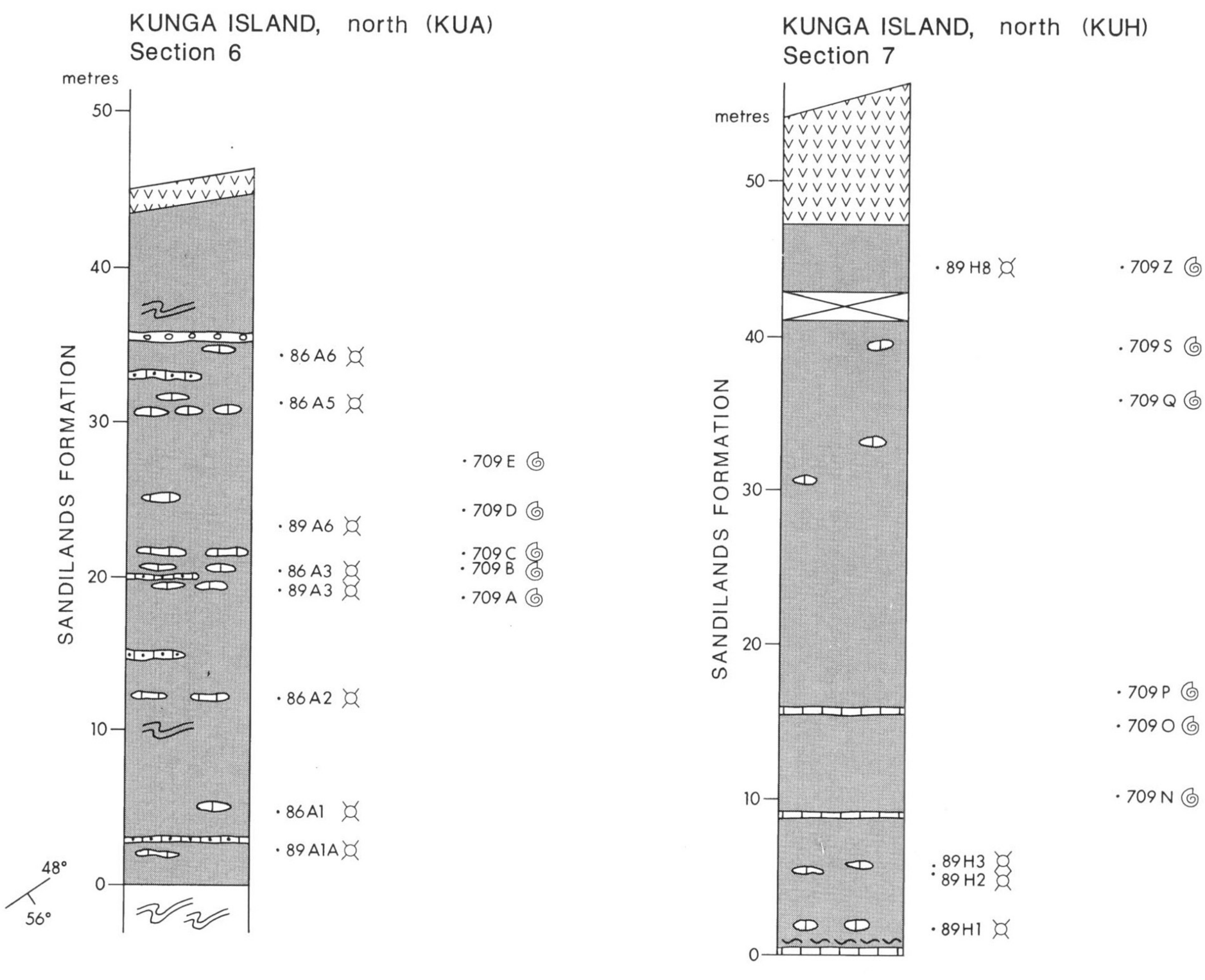


Figure 11. Section 6 (KUA) and section 7 (KUH), Kunga Island, north side. The stratigraphic position of productive radiolarian samples and macrofossil collections is indicated to the right of the column; for legend see Figure 2. See Appendix 1 for detailed sample locality information and Appendix 2 for ammonite identifications.

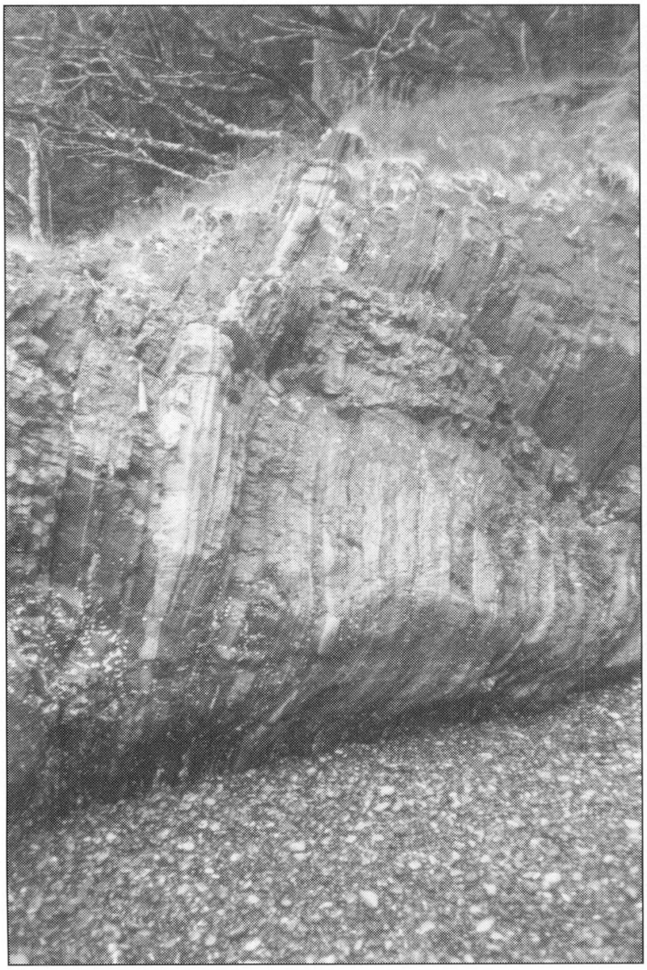


Figure 12. *Steeply dipping beds (middle to upper Hettangian) at the base of section 3 (KUD) and section 8 on the north side of Kunga Island. Photograph by E.S. Carter. GSC 1996-170E*

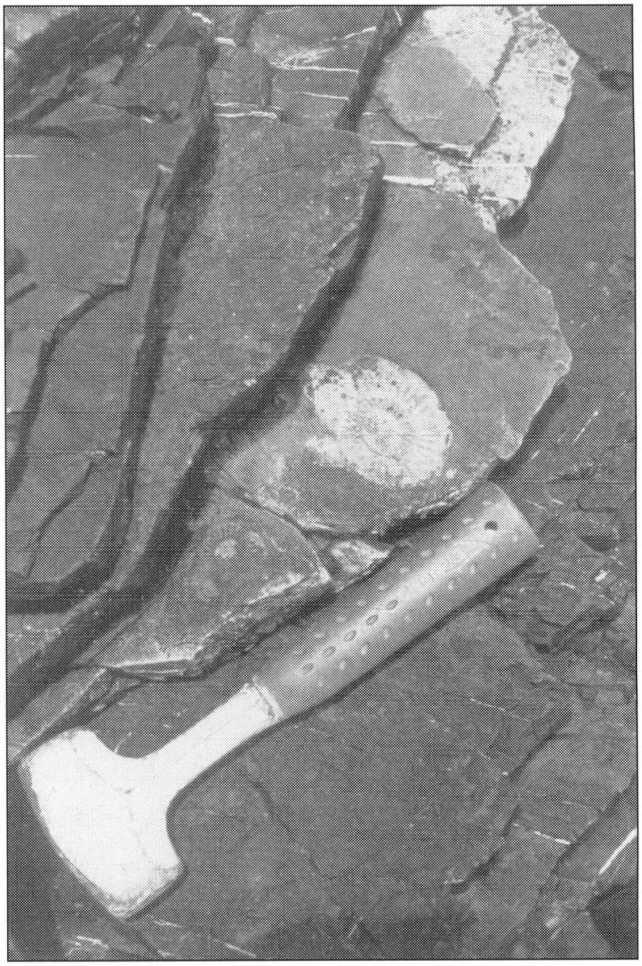


Figure 13. *Ammonite Badouxia canadensis (QC 644) collected at 75.1 m in section 8, Kunga Island, north side. Photograph by P.A. Whalen. GSC 1996-170F*

Figure 14.

Typical exposure of the upper Sinemurian part of the sequence on the north side of Kunga Island. Radiolarians of the Canutus rockfishensis-Wrangellium thurstonense Zone are found at this level. Note the thinly bedded siltstones and calcareous concretions. Photograph by P.A. Whalen. GSC 1996-170G

Figure 15.

Limestone concretion typical of those containing excellently preserved Radiolaria. Section 8, Kunga Island, north side. Photograph by P.A. Whalen. GSC 1996-170H

interval between 12 and 25 m contains ammonites of the *Franziceras* Assemblage (middle to upper Hettangian); from 25 m to about 39 m ammonites representative of the *Doetzkirchneri* Assemblage (upper Hettangian) are found. Above this interval all ammonites are from the Canadensis Zone. This zone is considered to span the Hettangian-Sinemurian boundary (Pálfy et al., 1994); the lower part is uppermost Hettangian, and the upper part is lowest Sinemurian.

Unfortunately, radiolarians are not abundant in this excellently dated section. Moderately preserved faunas (samples 87-CNA-KPB-1 to 88-CNA-KPB-7) are present in the lower part of the section in strata equivalent to the *Euphyllites* Assemblage (upper Planorbis Zone equivalent), and well preserved radiolarians (samples 87-CNA-KPB-9 to 89-CNA-KPB-15) occur in the upper part of the section, equivalent to the Canadensis Zone. Middle to upper Hettangian parts of the sequence (*Franziceras* and *Doetzkirchneri* equivalents) are quite sandy and lack fine grained limestone concretions. Despite intensive sampling, these beds have not yielded radiolarians.

Kunga Island, southeast

On the southeast side of Kunga Island, the transition from Rhaetian to Hettangian is observed in continuous beds near the base of section 1 (SKUD, Fig. 5). This transition occurs a little higher in section 2 (SKUE, Fig. 5) but is faulted. Ammonites are rare at both localities but are sufficient to date both sequences fairly accurately. Earliest Hettangian ammonites have not been found in the base of section 1, but radiolarian sample 89-CNA-SKUD-339 (collected 2.4 m above sample 89-CNA-SKUD-25 which contains uppermost Rhaetian radiolarians and conodonts) contains an assemblage identical to the primitive faunas that occur below the lowest Hettangian ammonites at Kennecott Point. The oldest Hettangian ammonites in section 1 (collections 89-KGS-1 to 89-KGS-4) are early Hettangian and are associated with radiolarian samples 89-CNA-SKUD-27 and 89-CNA-SKUD-28. Higher in section 1, ammonites from the *Franziceras* Assemblage (middle Hettangian) are associated with radiolarian samples 89- CNA-SKUD-28 to 89-CNA-SKUD-36. No ammonites have been found above this level, but radiolarian assemblages in samples 89-CNA-SKUD-38 and 89-CNA-SKUD-39 (higher in the sequence) are identical to those from the middle Hettangian interval.

The basal Jurassic part of section 2 (SKUE, Fig. 5) contains ammonites assigned to the Pacificum Zone. A recent publication by J. Guex (1995) indicates this zone is the second lowest zone of the Jurassic in North America. In the upper part of the section, radiolarian sample 89-CNA-SKUE-6 is associated with ammonites that are probably late early Hettangian.

Kunga Island, north

Ammonites are rare at the base of the Jurassic Sandilands Formation sequence (Hettangian) on the north side of Kunga Island, but they become more common upsection in the Sinemurian. In the late 1970s, E.A. Pessagno and others collected a few ammonites from this section that were tentatively identified by H.W. Tipper (see Pessagno and Blome, 1980; Pessagno and Whalen, 1982). Recent studies by Pálfy et al. (1994) have revised these identifications and refined the age. The same authors proposed preliminary assemblages for the Sinemurian of North America, which are (in ascending order): the upper part of the Canadensis Zone (Frebold, 1967), the "*Coroniceras*", *Arnouldi*, *Varians*, *Harbledownense*, and *Tetraspidoceras* assemblages, with the last ranging into the base of the Pliensbachian (see Table 1).

Ammonite collections 89-KGN-9 to 89-KGN-2 near the base of section 3 (KUD, Fig. 9) are mid- to late Hettangian. These faunas are associated with radiolarian samples 89-CNA-KUD-3 to 89-CNA-KUD-11 in section 3, and most likely with samples QC 543 and QC 545 in section 8 (Fig. 8). Higher in section 3 (between 58 m and 130 m), ammonite collections 704A to 704F (*Badouxia canadensis, Badouxia* sp., *Vermiceras* sp., etc.) are indicative of the Canadensis Zone (latest Hettangian - earliest Sinemurian). Ammonites collected by Whalen at 75.1 m and 80.6 m in section 8 are also assigned to this zone. Radiolarian samples 87-CNA-KUD-8 to 87-CNA-KUD-11 in section 3, and samples QC-568 to QC-574 in section 8 are included in the Canadensis interval.

Correlation between the ammonite and radiolarian successions is more difficult in the lower Sinemurian. In section 3, ammonite collections 708A and 708B are questionably assigned to the "*Coroniceras*" Assemblage (lower Sinemurian) by Pálfy (1991), whereas collections 708C to 708E (708D and 708E are in section 4) contain *Arnioceras arnouldi* and belong to the *Arnouldi* Assemblage (late lower Sinemurian) (Pálfy, 1991). Radiolarian samples from this interval (87-CNA-KUD-13 to 87-CNA-KUD-15 in section 3, and QC-575 and QC-549 in section 8) are similar in species composition, and are distinct from other assemblages below and above. As the presence of the "*Coroniceras*" Assemblage cannot be confirmed, we believe these samples are more likely equivalent to the *Arnouldi* Assemblage.

The upper Sinemurian on the north side of Kunga Island is very thick (>250 m) and appears to represent a period of rapid sedimentation. Frequent minor disruptions are seen in these beds, and faulting and repetition may contribute to the vast thickness. All ammonites collected in sections 4, 5, 6, and the basal part of section 7 (709N-709P) (Fig. 10 and 11) are assigned to the *Varians* Assemblage (Pálfy, 1991); only collections 709Q, 709S, and 709Z in the topmost 12 m of section 7 are indicative of the *Harbledownense* Assemblage (Pálfy, 1991). Comparison of ammonite assemblages with the new radiolarian zonation presented here (see biostratigraphic correlation, Fig. 20) indicates that radiolarian samples 86-OF-KUA-6 (section 6), 89-CNA-KUH-1 to 89-CNA-KUH-3 (section 7), and QC-677 (section 8) contain a radiolarian fauna coeval with younger assemblages equivalent in age to the *Harbledownense* Assemblage, although these samples were collected in strata apparently containing ammonites from the *Varians* Assemblage. This may indicate previously undetected repetitions and/or reworking in the upper Sinemurian sequence.

Central Graham Island, Maude Island, and Sandilands Island

B.E.B. Cameron collected ammonites from section 11 on the Yakoun River; these have been identified by H.W. Tipper as upper Sinemurian echioceratids of the *Harbledownense* Assemblage. Coeval *Paltechioceras* faunas are present in sections 13 (Sandilands Island) and 14 (Maude Island).

Foraminifera

Rare foraminifers were collected from sections 3 and 8 on the north side of Kunga Island by E.S. Carter and P.A. Whalen, respectively. Scanning electron microscope photographs of two siliceous foraminifers were sent to P.R. Thompson (ARCO research, Plano, Texas) for identification. These specimens are from radiolarian samples 89-CNA-KUD-18 (section 3) and QC-674 (section 8). The samples are dated by ammonites as uppermost Hettangian to lowermost Sinemurian, and upper Sinemurian, respectively. Thompson indicates both foraminifers belong to the genus *Spirillina*, a small, calcareous neritic taxon. Regarding species identification, for the specimen in 89-CNA-KUD-18, Thompson wrote in a letter to Carter dated 11 July 1994 "Given the 4+ coils...and the suspected Sinemurian/Hettangian stratigraphic position, *S. orbicla* is a good choice of published names, closely followed by *S. gurgitata*. They may be related forms or synonyms."; the former is Middle Liassic, the latter, Upper Triassic. For the specimen in QC 674, Thompson writes, "The shell is broken: the penultimate chamber is missing. The aperture is odd, but this single side view looks quite like *S. orbicula*." Both foraminifers broadly confirm a Late Triassic to Middle Liassic age.

RADIOLARIAN FAUNAS

The radiolarians utilized in this study were extracted from limestone lenses and concretions using acetic (Carter) and HCl (Whalen) acids and standard laboratory techniques. Radiolarian tests are usually siliceous, but a few well preserved pyritized faunas have been found. Preservation is generally excellent; many specimens are entire, with fragile spines and terminal tubes intact and well defined meshwork. Broken specimens have been viewed with the binocular microscope and scanning electron microscope to discern internal structures, and some specimens have been photographed in transmitted light (see Pl. 26 and 27).

One hundred nineteen species, representing approximately 80 per cent of the fauna, comprise the Unitary Associations (UA) database for this study. One subfamily (the Charlotteinae), 14 genera, and 68 species are described as new, and many other forms are discussed informally. With the exception of *Cuniculiformis plinius*, *Ectonocorys*? sp., and *Jacus*? *sandspitensis* all forms are illustrated on Plates 1-27. The distribution of taxa at all sampled localities is shown on Figure 16 and 17 (in pocket) and in the database for Unitary Associations (Appendix 3).

Radiolarian diversity and composition of the fauna

Following the almost complete extinction of Radiolaria at the end of the Triassic (Carter, 1994a, b; Tipper et al., 1994), the gradual rebuilding of the fauna through the Hettangian and Sinemurian can be traced in our samples. Spumellarians dominate the earliest Hettangian fauna. Diversity is very low (see sample 89-CNA-SKUD-339 in section 1, and all samples in section 9) but increases markedly toward the end of the Hettangian. New genera appear, along with surviving Triassic genera, but rarely more than one or two species per genus are observed. The fauna becomes more diverse in the Sinemurian and nassellarians (especially multicyrtids) become increasingly dominant.

The Hettangian-Sinemurian fauna is composed of entactinids such as *Charlottea* n. gen., *Danubea* n. gen., *Sophia* n. gen., *Thurstonia* n. gen., *Tozerium* n. gen., and *Parentactinia* Dumitrica; the saturnalids *Kozurastrum* De Wever, *Mesosaturnalis* Kozur and Mostler, *Palaeosaturnalis* Kozur and Mostler, *Praehexasaturnalis* Kozur and Mostler, and *Pseudoheliodiscus* Kozur and Mostler; hagiastrids including *Archaeohagiastrum* Baumgartner, *Hagiastrum* Haeckel, and *Homoeoparonaella* Baumgartner; the patulibracchiids *Crucella* Pessagno and *Paronaella* Pessagno; and other genera such as *Amuria* n. gen., *Archaeocenosphaera* Pessagno and Yang, *Empirea* n. gen., *Praeorbiculiformella* Kozur and Mostler, *Pantanellium* Pessagno, *Udalia* n. gen., and several indeterminate spongy spumellarians. The nassellarian fauna is comprised mainly of *Bipedis* De Wever, *Katroma* Pessagno and Poisson, *Protokatroma* n. gen., and the multicyrtids *Bagotum* Pessagno and Whalen, *Canoptum* Pessagno, *Canutus* Pessagno and Whalen, *Droltus* Pessagno and Whalen, *Pseudoeucyrtis* Pessagno, *Relanus* Pessagno and Whalen, *Trexus* n. gen., and *Wrangellium* Pessagno and Whalen. *Ares* De Wever, *Atalanta* Cordey and Carter, *Broctus* Pessagno and Whalen, *Cuniculiformis* De Wever, *Foremania* n. gen., *Jacus* De Wever, *Laxtorum* Blome, *Napora* Pessagno, *Nitrader* Cordey and Carter, *Parahsuum* Yao, *Saitoum* De Wever, *Solidea* n. gen., and *Teesium* n. gen. form a lesser part of the fauna. Hettangian and Sinemurian faunas are discussed below in terms of diversity and the first appearance of species.

Hettangian

The pattern of radiolarian evolution through the Hettangian is mainly one of increasing diversity, with spumellarian genera outnumbering nassellarian genera by a ratio of greater than 2:1. Lowest Hettangian radiolarians in Queen Charlotte Islands are equivalent to the *Psiloceras* Assemblage of Tipper and Guex (1994). These low diversity faunas are composed of abundant *Archaeocenosphaera laseekensis* Pessagno and Yang and *Pantanellium tanuense* Pessagno and Blome, together with *Bipedis elizabethae* n. sp., *Canoptum merum* Pessagno and Whalen, *Droltus hecatensis* Pessagno and Whalen, *Relanus reefensis* Pessagno and Whalen, *Tozerium nascens* n. gen., n. sp., *Udalia primaeva* n. gen., n. sp. and a host of poorly known spherical forms not included in this study. The majority of this early fauna ranges upward through the Hettangian.

In strata approximately equivalent to the *Euphyllites* Assemblage of Tipper and Guex (1994) (upper lower Hettangian) the radiolarian fauna is augmented by one or more species of *Atalanta* Cordey and Carter, *Bipedis* De Wever, *Canoptum* Pessagno, *Charlottea* n. gen., *Danubea* n. gen., *Empirea* n. gen., *Pseudoeucyrtis* Pessagno, *Palaeosaturnalis* Kozur and Mostler, *Paronaella* Pessagno, *Praehexasaturnalis* Kozur and Mostler, *Protokatroma* n. gen., *Pseudoheptacladus* Lahm, *Thurstonia* n. gen., *Udalia* n. gen., and several indeterminate spumellarian and nassellarian genera (see "Systematic Paleontology"). Previously described species first appearing in this interval include *Atalanta epaphrodita* Cordey and Carter, *Palaeosaturnalis prinevillensis* (Blome), and *Praehexasaturnalis tetraradiatus* Kozur and Mostler.

In middle and upper Hettangian strata approximately equivalent to the *Franziceras* Assemblages of Tipper and Guex (1994), the first species of *Jacus* De Wever and *Parentactinia* Dumitrica appear, and all pre-existing genera become slightly more diverse. Previously described species first appearing in this interval include *Canoptum unicum* Pessagno and Whalen, *Palaeosaturnalis liassicus* Kozur and Mostler, *Pantanellium browni* Pessagno and Blome, *P.danaense* Pessagno and Blome, *P. kluense* Pessagno and Blome, *Protokatroma* sp. A and *Jacus*? *anatiformis* De Wever.

Hettangian-Sinemurian boundary

The Hettangian-Sinemurian boundary falls within strata equivalent to the Canadensis Zone (Tipper and Guex, 1994; Pálfy et al., 1994). This boundary, and consequently the base of the Sinemurian, cannot be identified precisely either by ammonites or radiolarians. At the approximate position of the Hettangian-Sinemurian boundary, however, both ammonite and radiolarian assemblages contain taxa that are distinct from both underlying and overlying faunas. Radiolarian genera first appearing at this time in our samples include *Archaeohagiastrum* Baumgartner, *Beatricea* n. gen., *Crucella* Pessagno, *Ectonocorys* De Wever, *Laxtorum* Blome, *Nitrader* Cordey and Carter, *Saitoum* Pessagno, and *Trexus* n. gen. These are all new to the Jurassic except Crucella and *Laxtorum*. *Crucella* first appears in the Rhaetian of the Sandilands Formation in Queen Charlotte Islands (see *Crucella*? *flowerpotensis*, *C.* sp. B and *C.* sp. C in Carter, 1993), and rare specimens have been found in earliest Hettangian strata at Kennecott Point (sample 90-TD-11A). These occurrences point to a Late Triassic origin for the genus but *Crucella* is not consistently present in our samples until the latest Hettangian (see also Kozur and Mostler, 1990). *Laxtorum* Blome undergoes rapid morphological change in the Rhaetian, developing a terminal tube, medial spines, etc. (Carter, 1993; Carter and Guex, in press), but all these forms are extinct at the end of the Triassic. Jurassic laxtorids have a simple (primitive) multicyrtid shape and seemingly conform to Blome's original definition of the genus (Blome, 1984). *Laxtorum hemingense* n. sp. is the only species included in our database, but several other forms of mid- to late Hettangian age are figured on Plate 25, figures 17-20. Other described species first appearing around the Hettangian-Sinemurian boundary include *Crucella carteri* Kozur and Mostler, *C. hettangica* Kozur and Mostler, *Droltus laseekensis* Pessagno and Whalen, and *Nitrader montegufonensis* Cordey and Carter.

Sinemurian

The oldest radiolarians of confirmed Sinemurian age occur in strata approximately equivalent to the *Arnouldi* Ammonite Assemblage of Pálfy et al. (1994) which is upper Lower Sinemurian. Some important radiolarian genera first appearing at this time are *Ares* De Wever, *Bagotum* Pessagno and Whalen, *Sophia* n. gen., *Katroma* Pessagno and Poisson, *Parahsuum* Yao, and *Foremania* n. gen. (previously figured by De Wever (1982) as gen. indet 1). Previously described species characterizing this interval include *Atalanta emmela* Cordey and Carter, *Bagotum erraticum* Pessagno and Whalen, *Crucella prisca* Kozur and Mostler, *Droltus lyellensis* Pessagno and Whalen, *Pantanellium kungaense* Pessagno and Blome, and *Parahsuum simplum* Yao.

Upper Sinemurian radiolarians associated with ammonites of the *Varians* and *Harbledownense* assemblages of Pálfy et al. (1994) are abundant and diverse. The first true representatives of *Hagiastrum* Haeckel appear at this time along with earliest Jurassic species of *Homoeoparonaella* Baumgartner, *Mesosaturnalis* Kozur and Mostler, *Kozurastrum* De Wever, and a form attributed to the Leugeonidae Wang and Yang. Nassellarians are dominant in this fauna, especially the multicyrtids *Canutus* Pessagno and Whalen, *Droltus* Pessagno and Whalen, *Bagotum* Pessagno and Whalen, and *Wrangellium* Pessagno and Whalen. Less abundant genera are *Broctus* Pessagno and Whalen, *Cuniculiformis* De Wever, *Farcus* Pessagno, Whalen and Yeh, *Napora* Pessagno, *Solidea* n. gen., and *Teesium* n. gen. In addition to the many new taxa characterizing this interval, the following species first appear: *Bagotum helmetense* Pessagno and Whalen, *Broctus kuensis* Pessagno and Whalen, *Broctus selwynensis* Pessagno and Whalen, *Canoptum dixoni* Pessagno and Whalen, *Canutus blomei* Pessagno and Whalen, *C. rockfishensis* Pessagno and Whalen, *Cuniculiformis plinius* De Wever, *Jacus*? *sandspitensis* Pessagno, Whalen and Yeh, *Napora*? *graybayensis* Pessagno, Whalen and Yeh, *Pantanellium skedansense* Pessagno and Blome, *Paronaella* cf. *corpulenta* De Wever, *Pseudoheliodiscus yaoi* Pessagno and Poisson, and *Wrangellium thurstonense* Pessagno and Whalen.

The topmost Sandilands Formation contains uppermost Sinemurian to lowermost Pliensbachian ammonites belonging to the *Tetraspidoceras* Assemblage of Pálfy et al. (1994). Radiolarians of equivalent age have not yet been found in Queen Charlotte Islands.

RADIOLARIAN BIOCHRONOLOGY

Introduction

Since 1977, a large volume of biostratigraphic data has accumulated relating to the occurrence of Hettangian and Sinemurian radiolarians in the middle and upper Sandilands Formation of Queen Charlotte Islands. The present study utilizes over 90 well preserved radiolarian collections to construct a radiolarian zonation calibrated with ammonite assemblages of Tipper and Guex (1994) and Pálfy et al. (1994).

Unitary Associations

In recent years the Unitary Association (UA) method developed by Guex (1977) has been used effectively to integrate large quantities of data into a biochronological framework. This method analyses the first and final occurrences of species in all available sections and defines maximal sets of mutually co-existing species (UA). It also produces maximum ranges of the taxa relative to each other by stacking co-occurrence data from all sections to compensate for local dissolution effects (poor preservation). These procedures are described in detail in Guex (1991) and are not repeated here. More recently, Savary and Guex (1991) developed the computer program BioGraph to deal more efficiently with a large volume of data. This program was used by Jud (1994), Gorican (1994), and O'Dogherty (1994) in zoning Jurassic and Cretaceous radiolarians from differing areas of the western Mediterranean; by Baumgartner et al. (1995) in constructing worldwide zonation for low latitude Middle Jurassic to Cretaceous radiolarians of Tethys; and by Carter (1993) in zoning Rhaetian radiolarians from the Sandilands Formation of Queen Charlotte Islands.

Procedures – database

A database (Appendix 3) was constructed consisting of 119 species in 95 stratigraphic horizons from nine localities in Queen Charlotte Islands. Sections 1-2 (Kunga Island, south), 3-8 (Kunga Island, north), and 9-10 (Kennecott Point) are stratigraphic sections containing many superposed samples (or horizons). All other sections are from lesser-exposed or isolated outcrops: sections 11 and 12 are from central Graham Island; 13 is from Sandilands Island;

14 is from Maude Island; and 15 and 16 are from Lomgon Bay and Wilson Bay, respectively, in Tasu Sound. The morphotypes selected were carefully compared with scanning electron microscope photographs of 'newly-defined types' and in most cases only those having sharply defined limits of variation were utilized. A few taxa are included that consistently are more variable but seem useful. For each of these, species variability is discussed in the systematics and illustrated on the plates. Very rare species were excluded from the database, but a few are discussed in open nomenclature and figured on the plates. All morphotypes in the database were given codes consisting of five characters: three letters (usually an abbreviation of genus) and two numbers. The database lists each section and records the appearance of all morphotypes present in each stratigraphic horizon. The protoreferential (see Guex, 1991, p. 6) or "range chart" for all Hettangian and Sinemurian species in the database is shown in Figures 18A and 18B.

Definition of zones

Radiolarian zonation consisting of 25 vertically ordered UA divided into seven zones is distinguished for Lower Jurassic (Hettangian and Sinemurian) strata of the Sandilands Formation (Fig. 19). Each zone contains one or more UA, and each UA is defined by coexisting species pairs and by the totality of its co-occurring species. Thus a sample can be assigned to a zone if one or more of its UA can be identified. Co-existing taxa in a zone are not automatically co-occurrent in the Unitary Associations included in that zone. Because radiolarians are dissolution controlled, morphotypes sparsely represented in one section are sometimes better represented in other sections (see section 16). The UA method considers the combined occurrence (in all sections) of each species and plots its maximum range. The more species included in an assemblage, the broader the assemblage definition, and the easier it can be recognized in poorly preserved material.

Two types of zones are utilized in this zonation: Unitary Associations zones (UAZ) and Interval zones (IZ). Unitary Associations zones are defined by UA alone and are equivalent to concurrent range zones; Interval zones are defined as the interval between two events, i.e. First Appearance Datums (FADs) in one zone and FADs in the immediately overlying zone.

The lower part of the Hettangian cannot be characterized unequivocally by short ranging radiolarian species. To illustrate the concept of increasing radiolarian diversity and the lack of Last Appearance Datums (LADs), three ammonite groups were used in the UA database to constrain these intervals: *Psiloceras* spp., *Euphyllites* ex. gr. *occidentalis*, and *Badouxia* ex. gr. *canadensis*. Without the ammonite data to constrain the biochronology, all lowermost Hettangian Radiolaria would fall within one large zone. New radiolarian zonation for the Hettangian and Sinemurian shown against Ammonite assemblages for this interval (Tipper and Guex, 1994; Pálfy et al., 1994) is illustrated in Figure 20.

Canoptum merum Zone (IZ) (UA 1). Zone defined by the interval separating the first appearance of *Canoptum merum* and the first appearance of *Protokatroma aquila* n. sp. The ammonite genus *Psiloceras* is restricted to the zone. Unitary Association 1 is strictly recognized only in section 9 (Kennecott Point).

Protokatroma aquila Zone (IZ) (UA 2). Zone defined by the interval separating the first appearance of *Protokatroma aquila* and the first appearance of *Pantanellium browni*. The ammonite *Euphyllites* ex. gr. *occidentalis* is restricted to the zone. Unitary Association 2 is strictly identified in sections 1 and 2 (Kunga Island, south) and in section 10 (Kennecott Point).

Pantanellium browni Zone (UAZ) (UA 3-4). Zone defined by the co-existence of *Pantanellium browni* and Spumellarian indet. A. This zone is approximately equivalent to the *Franziceras* Assemblage of Tipper and Guex (1994). Unitary Associations 3-4 are recognized in sections 3 and 8 (Kunga Island, north) and in section 1 (Kunga Island, south).

Crucella hettangica Zone (UAZ) (UA 5-12). Zone defined by the co-existence of *Saitoum triumphense, Ectonocorys*? sp., *Laxtorum hemingense*, *Trexus dodgensis*, *Nitrader montegufonensis, Beatricea christovalensis, Crucella hettangica* and *Pantanellium tanuense, Paronaella ravenensis*, and *Relanus reefensis*. The ammonite *Badouxia* ex. gr. *canadensis* is restricted to the zone. Unitary Associations 6-7 are recognized in section 3 (Kunga Island, north); UA 5, 8, and 9 in section 8 (Kunga Island, north); and UA 10-12 in section 10 (Kennecott Point). Unitary Associations 5-12 (see Fig. 19) are generated by local sequences of distinct and well preserved samples from sections 3, 8, and 10. Such geographically restricted UA sequences are meaningless from a chronological point of view because they show no lateral traceability (see Guex 1991, p. 7-11). For this reason, a more detailed subdivision of the *Crucella hettangica* Zone is not proposed.

Parahsuum simplum Zone (UAZ) (UA 13-16). Zone defined by the co-existence of *Parahsuum simplum* and *Archaeocenosphaera laseekensis*, *Bipedis elizabethae, Tozerium nascens, Thurstonia timberensis*, and *Bipedis hiberniaensis*. This zone is approximately equivalent to the *Arnouldi* Assemblage of Pálfy et al. (1994). Unitary Association 13 is identified in section 16 (Wilson Bay, Tasu Sound); UA 14 and 16 are recognized in section 8 (Kunga Island, north); and UA 15 is identified in section 3 (Kunga Island, north).

Canutus rockfishensis-Wrangellium thurstonense Zone (UAZ) (UA 17-23). Zone defined by the co-existence of *Canutus rockfishensis, Wrangellium thurstonense*, and

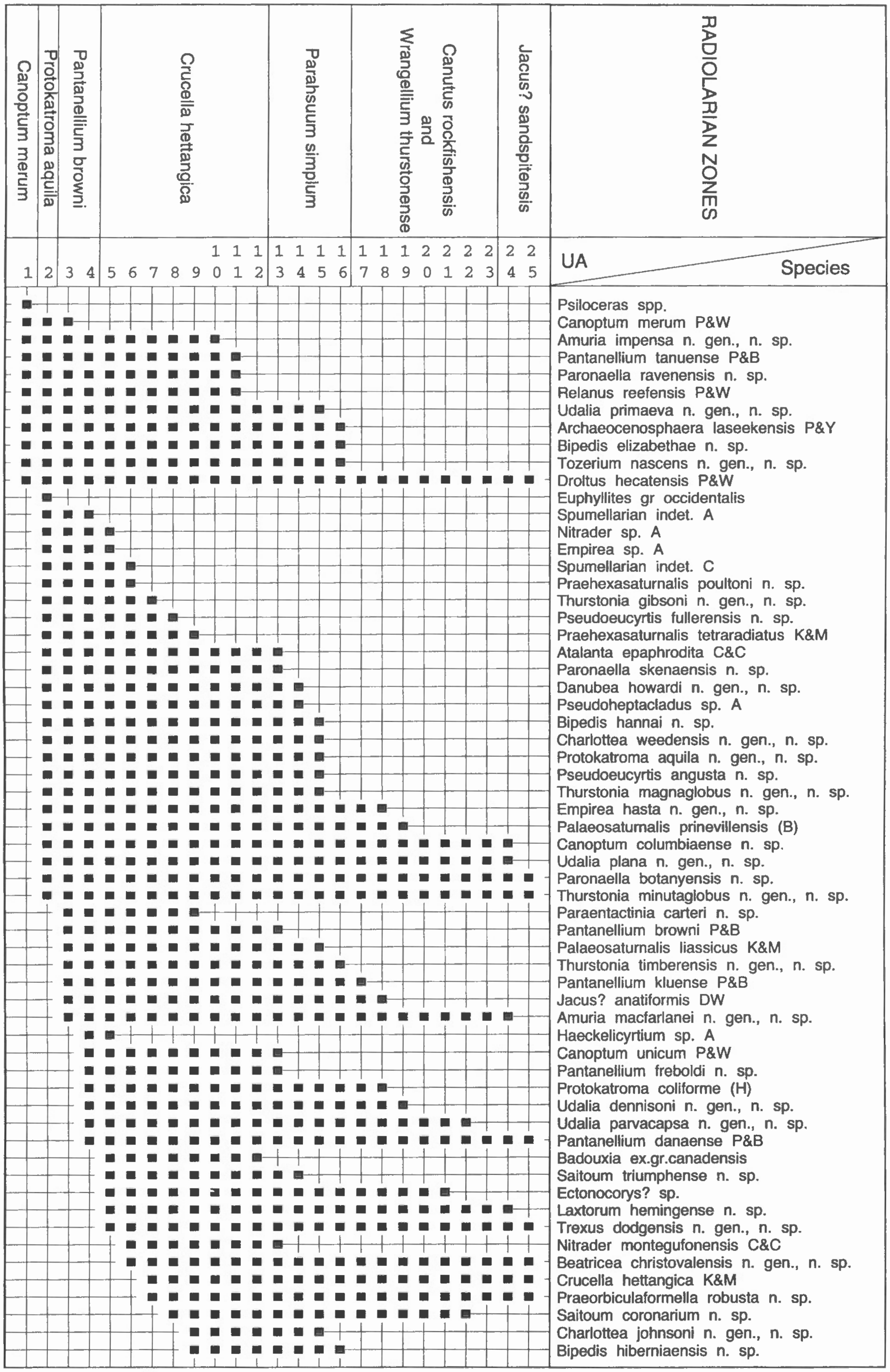


Figure 18. *Protoreferential ("range chart") for Hettangian and Sinemurian radiolarians based on Unitary Associations (output of BioGraph program v. 2.02, Savary and Guex, 1991).* *See note regarding* Protokatroma sp. A, p. 72.

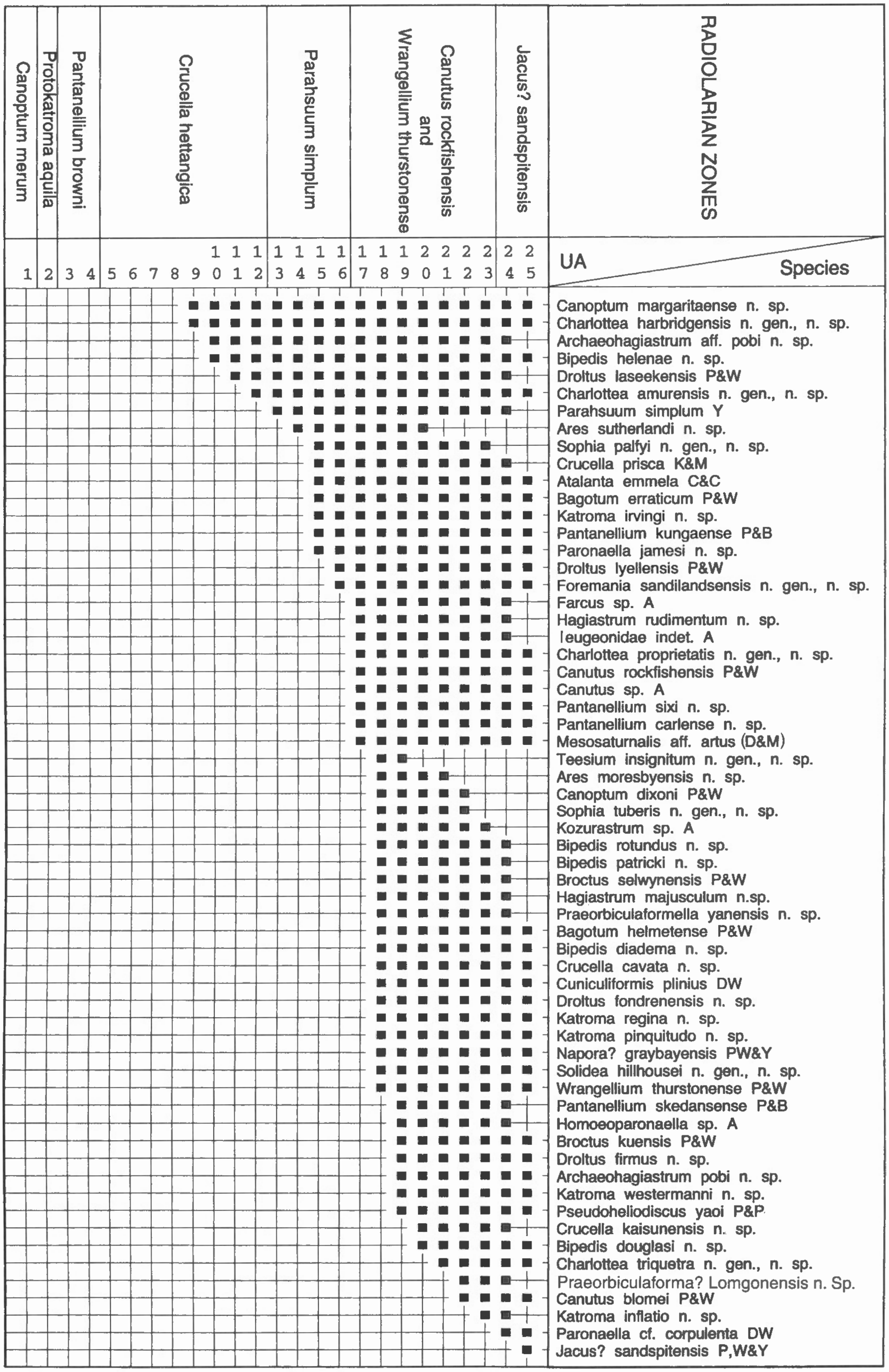


Figure 18. (cont.)

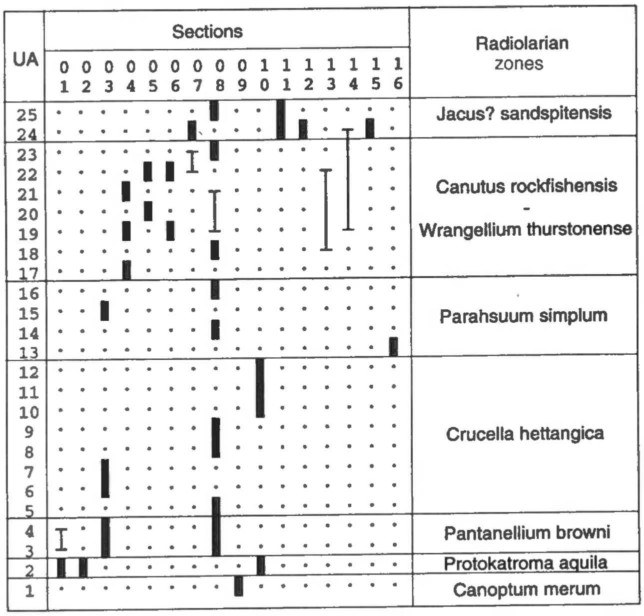


Figure 19. Reproducibility of 25 Unitary Associations from data of investigated sections at Kennecott Point, Kunga Island, central Graham Island, Sandilands Island, Maude Island, and Lomgon and Wilson Bay in Tasu Sound, Queen Charlotte Islands, and correlation to the chronostratigraphy (output of BioGraph program v. 2.02, Savary and Guex, 1991). Solid bars indicate Unitary Associations identified in the sections. Narrow bars indicate adjacent unions of Unitary Associations which are not individually reproducible.

STAGE	AMMONITE ASSEMBLAGES (Tipper and Guex, 1994; Pálfy et al., 1994)	RADIOLARIAN ZONES
	↑ TETRASPIDOCERAS ↑	
SINEMURIAN	HARBLEDOWNENSE	*Jacus? sandspitensis*
	VARIANS	*Canutus rockfishensis-Wrangellium thurstonense*
	ARNOULDI	*Parahsuum simplum*
	"CORONICERAS"	
	CANADENSIS	*Crucella hettangica*
HETTANGIAN	DOETZKIRCHNERI	
	FRANZICERAS	*Pantanellium browni*
	EUPHYLLITES	*Protokatroma aquila*
	PSILOCERAS	*Canoptum merum*

Figure 20. Proposed radiolarian zonation for the Lower Jurassic of Queen Charlotte Islands. Position of new radiolarian zones shown against ammonite zonation for the Hettangian and Sinemurian. Stippled pattern in far right column indicates intervals for which strata and ammonites are present but no radiolarians were obtained.

Sophia palfyi n. sp. The species *Teesium insignitum, Ares moresbyensis, Canoptum dixoni, Sophia tuberis*, and *Kozurastrum* sp. A are restricted to the zone. This zone is approximately equivalent to the *Varians* Assemblage of Pálfy et al. (1994). The faunal assemblages observed in the *C. rockfishensis-W. thurstonense* Zone are highly diverse and the potential for finer subdivision of this zone is clear. However, the stratigraphical superpositions between the taxa occurring in this zone are highly conflicting from one section to another. Such highly contradictory relationships are responsible for the presence of large, strongly connected components in the graph Gk (see Guex, 1991, p. 82-83). We suspect undetected repetitions by faulting and have not subdivided this interval further.

Jacus? sandspitensis (UAZ) (UA 24-25). Zone defined by the occurrence of the index species and by *Paronaella* cf. *corpulenta* De Wever. This zone is approximately equivalent to the *Harbledownense* Assemblage of Pálfy et al. (1994). Unitary Association 24 is recognized in sections 7 (Kunga Island, north), 11-12 (central Graham Island), and 15 (Lomgon Bay, Tasu Sound); UA 25 is recognized in sections 8 (Kunga Island, north) and 11 (Yakoun River, central Graham Island).

The radiolarian zones described above and illustrated on Figure 20 are for local use in Queen Charlotte Islands and nearby areas. Biostratigraphic correlation of sections at Kennecott Point and Kunga Island using these zones is illustrated in Figure 21 (in pocket). The correlation of UA for all sections included in this study is shown on Table 2.

CHRONOSTRATIGRAPHY

Chronostratigraphic correlation with other zonations

The new zonation for the Hettangian and Sinemurian of Queen Charlotte Islands is compared with existing zonation for North America, Japan, and the Russian Far East (Fig. 22).

Comparison with North American zonation

Preliminary radiolarian zonation for the Hettangian and Sinemurian of western North America consisting of three superposed zones was established by Pessagno et al. (1987). The base of Zone 05 (Hettangian) was defined by the first appearance of primary taxa *Canoptum merum* Pessagno and Whalen and *Pantanellium kluense* Pessagno and Blome, and supplementary taxa *P. tanuense* Pessagno and Blome and *Relanus reefensis* Pessagno and Whalen. The top of the zone was defined by the last appearance of *Canoptum merum* Pessagno and Whalen and *Relanus reefensis* Pessagno and Whalen. In new zonation presented here, Zone 05 is divided into three main zones: the *Canoptum merum, Protokatroma aquila*, and *Pantanellium browni*

Table 2. Correlation of radiolarian Unitary Associations in sections 1-15, Queen Charlotte Islands.

Section 1 KUNGA, south
10: 3 - 4
9: 3 - 4
8: 3 - 4
7: 3 - 4
6: 2 - 4
5: 2 - 4
4: 2 - 4
3: 2 - 2
2: 2 - 2
1: 1 - 11

Section 2 KUNGA, south
1: 2 - 2

Section 3 KUNGA, north
18: 15 - 15
17: 15 - 15
16: 15 - 15
15: 7 - 15
14: 7 - 7
12: 6 - 6
11: 6 - 6
10: 6 - 6
9: 5 - 6
8: 4 - 4
7: 4 - 4
6: 4 - 4
5: 4 - 4
4: 4 - 4
3: 3 - 3
2: 3 - 4
1: 2 - 9

Section 4 KUNGA, north
8: 21 - 21
7: 19 - 19
6: 19 - 19
5: 17 - 17
4: 17 - 23
3: 17 - 23
2: 17 - 24
1: 17 - 24

Section 5 KUNGA, north
5: 22 - 22
4: 22 - 22
3: 20 - 20
2: 19 - 24
1: 19 - 25

Section 6 KUNGA , north
8: 22 - 24
7: 22 - 23
6: 22 - 22
5: 22 - 22
4: 19 - 22
3: 19 - 20
2: 19 - 19
1: 19 - 24

Section 7 KUNGA, north
4: 24 - 24
3: 22 - 24
2: 22 - 23
1: 22 - 24

Section 8 KUNGA, north
13: 25 - 25
12: 23 - 23
11: 19 - 21
10: 18 - 18
9: 18 - 18
8: 18 - 18
7: 16 - 16
6: 14 - 14
5: 9 - 9
4: 8 - 8
3: 5 - 5
2: 4 - 4
1: 3 - 3

Section 9 KENNECOTT POINT
4: 1 - 1
3: 1 - 1
2: 1 - 1
1: 1 - 3

Section 10 KENNECOTT POINT
15: 12 - 12
14: 12 - 12
13: 12 - 12
12: 11 - 11
11: 9 - 10
10: 10 - 10
9: 5 - 10
8: 2 - 2
6: 2 - 2
5: 2 - 2
4: 2 - 2
3: 2 - 2
2: 2 - 2
1: 2 - 2

Section 11 YAKOUN RIVER
3: 25 - 25
2: 24 - 24
1: 24 - 24

Section 12 GRAHAM ISLAND
2: 22 - 24
1: 24 - 24

Section 13 SANDILANDS ISLAND
3: 18 - 22
2: 18 - 22
1: 15 - 22

Section 14 MAUDE ISLAND
1: 19 - 24

Section 15 LOMGON BAY
1: 24 - 24

Section 16 WILSON BAY
1: 13 - 13

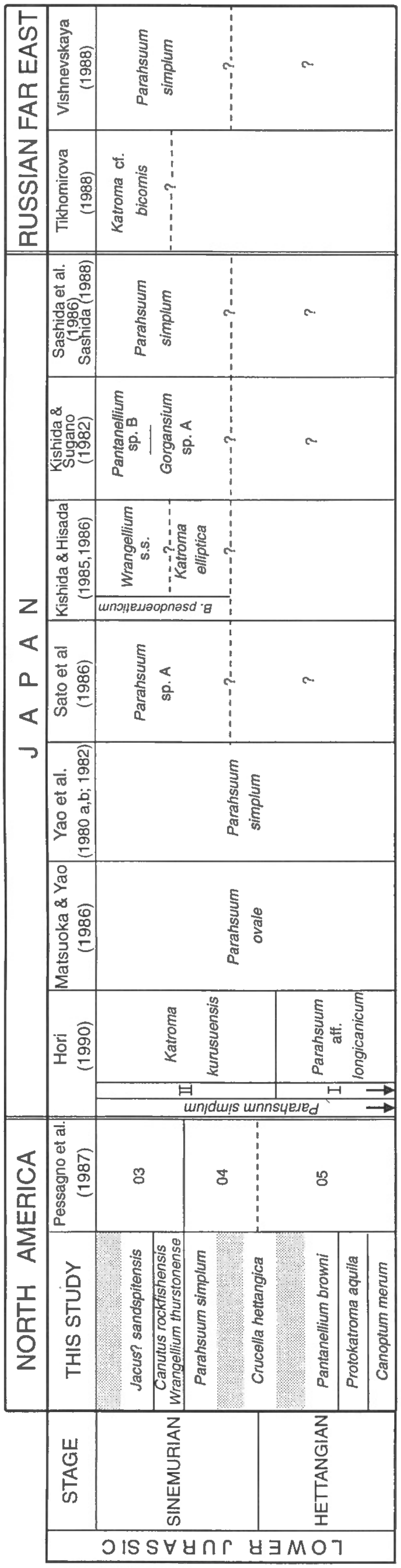


Figure 22. *Correlation of newly proposed radiolarian zones with radiolarian zones proposed for North America, Japan, and eastern Russia from 1980 to 1990. Stippled pattern in second left column indicates intervals for which strata and ammonites are present but no radiolarians were obtained.*

zones in ascending order, plus an upper undefined interval, and the lower part of the *Crucella hettangica* Zone. *Canoptum merum* Pessagno and Whalen ranges through all three zones but no higher. *Pantanellium tanuense* Pessagno and Blome and *Relanus reefensis* Pessagno and Whalen first appear in the *Canoptum merum* Zone and range into the *Crucella hettangica* Zone which is latest Hettangian-earliest Sinemurian in age. In our zonation, *Pantanellium kluense* Pessagno and Blome does not appear until the *Pantanellium browni* Zone.

Zone 04 of Pessagno et al. (1987) was interpreted to be lower Sinemurian. The base was defined primarily by the first appearance of *Crucella* Pessagno s.s. and *Katroma* Pessagno and Poisson, and secondarily by the first occurrence of the Hagiastridae Riedel (sensu Baumgartner, 1980). The top of the zone was defined by the final appearance of *Pantanellium kungaense* Pessagno and Blome. In our new zonation, Zone 04 is divided into the *Crucella hettangica* Zone (upper part), a middle undefined interval, and the upper *Parahsuum simplum* Zone. The first appearance of *Crucella* Pessagno s.s. and *Archaeohagiastrum* Baumgartner occurs in the *Crucella hettangica* Zone and the first appearance of *Katroma* Pessagno and Poisson takes place in the *Parahsuum simplum* Zone. In contrast to the zonation of Pessagno et al. (1987), we find that *Pantanellium kungaense* Pessagno and Blome ranges to the top of the Sinemurian.

The base of Zone 03 (upper Sinemurian) was defined by the first appearance of *Canutus* Pessagno and Whalen s.s. and by the supplementary taxon *Wrangellium* Pessagno and Whalen; the top was defined by the final appearance of *Pantanellium danaense* Pessagno and Blome. We have subdivided Zone 03 into the lower *Canutus rockfishensis-Wrangellium thurstonense* Zone and the upper *Jacus*? *sandspitensis* Zone. *Canutus* s.s. and *Wrangellium* are distinctive marker taxa that first appear near the base of the upper Sinemurian. *Pantanellium danaense* is too rare and variable in our samples to be used as a zonal marker.

Comparison with zonations from Japan

Parahsuum simplum Yao is an important indicator in all radiolarian zonal schemes in Japan (see Fig. 22). In contrast to the Japanese succession, *Parahsuum simplum* does not appear in Queen Charlotte Islands until the lower Sinemurian and is not abundant until the Pliensbachian (E.S. Carter, unpub. data, 1994). It is possible that paleoceanographic conditions in the earliest Jurassic precluded the presence of *Parahsuum simplum* in the northeastern Pacific in the Hettangian. On the other hand, the well dated successions in Queen Charlotte Islands may reflect a more accurate range for this species than reported previously. Lacking *Parahsuum*, satisfactory correlation with Japanese zonations is difficult unless other genera comparable to ours (e.g. *Bagotum, Bipedis, Droltus, Canutus, Katroma,* *Wrangellium*) are present. This difficulty is compounded by the fact that very few Hettangian taxa described here have been recognized in Japan. In general, Japanese faunas compare reasonably well with our Sinemurian faunas; the first appearance of genera such as *Ares* De Wever, *Bagotum* Pessagno and Whalen, *Katroma* Pessagno and Poisson, and *Wrangellium* Pessagno and Whalen roughly coincides in both Japan and Queen Charlotte Islands.

Correlation with Hori (1990)

Hori (1990) established three zones for the uppermost Triassic and Lower Jurassic. The lowermost zone, the *Parahsuum simplum* Zone, was believed to span the Rhaetian, Hettangian, Sinemurian, Pliensbachian, and lower Toarcian. The base of this zone is defined by the first appearance of *Parahsuum simplum* Yao in association with *Dictomitrella* sp. C (the latter bears moderate resemblance to *Proparvicingula moniliformis* Carter). Hori divided the *Parahsuum simplum* Zone into four subzones; the lowest of these, the *Parahsuum* aff. *longiconicum* Subzone, is probably equivalent to the *Proparvicingula moniliformis* and *Globolaxtorum tozeri* zones of Carter (1993) plus the *Canoptum merum*, *Protokatroma aquila*, and *Pantanellium browni* zones (Hettangian) in our new zonation. Hori suggests that many of the species characterizing the *Parahsuum* aff. *longiconicum* Zone range downwards into the topmost Triassic *Canoptum triassicum* Assemblage-zone of Yao (1982). In Queen Charlotte Islands, there is a very sharp break between the topmost Rhaetian *Globolaxtorum tozeri* Zone and the lowermost Hettangian *Canoptum merum* Zone with almost no species crossing the Triassic-Jurassic boundary.

Hori's overlying *Katroma kurusuensis* Subzone is defined by the co-occurrence of *K. kurusuensis* and *Gigi* aff. *fustis* and is considered to be Sinemurian to ?lower Pliensbachian. The genera *Ares* De Wever and *Bagotum* Pessagno and Whalen first appear in this zone and many species of *Bipedis* De Wever are present also. The lower part of the *Katroma kurusuensis* Subzone is likely equivalent to the *Crucella hettangica*, *Parahsuum simplum*, *Canutus rockfishensis-Wrangellium thurstonense*, and *Jacus*? *sandspitensis* zones in Queen Charlotte Islands. In these zones, we also note the first appearance of *Ares* and *Bagotum* plus the increasing diversity of *Bipedis* De Wever. *Gigi* De Wever is not present in any of our Sinemurian zones and does not appear until the lower Pliensbachian in Queen Charlotte Islands (E.S. Carter, unpub. data, 1987).

Correlation with Matsuoka and Yao (1986)

Based on earlier zonations by Yao et al. (1980a, b, 1982), Matsuoka and Yao (1986) proposed three radiolarian zones for the Lower Jurassic of southwest Japan defined by biohorizons of the first and last appearance of characteristic species. The lowest of these zones (an interval zone) was originally designated the *Parahsuum* sp. C (= *P. ovale* Hori and Yao 1988) Zone and defined by the interval between the first appearance of *P. simplum* Yao and the first appearance of *Archicapsa pachyderma* Tan Sin Hok. The authors also state that species of *Parahsuum, Canoptum, Katroma*, and *Bipedis* occur abundantly in this zone. The age was determined to be earliest Jurassic. The *Parahsuum ovale* Zone overlies the *Canoptum triassicum* Zone which, in addition to the nominal species, contains typically Rhaetian taxa such as *Dreyericyrtium* sp. A and *Palaeosaturnalis bifidus* (Kozur and Mostler). The lower part of the long-ranging *Parahsuum ovale* Zone probably correlates with all new Hettangian and Sinemurian zones described in this paper. We cannot confirm the upper range of the *P. ovale* Zone because the species *Archicapsa pachyderma* has not been found in Queen Charlotte Islands.

Correlation with Sato, Murata and Yoshida (1986)

Sato et al. (1986) established the *Parahsuum* sp. A Zone for earliest Jurassic strata in the southern part of the Chichibu terrane in Kyushu. In addition to the nominal species, the *Parahsuum* sp. A Zone contains taxa such as *Katroma* sp. A, *Canoptum rugosum* Pessagno and Poisson, and *C. poissoni* Pessagno. The lower and middle parts of this zone probably correlate with the *Parahsuum simplum*, *Canutus rockfishensis-Wrangellium thurstonense*, and *Jacus*? *sandspitensis* zones proposed herein but the upper part more likely extends into the Pliensbachian.

Correlation with Kishida and Sugano (1982), Kishida and Hisada (1985, 1986)

Kishida and Sugano (1982) established four assemblage zones for uppermost Triassic and lowermost Jurassic strata from the Southern Chichibu terrane in Shikoku and Kyushu, Japan. The *Pantanellium* sp. B – *Gorgansium* sp. A Assemblage was originally believed to be Rhaetian but later determined to be earliest Jurassic. Neither of these zonal indicators are present in our assemblages. Kishida and Hisada (1986) subsequently revised the *Pantanellium* sp. B – *Gorgansium* sp. A Zone to the *Bagotum pseudoerraticum* Assemblage and later subdivided it into the lower *Katroma elliptica* Subassemblage and the upper *Wrangellium* s.s. Subassemblage. These subassemblages do not correlate with any of our Hettangian zones because the genus *Bagotum* does not appear in Queen Charlotte Islands until the lower Sinemurian. Furthermore, none of the species illustrated by Kishida and Hisada (1986) resemble our Hettangian faunas. If the base of the *Wrangellium* s.s. Subzone coincides with the first appearance of *Wrangellium* in Japan, then the lower part of *Wrangellium* s.s. Subassemblage may correlate with our *Canutus rockfishensis – Wrangellium thurstonense* Zone.

Correlation with Sashida, Tonishi and Igo (1986), Sashida (1988)

Sashida et al. (1986) recognized three radiolarian assemblage zones in Lower Jurassic strata in the Kanto region of the Chichibu terrane. Sashida (1988) later proposed four zones for this interval based on new sections in the Kanto Mountains. The *Parahsuum simplum* Assemblage is basal in each zonal scheme. This assemblage correlates with all Sinemurian zones proposed here but we cannot confirm it is Hettangian.

Comparison with zonations from eastern Russia

In the Russian Far East, Tikhomirova (1988) proposed four radiolarian assemblages for the Lower Jurassic. The lower part of Assemblage R:2 (beds with *Katroma*(?) cf. *bicornis*) may correlate with our upper Sinemurian zones but in our estimation, this assemblage is more likely uppermost Sinemurian to Pliensbachian. In Vishnevskaya's (1988) twelve-fold zonation for the Hettangian to Albian Tethyan and Pacific margin of Russia, the lowest assemblage, the *Parahsuum simplum* Assemblage, probably correlates with our newly proposed Sinemurian zones but again, we cannot confirm the Hettangian.

PALEOBIOGEOGRAPHY

Ammonite biogeography

Since the Lower Jurassic ammonite faunas of Queen Charlotte Islands provide the biostratigraphic framework for the new radiolarian biochronology presented here we should briefly examine the biogeography of this group first. Hettangian and Sinemurian ammonite faunas of Queen Charlotte Islands are broadly allied to the Tethyan Realm. The Hettangian fauna contains many cosmopolitan ammonites commonly regarded as Tethyan and totally lacks Boreal forms. The diverse Sinemurian fauna is mostly cosmopolitan or pandemic but Pálfy (1991) indicates that some families of Lytoceratina and Phylloceratina are likely indicators of the Tethyan Realm, and a few genera are endemic, prominently eastern Pacific, such as the genus *Badouxia*. Sinemurian faunas are closely related to the faunas of western Canada (Taseko Lakes area), southern United States (Nevada), southern Europe, and South America (Pálfy, 1991).

Radiolarian biogeography

Evidence for cosmopolitan distribution

The radiolarian succession in the Sandilands Formation of Queen Charlotte Islands is the best Hettangian to Sinemurian sequence known. The radiolarians are diverse and the many new species described in this paper, in addition to those described previously from Queen Charlotte Islands (Pessagno and Blome, 1980; Pessagno and Whalen, 1982; Pessagno et al., 1986; Cordey and Carter, 1996), Bavaria (Kozur und Mostler, 1990), and northeast China (Yang and Mizutani, 1991), provide an extensive database that can be used for biogeographic studies. Information on Hettangian and Sinemurian faunas in other areas is sparse.

In our samples, species reported from other localities include the following: *Crucella hettangica, C. carteri, C. prisca, Palaeosaturnalis liassicus*, and *Praehexasaturnalis tetraradiatus*, described by Kozur and Mostler (1990) from the upper Hettangian of Bavaria; as well as *Relanus reefensis* Pessagno and Whalen (= *Relanus hettangicus* Kozur and Mostler), *Cuniculiformis plinius, Jacus*? *anatiformis, Paronaella* sp. cf. *P. corpulenta, Ectonocorys*? sp., and gen. and sp. indet. 1, 2, 3 (= *Foremania sandilandsensis* Whalen and Carter n. gen., n. sp.), described by De Wever (1981a, 1982), and *Pseudoheliodiscus yaoi* (Pessagno and Poisson, 1981) from the Liassic (Pliensbachian) of Turkey; and *Parahsuum simplum* Yao 1982 from the Lower Jurassic of Japan. Elsewhere, *Pseudoheliodiscus* (?) sp. (= *Praehexasaturnalis tetraradiatus* Kozur and Mostler), and *Katroma* sp. 2 (= *Pseudoeucyrtis angusta* Whalen and Carter n. sp.) have been reported from the Vizcaino Peninsula, Baja California Sur (Whalen and Pessagno, 1984); *Cuniculiformis plinius* De Wever, *Eucyrtis*? sp. (= *Protokatroma aquila* Whalen and Carter n. gen., n. sp.), *Pantanellium tanuense* Pessagno and Blome, and *Pseudocrucella* sp. (= *Crucella hettangica* Kozur and Mostler) are present at Kawakawa Bay, New Zealand (Sporli and Aita, 1988); *Palaeosaturnalis liassicus* Kozur and Mostler and *Praehexasaturnalis tetraradiatus* Kozur and Mostler occur in the Nadanhada Terrane, northeast China (Yang and Mizutani, 1991); *Droltus hecatensis* Pessagno and Whalen, *Pantanellium kungaense* Pessagno and Blome, *Tetraditryma* sp. A (= *Archeohagiastrum* sp. aff. *A. pobi* Whalen and Carter, herein) (Hattori, 1987, 1988), and *Syringocapsa* sp. B (= *Katroma westermanni* Whalen and Carter n. sp.) (Imoto et al., 1982) are reported from Japan; and *Canoptum dixoni* Pessagno and Whalen is known in Primorye, Russian Far East (Oleinik, 1993). These limited occurrences bolster our belief that in spite of the many species extinctions at the end of the Triassic (Carter, 1993, 1994a, b) some surviving genera and newly appearing species were able to achieve cosmopolitan distribution by the middle to upper Hettangian and Sinemurian.

Widely distributed genera include *Crucella* Pessagno, *Pantanellium* Pessagno, the saturnalids *Palaeosaturnalis, Pseudoheliodiscus, Praehexasaturnalis*, and *Pseudacathocircus* described by Kozur and Mostler, and nassellarians *Cuniculiformis* De Wever, *Droltus* Pessagno and Whalen, *Katroma* Pessagno and Poisson, *Parahsuum* Yao, *Protokatroma* Whalen and Carter n. gen., *Pseudoeucyrtis* Pessagno, and *Relanus* Pessagno and Whalen. Species occurring in Queen Charlotte Islands and in other localities include the following: *Ares moresbyensis* Whalen and Carter n. sp. (Baja California Sur); *Crucella hettangica* Kozur and Mostler (Bavaria, Japan, New Zealand); *C. prisca* Kozur and Mostler (Bavaria, Japan); *Droltus hecatensis* Pessagno and Whalen (Japan); *Katroma westermanni* Whalen and Carter n. sp. (Japan); *Palaeosaturnalis liassicus* Kozur and Mostler (Bavaria, northeast China); *Pantanellium kungaense* Pessagno and Blome (Japan); *Pantanellium tanuense* Pessagno and Blome (Montenegro, New Zealand); *Praehexasaturnalis tetraradiatus* Kozur and Mostler (Baja California Sur, Bavaria, and northeast China); *Pseudoheliodiscus yaoi* Pessagno and Poisson (Turkey); *Cuniculiforma plinius* (New Zealand, Turkey), *Jacus*? *anatiformis* De Wever (Japan, Turkey), *Parahsuum simplum* Yao (Japan), and *Relanus reefensis* Pessagno and Whalen (Bavaria) (see synonymies for each species mentioned).

No endemic species are known in Queen Charlotte Islands but if the distribution of Lower Jurassic radiolarians and ammonites are in any way related, future biogeographic studies may ascertain the presence of an Eastern Pacific radiolarian fauna.

Paleolatitudinal affinities and the role of preservation

Thus far, the Upper Jurassic biogeographic model of Pessagno and Blome (1986) and a similar model for the Upper Triassic and Lower Jurassic by Blome (1987) are the only attempts to use radiolarians as paleolatitudinal indicators for the Mesozoic. In the Upper Jurassic model (Pessagno and Blome, 1986; Pessagno et al., 1993), the Pantanelliidae and Parvicingulidae are used as paleolatitudinal indicators of the Tethyan and Boreal realms. The pantanelliids are believed to be abundant and diverse in northern and southern Tethyan assemblages, less diverse and abundant in southern Boreal and northern Austral assemblages, and totally lacking in the northern Boreal and southern Austral assemblages. In the Upper Triassic to Lower Jurassic model of Blome (1987), pantanellids and other groups are used to biogeographically differentiate high latitude faunas of the Brooks Range, northern Alaska, from the lower latitude faunas of southern Alaska to central Mexico. This model applies directly to Sinemurian faunas of Queen Charlotte Islands and is discussed in more detail below. The Pantanelliidae are thus central to both paleobiogeographic models and as such have garnered much attention from the radiolarian community. In an alternative theory of pantanellid distribution and abundance, Baumgartner (1984, 1987) suggests that abundant pantanelliids are indicative of high fertility upwelling areas, based on his studies of Tethyan samples from the Jurassic Atlantic and Mediterranean. Upwelling is common along the western coasts of continents (Beers and Stewart, 1967, 1969, 1971; Casey et al., 1982), and in the modern ocean is recognized in the Santa Barbara Basin off southern California (Casey et al., 1986; Weinheimer, 1986).

Hettangian and Sinemurian faunas of Queen Charlotte Islands contain abundant *Pantanellium* Pessagno. Diversity increases gradually from a single species (*Pantanellium tanuense* Pessagno and Blome (see also Hull, 1995)) in low diversity assemblages of the lower Hettangian to over a dozen species by the upper Sinemurian. *P. tanuense* ranges from the base of the Hettangian to the uppermost Hettangian or lowest Sinemurian and is the oldest Jurassic species of *Pantanellium*. It has a huge cortical shell composed of large, simply-packed, hexagonal pore frames and a relatively large medullary shell of similar configuration. In older specimens, polar spines (one or both) are frequently circular in axial section (see Pl. 1, fig. 4), but by the middle to upper Hettangian all spines are triradiate and this morphological descriptor remains constant through the range of the genus. In lowest Hettangian assemblages *P. tanuense* and *Archaeocenosphaera laseekensis* Pessagno and Yang (another possibly primitive form with simple, hexagonally-packed pore frames) are both extremely abundant and together compose well over 50% of specimens. This suggests that in conjunction with being a probable indicator of high oceanic fertility the genus *Pantanellium* is an opportunist capable of rapidly colonizing empty niches, in this case niches vacated by the massive extinction of radiolarian species at the end of the Triassic (Carter, 1993, 1994a, b). *Pantanellim* becomes much more diverse by the Sinemurian and Pliensbachian (Pessagno and Blome, 1980; E.S. Carter, unpub. data, 1993) and genus abundance is distributed over a whole spectrum of new species.

In an effort to discriminate between the high latitude Sinemurian faunas of the Brooks Range, Alaska, and low latitude faunas of Queen Charlotte Islands, Blome (1987) plotted the abundance of pantanelliids, "undescribed ferressids" (= the Subfamily Charlotteinae described herein i.e. *Charlottea, Danubea, Sophia, Thurstonia*, and *Tozerium*), canoptids, and pseudoheliodiscids in two samples from each area (Queen Charlotte Island species counts from P.A. Whalen, written comm. to Blome, 1986). The resulting histogram (Blome, 1987, p. 376, Fig. 7) shows that Brooks Range faunas are characterized by abundant charlotteids and canoptids, and considerably fewer pseudoheliodiscids and pantanellids. Conversely, Queen Charlotte Islands faunas are characterized by abundant pantanellids and common charlotteids, while canoptids and pseudoheliodiscids are rare to absent. Blome (1987) further mentions that species of the nassellarian Bagotidae Pessagno and Whalen (e.g. *Bagotum, Broctus*, and *Droltus*) are much more abundant in Queen Charlotte Islands than in the Brooks Range.This biogeographic assessment of Queen Charlotte Islands' faunas generally holds true for well preserved samples. However, we note that in moderate to poorly preserved samples pantanellids are usually rare, and the more robust canoptids are more common. Pantanellids are also absent in Toarcian and Aalenian radiolarian faunas of Queen Charlotte Islands (Carter et al., 1988) which in all other respects have strong affinities to Tethyan assemblages in other parts of the world. These examples illustrate the kinds of problems introduced by preservational bias when dealing with groups such as the pantanellids that can so easily be destroyed during diagenesis and/or processing (for discussion of preservational bias see Blome and Reed, 1993; Hull, 1995). It also points to the necessity of using only abundant, well preserved faunas when assessing the biogeographic potential of Radiolaria.

Conclusions

1. Earliest Jurassic radiolarian faunas are diverse and, based on faunal comparison with the few localities of this age reported, some species were able to achieve cosmopolitan distribution by the middle to late Hettangian and Sinemurian.
2. No endemic species are presently known from Queen Charlotte Islands.
3. Hettangian and Sinemurian radiolarians of Queen Charlotte Islands have affinities to the Tethyan Realm based on the presence of abundant pantanellids, charlotteids, bagotids, and other low latitude species.
4. As evidenced from lowest Hettangian assemblages, the genus *Pantanellium* Pessagno is an opportunist, able to colonize open niches very rapidly. The nutrient-rich environment of offshore upwelling areas may aid greatly in this process.
5. The possibility of preservational bias should always be considered when using pantanellids for interpreting paleolatitude. Therefore, only abundant, well preserved samples should be utilized for this purpose.

PART II. SYSTEMATIC PALEONTOLOGY

(P.A. Whalen and E.S. Carter)

INTRODUCTION

Radiolarian taxonomy follows chiefly the polycystine systematic classification of Riedel (1967a, b, 1971) and Deflandre (1963) with modifications by Pessagno (1971, 1973, 1977b, Foreman (1973), Dumitrica (1978, 1985, 1995), Kozur and Mostler (1979), Baumgartner (1980), Pessagno and Blome (1980), De Wever (1981a, 1982, 1984), Pessagno and Whalen (1982), and Pessagno et al. (1979, 1986, 1989). Radiolarians are classified to family where possible; genera and species are discussed alphabetically.

Basis for description of new taxa

Definitions of new taxa are based where possible on elements of internal structure as well as external diagnostic features of the cortical shell that are visible with the binocular or scanning electron microscope. Some of Whalen's specimens were also photographed in transmitted light. Less certainly identifiable forms, such as those poorly preserved, those with nondiagnostic or incompletely understood morphology, or those represented by insufficient numbers for variation to be documented, are recorded in open nomenclature.

Measurements of the Pantanellidae follow a system of measurements proposed by Pessagno and Blome (1980, p. 241); those of the Hagiastridae and Patulibracchiidae follow Pessagno (1971, p. 18), and those for the Subfamily Charlotteinae are illustrated on Plate 4, figure 11. Among the Nassellariina, both the length and maximum width of the test are measured. Length of horn is measured separately and is not included in total test length. For other supraspecific taxa, measurements are normally self-explanatory.

Repository

Holotypes and some paratypes illustrating specific morphological features were mounted on standard aluminum SEM stubs, coated with gold/palladium, and photographed with the scanning electron microscope. Holotypes and all illustrated SEM material are catalogued and deposited with the Geological Survey of Canada, Ottawa, under numbers GSC 107675 to GSC 107910 and GSC 108549 to GSC 108669.

Phylum PROTOZOA
Subclass RADIOLARIA Müller 1858
Order POLYCYSTINA Ehrenberg 1838, emend. Riedel 1967b
Suborder SPUMELLARIINA Ehrenberg 1875
Family ENTACTINIIDAE Riedel 1967

Type genus. Entactinia Foreman 1963.

Range. Paleozoic (Devonian)-Mesozoic (Cretaceous).

Occurrence. Worldwide.

Genus *Parentactinia* Dumitrica 1978

Type species. Parentactinia pugnax Dumitrica 1978.

Range. Triassic (Ladinian)-Lower Jurassic (Hettangian).

Occurrence. Italy, Romania, Japan, and British Columbia.

Parentactinia carteri Whalen and Carter n. sp.
Plate 8, figures 3, 4, 8, 11, 14
Species code: PET01

Description. Test with closed, subspherical latticed shell and three apical spines. Spines oblique to short median bar, circular in axial section, tapering distally with one spine much longer and more massive than other two. Four sigmoidal basal spines all approximately equal in length, circular in axial section, tapering distally; each basal spine attached to latticed shell along longer, proximal part of sigmoidal curve, extending beyond the shell along the shorter, distal part of sigmoidal curve; all basal spines exposed along entire length but slightly recessed in a broad trough. Latticed shell attached to basal spines by irregular, transverse bars; large, irregularly shaped and sized polygonal pore frames inserted between transverse bars and basal spines; very large, triangular pores formed on latticed shell at junction of basal spines and apical spines.

Remarks. Parentactinia carteri n. sp. is distinguished from *P. inerme* Dumitrica 1978, in possessing one large and two small apical spines rather than three equal-sized apical spines.

Etymology. This species is named for Dr. James Carter, Program for Geosciences, University of Texas at Dallas.

Measurements (μm).

Maximum diameter of cortical shell	Length of basal spines*	Length of apical spine	
180	43	135	Holotype
203	143	135	Maximum, 7 specimens
150	90	75	Minimum, 7 specimens
173	108	101	Mean, 7 specimens

* Section of basal spine attached to cortical shell.

Type locality. QC-543. See Locality Descriptions, Appendix 1.

Range. Pantanellium browni Zone to *Crucella hettangica* Zone. Lower Jurassic; middle to upper Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107769 (holotype) from type locality; GSC 107770 (paratype) from QC-545. See occurrence chart, Figure 16.

Subfamily CHARLOTTEINAE Whalen and Carter, n. subfam.

Type genus. Charlottea Whalen and Carter n. gen.

Description. Test varying in outline from spherical, subspherical to triangular (with planiform upper and lower surfaces) with two, three, four, or six primary spines. Cortical shell with two layers; outer layer with polygonal pore frames (commonly triangular or tetragonal) usually with prominent nodes at pore frame vertices; pore frame bars usually much thinner in Y direction than Z direction (refer to Pl. 4, fig. 11 for measurement system); inner layer composed of large, loosely constructed polygonal pore frames; vertices of polygonal pore frames of inner layer aligned with nodes of outer layer. Centre of test with eccentric spicular network connected to primary spines by primary radial beams.

Remarks. Xenorum Blome 1984a is tentatively included in this subfamily but is distinguished from Charlottea n. gen. by the presence of twisted spines.

Range. Upper Triassic (upper Carnian?; lower Norian) to Lower Jurassic (Toarcian).

Occurrence. Alaska, British Columbia, east-central Oregon, California, Baja California Sur.

Genus *Charlottea* Whalen and Carter n. gen.

Type species. Charlottea amurensis Whalen and Carter n. sp.

Description. Test with three prominent spines in same plane, equally spaced or with two spines closer together; spines triradiate in axial section, tapering distally. Cortical shell spherical to subspherical, sometimes triangular in outline with flattened upper and lower surfaces. Outer layer of pore frames on cortical shell irregularly shaped (usually tetragonal, triangular, pentagonal) and sized, with nodes at pore frame vertices; larger pores on cortical shell sometimes observed at base of spines.

Remarks. The external morphology of *Charlottea* n. gen. and *Ferresium* Blome is very similar but the inner structure is different: *Charlottea* n. gen. contains an eccentric spicular meshwork occupying a large part of the central area of the test; *Ferresium* Blome contains a small microsphere surrounded by a loosely constructed inner spongy meshwork of bars and small arches (see Family Ferresidae of Carter 1993, p. 68). *Charlottea* n. gen. is distinguished from all other genera of the Subfamily Charlotteinae by having three straight spines in the same plane.

Etymology. Charlottea n. gen. is named for the British ship *Queen Charlotte*, for which Captain George Dixon named the Queen Charlotte Islands in August of 1787.

Range. Lower Jurassic; Hettangian-Toarcian.

Occurrence. Queen Charlotte Islands, British Columbia; east-central Oregon.

Charlottea amurensis Whalen and Carter n. sp.
Plate 2, figures 8, 9, 10, 19; Plate 3, figures 1, 2, 9
Species code: CHA02

?*Acaeniotyle* spp. – Hattori 1989, Pl. 1, fig. G.

Description. Test with medium-sized cortical shell and three moderately long spines. Cortical shell subspherical and somewhat compressed in plane of spines; cortical shell composed of medium-sized, irregularly shaped, tetragonal and triangular pore frames with prominent elongated nodes at pore frame vertices; pore frame bars much thinner in Y direction than Z direction (refer to Pl. 4, fig. 11 for measurement system); large pores sometimes located on cortical shell at base of spines. Internal spicular network composed of delicate pore frames with no difference in thickness between Y and Z directions and no apparent pattern or orientation. Spines tapering distally, usually shorter than diameter of cortical shell, triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves; spines evenly spaced around cortical shell.

Remarks. The more delicate, elongated nodes and triradiate spines of *Charlottea amurensis* n. sp. distinguish it from *C. johnsoni* n. sp.

Etymology. This species is named for Amur Rocks in Dana Passage, located to the northwest of the type locality.

Measurements (μm).

Maximum diameter of cortical shell	Maximum length of primary spines	
146	105	Holotype
150	120	Maximum, 7 specimens
138	75	Minimum, 7 specimens
147	95	Mean, 7 specimens

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. *Crucella hettangica* Zone-*Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107706 (holotype) and GSC 107709 (paratype) from type locality; GSC 107708 (paratype) from 86-OF-KUB-2; and GSC 107707 (paratype) from QC-674. See occurrence chart, Figure 16.

Charlottea harbridgensis Whalen and Carter n. sp.
Plate 3, figures 3, 4, 6, 7, 8, 11, 12, 15
Species code: CHA04

Description. Test with small cortical shell and three relatively long, stout spines. Cortical shell nearly spherical with irregularly sized and shaped tetragonal, pentagonal, and triangular pore frames with low, rounded nodes at pore frame vertices; pore frame bars usually thinner in Y direction than Z direction. Internal spicular network composed of thin, delicate pore frames with no apparent pattern or orientation. Spines tapering distally, triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded grooves; length of spines approximately equal to or exceeding diameter of test; spines evenly spaced around cortical shell.

Remarks. The relatively longer spines and less prominent nodes of *Charlottea harbridgensis* n. sp. distinguish it from *C. amurensis* n. sp.

Etymology. This species is named for Harbridge Point on Talunkwan Island, located to the northwest of the type locality.

Measurements (μm).

Maximum diameter of cortical shell	Maximum length of primary spines	
120	101	Holotype
120	113	Maximum, 11 specimens
98	83	Minimum, 11 specimens
109	100	Mean, 11 specimens

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. *Crucella hettangica* Zone-*Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107710 (holotype), GSC 107711 (paratype), and GSC 107712 (paratype) from type locality. See occurrence chart, Figure 16.

Charlottea johnsoni Whalen and Carter n. sp.
Plate 3, figures 5, 10, 13, 14
Species code: CHA06

Description. Test with medium-sized, spherical cortical shell and three prominent spines. Cortical shell with variably sized (mostly large) and shaped (triangular and tetragonal) pore frames with massive, raised, rounded nodes at pore frame vertices; pore frame bars moderately thin along Y, much thicker along Z; three large elliptical pores at base of spines. Spines triradiate in axial section proximally with rounded ridges and grooves becoming circular in axial section throughout remaining length of spine. All spines long, approximately equal in length, with two spines closer together than third spine.

Remarks. See remarks under *C. amurensis* n. sp.

Etymology. This species is named in honor of Campbell Johnson, mining engineer at Hawksnest mine, a copper mine near Heming Head, Queen Charlotte Islands, British Columbia, in the early 1900s.

Measurements (μm).

Maximum diameter of cortical shell	Maximum length of primary spines	
143	75	Holotype
150	79	Maximum, 6 specimens
120	60	Minimum, 6 specimens
134	68	Mean, 6 specimens

Type locality. QC-574. See Locality Descriptions, Appendix 1.

Range. Crucella hettangica Zone-*Parahsuum simplum* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107713 (holotype) and GSC 107714 (paratype) from type locality. See occurrence chart, Figure 16.

Charlottea proprietatis Whalen and Carter n. sp.
Plate 4, figures 1, 6, 7, 8, 9, 10, 13
Species code: CHA03

Description. Test with large, inflated cortical shell with three long, broad spines. Cortical shell subspherical in shape and subrectangular in outline with irregularly sized and shaped tetragonal and triangular pore frames with prominent, elongated nodes at pore frame vertices; pore frame bars thin in Y direction, much thicker in Z direction; larger pores usually located at base of spines. Internal spicular network composed of thin, coarsely interwoven pore frames with no apparent pattern or orientation. Spines triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves; spines evenly spaced around cortical shell.

Remarks. The distinctive subrectangular outline of *Charlottea proprietatis* n. sp. distinguishes it from all other species of *Charlottea.*

Etymology. Proprietas, atis (Latin; noun) = a property, peculiarity.

Measurements (μm).

(n) = number of specimens measured

Maximum diameter of cortical shell (8)	Maximum length of primary spines (5)	
180	120	Holotype
180	221	Maximum
150	120	Minimum
161	188	Mean

Type locality. QC-675. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107715 (holotype), GSC 107716 (paratype), GSC 107718 (paratype), and GSC 107719 (paratype) from type locality. GSC 107717 (paratype) from 89-CNA-KUB-4. See occurrence chart, Figure 16.

Charlottea triquetra Whalen and Carter n. sp.
Plate 4, figures 2, 3, 4, 5, 11, 14, 15
Species code: CHA05

Description. Test with small, slightly elongated cortical shell compressed in plane of spines and three moderately long spines. Cortical shell with large, irregularly shaped and sized pentagonal and hexagonal pore frames with low, rounded nodes at pore frame vertices; pores irregularly sized (large and small), usually subcircular in outline. Internal spicular network composed of very delicate pore frames with no pattern or orientation. Spines triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves; spines usually shorter than or equal to long dimension of cortical shell; two spines closer together than third, sometimes curving inwards toward long axis of cortical shell.

Remarks. The shorter, less massive spines and less prominent nodes of *C. triquetra* n. sp. distinguish it from *Charlottea* sp. C.

Etymology. Triquetrus, a, um (Latin; adj.) = three cornered, triangular.

Measurements (μm).

(n) = number of specimens measured

Maximum diameter of cortical shell (6)	Maximum length of primary spines (5)	
75	71	Holotype
90	75	Maximum
75	68	Minimum
84	73	Mean

Type locality. QC-677. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107720 (holotype) and GSC 107721 (paratype) from type locality. See occurrence chart, Figure 16.

Charlottea weedensis Whalen and Carter n. sp.
Plate 1, figures 3, 9, 10, 15, 19, 20, 25
Species code: CHA01

Description. Test with small cortical shell and three long spines. Cortical shell subtriangular in outline and flattened in plane of three spines. Cortical shell with small- to medium-sized, irregularly shaped pentagonal and hexagonal pore frames with prominent rounded nodes at pore frame vertices; pores small- to medium-sized, usually subcircular in outline. Internal spicular network composed of large, very thin pore frames with no pattern of orientation. Spines triradiate in axial section with narrow, rounded longitudinal ridges and narrow, rounded longitudinal grooves; spines always longer than diameter of cortical shell; one spine sometimes slightly longer than other two.

Remarks. The small cortical shell and very long delicate spines distinguish *Charlottea weedensis* n. sp. from *C. triquetra* n. sp., *C. amurensis* n. sp., and *C. harbridgensis* n. sp.

Etymology. This species is named for Weed Creek which flows past the Carter Ranch in Vernonia, Oregon where much of the biostratigraphic work for this paper was carried out.

Measurements (µm).

Maximum diameter of cortical shell	Maximum length of primary spines	
140	160	Holotype
149	162	Maximum, 13 specimens
116	116	Minimum, 13 specimens
134	139	Mean, 13 specimens

Type locality. QC-545. See Locality Descriptions, Appendix 1.

Range. *Protokatroma aquila* Zone to *Parahsuum simplum* Zone. Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107686 (holotype) from type locality; GSC 107683 from 89-CNA-SKUD-31; GSC 107684 (paratype) from 89-CNA-SKUD-34B; GSC 107685 (paratype) from 87-CNA-KUD-2; and GSC 107687 (paratype) from QC-543. See occurrence chart, Figure 16.

Charlottea sp. A.
Plate 4, figure 12

Remarks. The massive spines and irregularly shaped pore frames distinguish this form from other species of *Charlottea*.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107722 from QC-675 (upper Sinemurian).

Charlottea sp. B.
Plate 5, figures 1, 17

Remarks. The massive nodes and slightly compressed cortical shell of *Charlottea* sp. B distinguish it from *C. harbridgensis* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107723 from QC-574 (lower Sinemurian).

Charlottea sp. C.
Plate 5, figures 6, 15

Remarks. See remarks under *C. triquetra* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107728 from QC-674 (upper Sinemurian).

Genus *Danubea* Whalen and Carter n. gen.

Type species. *Danubea howardi* Whalen and Carter n. sp.

Description. Test with two prominent spines in the polar positions. Cortical shell inflated, subelliptical in outline with slightly planiform surfaces adjacent to spines; meshwork composed of tetragonal and triangular pore frames with prominent nodes at pore frame vertices; large pores sometimes located on cortical shell at base of spines. Spines triradiate in axial section and tapering distally.

Remarks. The bipolar spines of *Danubea* n. gen. distinguish it from all other genera of the Subfamily Charlotteinae. *Danubea* n. gen. differs from *Pantanellium* Pessagno by having an inner eccentric spicular network. *Protopsium* Pessagno and Poisson differs from *Danubea* n. gen. by having spongy meshwork.

Etymology. *Danubea* n. gen. is named for the steamer *Danube*, a well known trading ship in the Queen Charlotte Islands in the late 1800s.

Range. Lower Jurassic; Hettangian-upper Pliensbachian.

Occurrence. Queen Charlotte Islands, British Columbia; Baja California Sur, east-central Oregon.

Danubea howardi Whalen and Carter n. sp.
Plate 5, figures 2, 3, 4, 14, 18
Species code: DAN01

Description. Test large with inflated cortical shell and two prominent polar spines. Cortical shell subelliptical in outline with planiform top and bottom surfaces (right angles to polar spines) and nearly vertical sides (plane of polar spines). Meshwork composed of irregularly shaped tetragonal and triangular pore frames with prominent nodes at pore frame vertices; pore frame bars usually very thin in Y direction, usually much thicker in Z direction (refer to Pl. 4, fig. 11 for measurement system). Large elliptical pores visible at base of polar spines. Spines approximately equal in length, triradiate in axial section, with narrow, rounded longitudinal ridges and grooves.

Remarks. The more regularly shaped pore frames and larger nodes of *Danubea howardi* n. sp. distinguish it from *Danubea* sp. aff. *D. howardi* n. sp.

Etymology. This species is named in honor of Dr. Howard Tipper of the Geological Survey of Canada, whose work on the Jurassic ammonites of the Queen Charlotte Islands has provided a solid biostratigraphic foundation for dating Hettangian and Sinemurian radiolarian faunas.

Measurements (µm).

Maximum diameter of cortical shell	Maximum length of primary spines	
116	135	Holotype
150	203	Maximum, 6 specimens
116	135	Minimum, 6 specimens
129	169	Mean, 6 specimens

Type locality. QC-571B. See Locality Descriptions, Appendix 1.

Range. Protokatroma aquila Zone to *Parahsuum simplum* Zone. Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107724 (holotype) from type locality; GSC 107725 (paratype) and GSC 107726 (paratype) from QC-545. See occurrence chart, Figure 16.

Danubea sp. aff. *D. howardi* n. sp.
Plate 5, figures 5, 11, 16

Remarks. See remarks under *D. howardi* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107727 from QC-571B (lower Sinemurian).

Genus *Sophia* Whalen and Carter n. gen.

Type species. Sophia tuberis Whalen and Carter n. sp.

Description. Test with four prominent, equally spaced spines in same plane; all spines triradiate in axial section, tapering distally. Cortical shell rectangular or square with planiform upper and lower surfaces and steep sides. Pore frames irregularly shaped (primarily tetragonal and triangular), usually with prominent nodes at pore frame vertices.

Remarks. Sophia n. gen. differs from other genera of the Charlotteinae in having a square, box-like shell with four primary spines. It differs from *Udalia* Whalen and Carter n. gen. in having an entactiniid-like inner structure, a thicker shell, fewer pore frames, and much larger nodes. *Sophia* n. gen. differs from *Emiluvia* Pessagno in having an inner entactinid-like spicular network rather than two medullary shells (see Dumitrica 1995, p. 24).

Etymology. This genus is named for the *Princess Sophia*, a passenger ship that plied the waters of southern Alaska and Hecate Strait in the early 1900s.

Range. Lower Jurassic; Sinemurian-lower Pliensbachian.

Occurrence. Queen Charlotte Islands, British Columbia.

Sophia palfyi Whalen and Carter n. sp.
Plate 9, figures 1, 5, 6, 7, 10
Species code: SOP07

Description. Cortical shell small, thin, cruciform to rectangular in outline with planiform upper and lower surfaces. Meshwork composed of large, irregularly shaped tetragonal and triangular pore frames with medium-sized nodes at pore frame vertices; pore frame bars very thin in Y direction, much thicker in Z direction. Internal spicular network composed of fragile pore frames lacking nodes at pore frame vertices. Test with four, very long, strong spines all equal in length and width and tapering distally; length of spines sometimes twice the maximum diameter of test; spines triradiate in axial section with narrow, rounded longitudinal ridges and broad, shallow longitudinal grooves sometimes showing slight torsion.

Remarks. The shape of the test and much longer spines distinguish *Sophia palfyi* n. sp. from *S. tuberis* n. sp.

Etymology. This species is named for Jozsef Pálfy for his studies of Sinemurian ammonites of Queen Charlotte Islands.

Measurements (μm).

Maximum diameter of cortical shell	Length of longest spine	
132	183	Holotype
188	275	Maximum, 11 specimens
132	172	Minimum, 11 specimens
161	215	Mean, 11 specimens

Type locality. 87-CNA-KUD-14. See Locality Descriptions, Appendix 1.

Range. Parahsuum simplum Zone to *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107772 (holotype) from type locality; GSC 107771 (paratype) from 87-CNA-KUD-15; and GSC 107773 (paratype) from QC-549. See occurrence chart, Figure 16.

Sophia tuberis Whalen and Carter n. sp.
Plate 5, figures 9, 10, 19
Species code: SOP06

Description. Cortical shell small, very thick, square to rectangular in outline with planiform upper and lower surfaces and vertical sides. Meshwork composed of large, irregularly shaped tetragonal and triangular pore frames with massive nodes at pore frame vertices; pore frame bars very thin in Y direction, much thicker in Z direction. Internal spicular network composed of more fragile pore frames lacking nodes at pore frame vertices. Test with four, long, strong spines, all equal in length and width; spines tapering distally, triradiate in axial section with narrow, rounded longitudinal ridges and broad, shallow longitudinal grooves.

Remarks. See remarks under *Sophia palfyi* n. sp.

Etymology. Tuber, eris (Latin; noun) = a swelling, protuberance, bump.

Measurements (μm).

Maximum diameter of cortical shell	Length of longest spine	
90	105	Holotype
90	105	Maximum, 7 specimens
68	75	Minimum, 7 specimens
79	89	Mean, 7 specimens

Type locality. QC-675. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107730 (holotype) from type locality. See occurrence chart, Figure 16.

Genus *Thurstonia* Whalen and Carter n. sp.

Type species. *Thurstonia minutaglobi* Whalen and Carter n. sp.

Description. Test with spherical shell and six prominent tapering spines; two spines bipolar, at right angles to four equally spaced spines, in radial plane. Cortical shell with triangular and tetragonal pore frames with rounded nodes at pore frame vertices; large pores sometimes apparent at base of spines. Spines circular or triradiate in axial section.

Remarks. The internal structure of *Thurstonia* n. gen. is not completely understood but because of the suggestion of an internal spicular network (see Pl. 8, fig. 13), we tentatively assign this genus to the Subfamily Charlottinae. *Thurstonia* n. gen. is distinguished from all the included genera of the Subfamily Charlotteinae by having six prominent spines, four of which are in the same plane.

Etymology. *Thurstonia* n. gen. is named for the *Nellie G. Thurston*, a schooner owned by the Pacific Fish and Cold Storage Company and a regular visitor to the fishing grounds of the Queen Charlotte Islands in the early 1900s.

Range. Lower Jurassic; Hettangian-Aalenian.

Occurrence. Queen Charlotte Islands, British Columbia; east-central Oregon.

Thurstonia gibsoni Whalen and Carter n. sp.
Plate 6, figures 1, 2
Species code: THU01

Description. Test with small, spherical cortical shell and six narrow spines. Cortical shell composed of small, irregularly shaped and distributed triangular and tetragonal pore frames with prominent rounded nodes at pore frame vertices. Spines approximately equal in length, circular in axial section with length of each spine slightly less than diameter of cortical shell.

Remarks. The small cortical shell and very delicate spines (circular in axial section) of *Thurstonia gibsoni* n. sp. distinguish it from *T. timberensis* n. sp.

Etymology. This species is named in honor of Gibson (Gib) Carter, Vernonia, Oregon, who assisted the authors in many aspects of this research.

Measurements (μm).

Maximum diameter of cortical shell	Length of longest spine	
135	85	Holotype
135	131	Maximum, 15 specimens
96	66	Minimum, 15 specimens
115	80	Mean, 15 specimens

Type locality. 89-CNA-SKUD-27. See Locality Descriptions, Appendix 1.

Range. *Protokatroma aquila* Zone to *Crucella hettangica* Zone. Lower Jurassic; lower Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107731 (holotype) and GSC 107732 (paratype) from type locality. See occurrence chart, Figure 16.

Thurstonia magnaglobus Whalen and Carter n. sp.
Plate 8, figures 1, 12
Species code: THU03

Description. Test with large spherical cortical shell and six prominent spines. Cortical shell composed of both large and small irregularly shaped triangular and tetragonal pore frames with prominent rounded nodes at pore frame vertices; pore frame bars very thin in Y direction, usually much thicker in Z direction (refer to Pl. 4, fig. 11 for measurement system); very large pore frames sometimes observed at contact of spine with cortical shell at base of spines; pores elliptical, triangular, and tetragonal in outline. All spines approximately equal in length, triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves; length of each spine less than diameter of cortical shell.

Remarks. The larger cortical shell, larger spines, and smaller nodes distinguish *Thurstonia magnaglobus* n. sp. from *T. minutaglobus* n. sp.

Etymology. *Magnus, a, um* (Latin; adj.) = great, large. *Globus – i* (Latin; noun) = a round ball, globe, sphere.

Measurements (μm).

(n) = number of specimens measured

Maximum diameter of cortical shell (9)	Maximum length of primary spines (8)	
128	75	Holotype
143	90	Maximum
116	45	Minimum
133	67	Mean

Type locality. QC-574. See Locality Descriptions, Appendix 1.

Range. *Protokatroma aquila* Zone to *Parahsuum simplum* Zone. Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107765 (holotype) from type locality. See occurrence chart, Figure 16.

Thurstonia minutaglobus Whalen and Carter n. sp.
Plate 6, figures 7, 9; Plate 8, figures 2, 5, 6, 7, 9, 10, 13
Species code: THU05

aff. gen. and sp. indet. - Hattori, 1989, Pl. 17, fig. B.

Description. Test with small, spherical cortical shell with six prominent spines. Cortical shell composed of medium-sized, irregularly shaped and distributed triangular and tetragonal pore frames with prominent, rounded nodes at pore frame vertices; pore frame bars very thin in Y direction and very thick in Z direction; very large pores present at contact of spine with cortical shell. All spines approximately equal in length, triradiate in axial section, with narrow rounded longitudinal ridges and broad, rounded longitudinal grooves; length of each spine approximately equal to or slightly larger than diameter of cortical shell.

Remarks. See remarks under *T. magnaglobus* n. sp.

Etymology. Minutus, a, um (Latin; adj.) - from the verb *minuo* - to make smaller; *globus – i* (Latin; noun) = a round ball, globe, sphere.

Measurements (µm).

Maximum diameter of cortical shell	Length of longest spine	
135	75	Holotype
135	120	Maximum, 9 specimens
90	60	Minimum, 9 specimens
104	86	Mean, 9 specimens

Type locality. QC-574. See Locality Descriptions, Appendix 1.

Range. Protokatroma aquila Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; lower Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107766 (holotype), GSC 107767 (paratype), and GSC 107768 (paratype) from type locality; GSC 107738 (paratype) from 89-CNA-SKUD-27; and GSC 107739 (paratype) from 89-CNA-KUD-18. See occurrence chart, Figure 16.

Thurstonia timberensis Whalen and Carter n. sp.
Plate 6, figures 3, 4, 5, 10
Species code: THU04

Description. Test with medium-sized spherical cortical shell with six strongly tapering spines. Cortical shell composed of small- to medium-sized, irregularly shaped and distributed triangular and tetragonal pore frames with prominent, rounded nodes at pore frame vertices; pore frame bars very thin in Y direction and very thick in Z direction; very large pores present at contact of spine with cortical shell. All spines approximately equal in length, usually longer than diameter of cortical shell. Spines triradiate in axial section proximally with narrow, rounded longitudinal ridges and broad, rounded, tapering longitudinal grooves; spines becoming circular in axial section distally.

Remarks. The broad, strongly tapering spines and smaller, more delicate pore frames of *Thurstonia timberensis* n. sp. distinguish it from *Thurstonia minutaglobi* n. sp.

Etymology. This species is named for Timber Road, the road leading to Beth Carter's ranch in Vernonia, Oregon where much of the biostratigraphic work for this paper was completed.

Measurements (µm).

Maximum diameter of cortical shell	Length of longest spine	
169	156	Holotype
169	188	Maximum, 11 specimens
131	122	Minimum, 11 specimens
152	151	Mean, 11 specimens

Type locality. 87-CNA-KUD-14. See Locality Descriptions, Appendix 1.

Range. Pantanellium browni Zone to *Parahsuum simplum* Zone. Lower Jurassic; middle to upper Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107733 (holotype), GSC 107734 (paratype), GSC 107735 (paratype), and GSC 107736 (paratype) from type locality. See occurrence chart, Figure 16.

Thurstonia sp. A
Plate 6, figure 6

Remarks. The large pore frames and massive spines distinguish *Thurstonia* sp. A. from all other species of *Thurstonia.*

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107737 from QC-677 (upper Sinemurian).

Genus *Tozerium* Whalen and Carter n. gen.

Type species. Tozerium nascens Whalen and Carter n. sp.

Description. Subspherical test with four spines in tetrahedral position. Cortical shell subspherical, pore frames irregularly shaped (usually tetragonal, triangular, pentagonal) and sized with nodes at pore frame vertices; larger pores on cortical shell sometimes observed at base of spines. Spines generally circular in axial section, tapering distally.

Remarks. The four tetrahedrally-positioned spines of *Tozerium* n. gen. distinguish it from all other members of the Subfamily Charlotteinae. *Tozerium* n. gen. differs from the many varied spongy forms with four tetrahedrally-positioned spines and hollow central cavity found in the Rhaetian and Hettangian. The internal spicular network of *Tozerium* n. gen. distinguishes it from the pantanelliid genus *Cantalum* Pessagno.

Etymology. This genus is named in honour of E.T. Tozer, Geological Survey of Canada for his studies of Triassic ammonites.

Range. Lower Jurassic; Hettangian-lower Sinemurian.

Occurrence. Queen Charlotte Islands, British Columbia.

Tozerium nascens Whalen and Carter n. sp.
Plate 1, figures 1, 7, 8, 13, 14, 18, 23, 24
Species code: TOZ01

Description. Cortical shell medium to large with four moderately long spines. Cortical shell subspherical composed of medium to large, irregularly shaped, tetragonal and triangular pore frames with rounded nodes at pore frame vertices; pore frame bars much thinner in Y direction than Z direction (refer to Pl. 4, fig. 11 for measurement system); large pores sometimes located at base of spines. Internal spicular network composed of delicate pore frames with no difference in thickness between Y and Z directions and no apparent pattern or orientation. Spines short, circular in axial section and slightly tapering distally; spines usually much shorter than diameter of cortical shell.

Remarks. The larger cortical shell and longer, slim spines of *Tozerium nascens* n. sp. distinguishes it from *Tozerium* sp. A.

Etymology. *Nascens* (Latin; noun) = arising, beginning.

Measurements (μm).

Maximum diameter of cortical shell	Length of longest spine	
165	74	Holotype
165	74	Maximum, 15 specimens
134	41	Minimum, 15 specimens
150	56	Mean, 15 specimens

Type locality. 89-CNA-SKUD-27. See Locality Descriptions, Appendix 1.

Range. *Canoptum merum* Zone to *Parahsuum simplum* Zone. Lower Jurassic; lowermost Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107675 (holotype), GSC 107676 (paratype), and GSC 107681 (paratype) from type locality. GSC 107677 (paratype) from 89-CNA-SKUD-32; GSC 107678 (paratype) from QC-545; GSC 107679 (paratype) from 89-CNA-SKUE6; GSC 107680 (paratype) from 89-CNA-SKUD-34A. See occurrence chart, Figure 16.

Tozerium sp. A
Plate 1, figure 2

Remarks. See remarks under *Tozerium nascens* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107682 from 90-CNA-KPD-5 (lower Hettangian).

Family HAGIASTRIDAE Riedel 1971, emend.
Baumgartner 1980

Type genus. *Hagiastrum* Haeckel 1881.

Range. Upper Triassic; Rhaetian, Lower Jurassic; Sinemurian-Cretaceous

Occurrence. Worldwide.

Subfamily HAGIASTRINAE Riedel 1971, emend.
Baumgartner 1980

Type genus. *Hagiastrum* Haeckel 1881, emend Baumgartner 1980.

Range. Upper Triassic; Rhaetian, Lower Jurassic; Sinemurian-Middle Cretaceous.

Occurrence. Worldwide.

Genus *Archaeohagiastrum* Baumgartner 1984

Type species. *Archaeohagiastrum minutum* Baumgartner 1984.

Range. Lower Jurassic; upper Hettangian to lower Sinemurian-Callovian.

Occurrence. Worldwide.

Archaeohagiastrum pobi Whalen and Carter n. sp.
Plate 10, figures 3, 4, 5, 9
Species code: HAG02

Description. Test composed of four short rays at right angles, terminating in very long, massive, triradiate spines. Each ray comprised of an internal primary beam, three primary canals and six external beams. External spine ridges and grooves part of integral geometry of four-rayed test. Longitudinal beams developed on edges of each spine ridge (two per spine, totaling six beams); transverse bars connecting these beams creating linear rows of fairly regular pore frames, most tetragonal (four to five horizontal rows of pores per ray). Large raised elliptical to subrectangular nodes aligned perpendicular to beams; nodes located at vertices of external beams and transverse bars. Three hagiastrid canals formed by transverse bars spanning the deeply grooved spine ridges. Central area large, composed mostly of triangular pore frames with large subrounded nodes at vertices. Spines very long with broad, rounded ridges and deep rounded grooves.

Remarks. Baumgartner (1980, p. 284) wrote, "An early Sinemurian sample (QC 549) contains 3 types of hagiastrids. One of them, a possible ancestor of *Hagiastrum*, has a central area similar to the *Emiluvia*-like forms" (= *Udalia* in this paper) "and possesses 3 primary canals and 6 external beams. It seems possible that this form is the first hagiastrid and has evolved from *Emiluvia*-like forms by developing transverse bars between raised ridges of primary spinies and thus enclosing primary grooves to form primary canals". We believe the two species of *Archaeohagiastrum* discussed and illustrated here conform to this statement. *Archaeohagiastrum pobi* n. sp. differs from *A. minutum* Baumgartner by the arrangement of pores and/or nodes in the central area and by having much longer spines. See *A.* sp. aff. *A. pobi* n. sp. for further comparison.

Etymology. Species name formed by an arbitrary combination of letters (ICZN, 1985, p. 199, Appendix D, pt. V, Recommendation 26). Species named in honour of Dr. Peter O. Baumgartner (POB), Université de Lausanne who investigated the early history of the hagiastrids (Baumgartner, 1980) and whose ideas have led us to the description of the earliest species of *Archaeohagiastrum* and *Hagiastrum*.

Measurements (μm).

Length of longest ray	Width of widest ray	Length of longest spine	
134	50	260	Holotype
134	64	260	Maximum, 9 specimens
94	41	103	Minimum, 9 specimens
114	50	170	Mean, 9 specimens

Type locality. 89-CNA-KUH-8. See Locality Descriptions, Appendix I.

Range. *Canutus rockfishensis*-*Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107794 (holotype) from type locality; GSC 107795 (paratype) and GSC 107796 (paratype) from 86-OF-KUA-2. See occurrence chart, Figure 16.

Archaeohagiastrum sp. aff. *A. pobi*
Whalen and Carter n. sp.
Plate 10, figures 1, 6, 10, 13, 17
Species code: HAG01

Tetraditryma sp A. - Hattori 1987, Pl. 1, fig. 1.

Remarks. This is the earliest hagiastrid to appear in our samples and we believe it is closely related to *Archaeohagiastrum* pobi n. sp. This species also has a primary beam, six external beams, and three longitudinal canals per ray. It differs from *A. pobi* n. sp. in having longer rays with about eight horizontal rows of pore frames per ray, a more distinctive central area, and shorter terminal spines. There is also a tendency for some rows of pore frames on the rays to connect to one another via the central area. The lack of adequate specimens precludes separate description.

Range. *Crucella hettangica* Zone-*Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands. Illustrated specimens GSC 107789 from 87-CNA-KUD-14 and GSC 107790 from QC-549. See occurrence chart, Figure 16.

Genus *Hagiastrum* Haeckel 1881, emend.
Baumgartner 1980

Type species. *Hagiastrum plenum* Rüst 1885.

Range. Lower Jurassic; Sinemurian-Middle Jurassic.

Occurrence. Worldwide.

Hagiastrum majusculum Whalen and Carter n. sp.
Plate 10, figures 11, 12, 14, 15, 16
Species code: HAG03

Description. Test composed of four long, nodose rays with bulbous tips terminating in moderately long triradiate spines. Rays usually composed of eight external nodose longitudinal beams; beams display strong linearity frequently becoming slightly twisted. Beams connected by transverse bars forming single, longitudinal rows of square to tetragonal pore frames; pores circular to subcircular. Nodes at vertices of pore frames elliptical to subrectangular, strongly raised, and highly distinctive. Central area small, composed of triangular and rectangular pore frames with large nodes at vertices. Bulbous ray tips composed of square pore frames with weak nodes at vertices. Spines moderate in length, triradiate.

Remarks. This form is likely derived from *Hagiastrum rudimentum* n. sp. It differs from the latter species in having longer rays with more strongly pronounced linearity, stronger nodes on both rays and central area, and in developing bulbous tips at the ends of the rays.

Etymology. Name from the Latin *majusculus, um* (m.) meaning somewhat larger or greater.

Measurements (μm).

Length of longest ray	Width of widest ray	Width of bulbous tips	Length of longest spine	
249	43	-	-	Holotype
395	52	99	131	Maximum, 14 specimens
205	37	74	75	Minimum, 14 specimens
292	43	85	92	Mean, 14 specimens

Type locality. 86-OF-KUB-2. See Locality Descriptions, Appendix I.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands. Illustrated specimen GSC 107797 (holotype) from type locality, GSC 107798 (paratype) from QC-676 and GSC 107799 (paratype) from 86-OF-KUA-2. See occurrence chart, Figure 16.

Hagiastrum rudimentum Whalen and Carter n. sp.
Plate 10, figures 2, 7, 8, 18, 19
Species code HAG04

Hagiastrum sp. C - Hattori, 1987, Pl. 3, fig. 14.

Description. Test with four long rays, almost cylindrical in cross-section, sometimes broadening slightly near tips. Rays terminating in long triradiate spines having broad ridges and grooves. Rays usually composed of eight external longitudinal beams separated by a single row of pore frames and connected by transverse bars to form a single linear row of pores between two beams. Nodes at vertices of pore frames round and moderately raised. Central area large, composed mostly of triangular and tetragonal pore frames with strongly raised circular nodes at vertices.

Remarks. This is the earliest species of *Hagiastrum* to appear in our samples. It has a few irregularly arranged pores on the rays but in all other aspects seems to conform to the definition of *Hagiastrum* as emended by Baumgartner (1980). See *H. majuscula* n. sp. for comparisons.

Etymology. Name from the Latin *rudimentum* meaning first principle, beginning.

Measurements (μm).

Length of longest ray	Width of widest ray	Length of longest spine	
181	38	43	Holotype
244	56	146	Maximum, 10 specimens
161	38	43	Minimum, 10 specimens
206	46	62	Mean, 10 specimens

Type locality. QC-675. See Locality Descriptions, Appendix I.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands. Illustrated specimen GSC 107791 (holotype) from type locality, GSC 107792 (paratype) from 86-OF-KUC-8, and GSC 107793 (paratype) from 86-OF-KUC-6. See occurrence chart, Figure 16.

Genus *Homoeoparonaella* Baumgartner 1980

Type species. *Paronaella elegans Pessagno* 1977a.

Range. Lower Jurassic; upper Sinemurian-Lower Cretaceous; Aptian.

Occurrence. Worldwide.

Homoeoparonaella sp. A
Plate 13, figures 13, 17
Species code: PAR12

Remarks. *Homoeoparonaella* sp. A differs from *Homoeoparonaella gigantea* Baumgartner by having more open meshwork with less development of nodes, and shorter spines.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107847 from 89-CNA-KUH-1 and GSC 107848 from 86-OF-KUC-7. See occurrence chart, Figure 16.

Family LEUGEONIDAE Yang and Wang 1990

Type genus. *Leugeo* Yang and Wang 1990.

Leugeonidae indet. A
Plate 13, figures 20, 21.
Species code: SPI05

Remarks. Very large, subspherical, inflated shell with four very long spines in the cruciform position. Upper and lower surfaces of shell convex, sides almost vertical with meshwork composed of massive triangular and rectangular pore frames. The average diameter of cortical shell is 270 μm. The long spines are usually broken but maximum length observed is 239 μm.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107854 from 89-CNA-KUG-1 and GSC 107855 from 86-OF-KUB-2. See occurrence chart, Figure 16.

Family PANTANELLIIDAE Pessagno 1977b; emend. Pessagno and Blome 1980

Type genus. *Pantanellium* Pessagno 1977a.

Range. Upper Triassic (Carnian)-Lower Cretaceous (upper Albian).

Occurrence. Worldwide.

Subfamily PANTANELLIINAE Pessagno 1977b

Type genus. *Pantanellium* Pessagno 1977a.

Range. Upper Triassic (Carnian)-Lower Cretaceous (Albian).

Occurrence. Worldwide.

Genus *Pantanellium* Pessagno 1977a.

Type species. Pantanellium riedeli Pessagno 1977a.

Range. Upper Triassic (lower Carnian)-Lower Cretaceous (base of upper Aptian).

Occurrence. Worldwide.

Pantanellium browni Pessagno and Blome
Plate 1, figures 6, 16
Species code: PAN10

Pantanellium browni Pessagno and Blome 1980, p. 259, Pl. 4, fig. 5-7, 12, 14, 16, 19, 20.

Pantanellium browni Pessagno and Blome, Tipper et al. 1991, p. 225, Pl. 8, fig. 13.

Range. Pantanellium browni Zone to *Parahsuum simplum* Zone. Lower Jurassic; middle to upper Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107693 from 87-CNA-KPB-10. See occurrence chart, Figure 16.

Pantanellium sp. cf. *P. browni* Pessagno and Blome
Plate 2, figure 3

Pantanellium browni Pessagno and Blome 1980, p. 259, Pl. 4, fig. 5-7, 12, 14, 16, 19, 20.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107699 from QC-571B (lower Sinemurian).

Pantanellium carlense Whalen and Carter n. sp.
Plate 2, figures 1, 2, 13, 14, 17, 18
Species code: PAN14

Description. Cortical shell subspherical in shape, slightly elongated in plane of polar spines, with medium- to large-sized pentagonal and hexagonal pore frames. Bars of pore frames thin along Y, thicker along Z (refer to Fig. 23). All pore frames with irregularly shaped, spinose nodes at vertices. Five pore frames visible along AA′; five to six pore frames visible along BB′. Polar spines triradiate in axial section with narrow, rounded longitudinal ridges and grooves; one polar spine approximately one third shorter than the other; base of shorter polar spine slightly wider at cc′ than base of other spine at dd′. First medullary shell with thin, fragile pentagonal and hexagonal pore frames.

Remarks. The elongated cortical shell with spiny nodes at pore frame vertices distinguishes *Pantanellium carlense* n. sp. from all other species of *Pantanellium*.

Etymology. This species is named for Mount Carl, located to the north of the type locality.

Measurements (μm).

(n) = number of specimens measured

AA′	A′S′	AS	BB′	cc′	dd′	
(7)	(6)	(6)	(7)	(7)	(7)	
60	120	86	71	34	45	Holotype
68	120	90	86	45	53	Maximum
60	105	79	71	34	38	Minimum
65	116	83	79	40	46	Mean

Type locality. QC-675. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107697 (holotype) and GSC 107698 (paratype) from type locality. See occurrence chart, Figure 16.

Pantanellium danaense Pessagno and Blome
Plate 2, figures 4, 5
Species code: PAN11

Pantanellium danaense Pessagno and Blome 1980, p. 259, Pl. 4, fig. 9-11, 15.

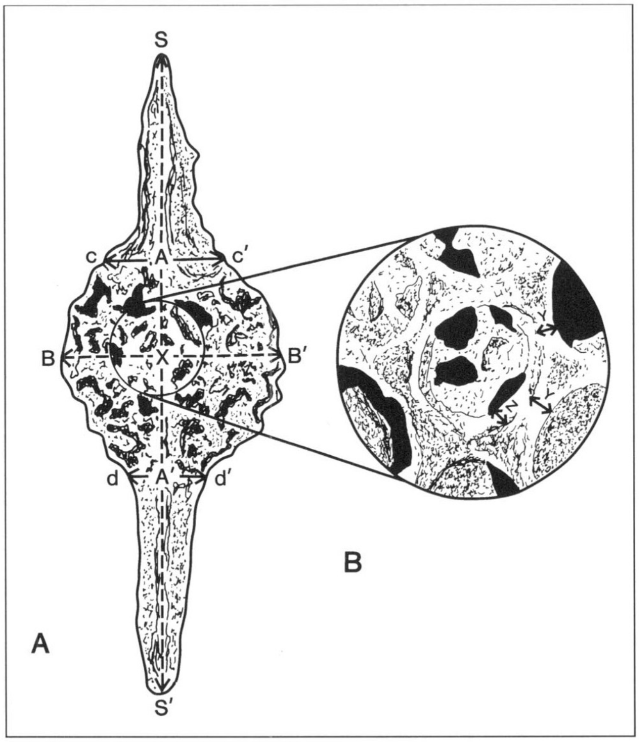


Figure 23. *System of measurement for Pantanelliinae with bipolar spines. Terminology for describing thickness of pore frame bars: Y= thickness of bar measured in plane tangential to test surface; Z = thickness of bar measured in a plane at right angles to test surface (from Pessagno and Blome, 1980, with permission Mircropaleontology Press).*

Range. Pantanellium browni Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; middle to upper Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107700 from QC-674 and GSC 107701 from QC-675. See occurrence chart, Figure 16.

Pantanellium freboldi Whalen and Carter n. sp.
Plate 1, figures 17, 21, 27
Species code: PAN12

Pantanellium sp. 1, Tipper et al. 1991, Pl. 8, fig. 14.

Description. Cortical shell small, spherical with small densely packed pentagonal and hexagonal pore frames. Bars of pore frames thinner along Y than Z (refer to Fig. 23). All pore frames with low, rounded nodes at vertices. Five pore frames visible along AA′ and seven to eight visible along BB′. Strong polar spines triradiate in axial section with moderately wide, rounded longitudinal ridges and deep, rounded longitudinal grooves; one polar spine usually slightly shorter than other; base of spine at cc′ almost as wide as diameter of cortical shell. First medullary shell with thin, fragile, hexagonal and pentagonal pore frames.

Remarks. The very broad base of the shorter polar spine and absence of prominent nodes at pore frame vertices distinguish *Pantanellium freboldi* n. sp. from *Pantanellium sixi* n. sp.

Etymology. This species is named in memory of Hans Frebold, a noted paleontologist with the Geological Survey of Canada.

Measurements (μm).

AA′	A′S′	AS	BB′	cc′	dd′	
86	97	86	100	50	44	Holotype
148	150	112	112	52	50	Maximum, 7 specimens
86	97	75	94	37	34	Minimum, 7 specimens
106	127	97	100	47	40	Mean, 7 specimens

Type locality. 87-CNA-KPB-12. See Locality Descriptions, Appendix 1.

Range. Pantanellium browni Zone to *Parahsuum simplum* Zone. Lower Jurassic; middle to upper Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107696 (holotype) and GSC 107695 (paratype) from type locality. See occurrence chart, Figure 16.

Pantanellium kluense Pessagno and Blome
Plate 1, figures 5, 22
Species code: PAN09

Pantanellium kluense Pessagno and Blome 1980, p. 259, Pl. 4, fig. 1, 2, 13, 17, 18, 21-24.

Range. Pantanellium browni Zone to *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; middle to upper Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107691 from 89-CNA-SKUD-34A and GSC 107692 from 87-CNA-KUD-2. See occurrence chart, Figure 16.

Pantanellium kungaense Pessagno and Blome
Plate 2, figure 6
Species code: PAN17

Pantanellium kungaense Pessagno and Blome 1980, p. 261; Pl. 5, fig. 6, 7, 12, 25.

Pantanellium aff. *kungaense* Pessagno and Blome - Hattori 1987, Pl. 5, fig. 10; Hattori 1988, Pl. 3, fig. 11.

Range. Parahsuum simplum Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; Japan. Illustrated specimen GSC 107702 from QC-674. See occurrence chart, Figure 16.

Pantanellium sixi Whalen and Carter n. sp.
Plate 2, figures 7, 11, 15, 16
Species code: PAN13

Description. Cortical shell small and spherical with small- to medium-sized pentagonal and hexagonal pore frames. Bars of pore frames thinner along Y than Z (refer to Fig. 23). All pore frames with distinct spinose nodes at vertices. Five to six pore frames visible along AA′ and BB′. Polar spines triradiate in axial section with narrow, rounded longitudinal ridges and broader, rounded longitudinal grooves; one polar spine slightly shorter than the other; base of shorter polar spine usually noticeably wider at cc′ than base of other spine at dd′. First medullary shell with thin, fragile, pentagonal and hexagonal pore frames.

Remarks. The small, spherical cortical shell with its spinose nodes distinguishes *Pantanellium sixi* n. sp. from *P. carlense* n. sp.

Etymology. This species is named for Tod Six, formerly at University of Texas at Dallas who provided valuable assistance with the Scanning Electron Microscope.

Measurements (μm).

(n) = number of specimens measured.

AA′	A′S′	AS	BB′	cc′	dd′	
(5)	(4)	(4)	(5)	(5)	(5)	
75	131	98	83	38	26	Holotype
75	131	98	83	41	41	Maximum
60	90	75	75	34	26	Minimum
66	111	84	80	38	32	Mean

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus? sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107703 (holotype) from type locality and GSC 107704 (paratype) from QC-675. See occurrence chart, Figure 16.

Pantanellium sp. aff. *P. sixi* Whalen and Carter n. sp.
Plate 2, figures 12, 20

Remarks. The more massive pore frames and wider cortical shell distinguish *P.* sp. aff. *P. sixi* n. sp. from *P. sixi* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107705 from QC-677 (upper Sinemurian).

Pantanellium skedansense Pessagno and Blome
Plate 1, figure 12
Species code: PAN16

Pantanellium skedansense Pessagno and Blome 1980, p. 261, Pl. 5, fig. 8, 9, 15, 20, 23.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus? sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107694 from 86-OF-KUC-8. See occurrence chart, Figure 16.

Pantanellium tanuense Pessagno and Blome
Plate 1, figures 4, 11, 26
Species code: PAN08

Pantanellium tanuense Pessagno and Blome 1980, p. 259, Pl. 4., fig. 3, 4, 24.

Pantanellium sp. aff. *tanuense* Pessagno and Blome - Spörli and Aita 1988, Pl. 4, fig. 2; Sporli, Aita and Gibson 1989, fig. 5, no. 6

Pantanellium tanuense Pessagno and Blome - Tipper et al. 1991, Pl. 8, fig. 5; Gorican 1994, Pl. 1, fig. 14-18.

Range. Canoptum merum Zone to *Crucella hettangica* Zone. Lower Jurassic; lowermost Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; New Zealand; Montenegro. Illustrated specimens GSC 107688 from 89-CNA-SKUE-6, GSC 107689 from QC-543; and GSC 99430 from 87-CNA-KUD-2. See occurrence chart, Figure 16.

Family PATULIBRACCHIIDAE Pessagno 1971, emend. Baumgartner 1980

Type genus. Patulibracchium Pessagno 1971.

Range. Late Paleozoic-Cretaceous.

Occurrence. Worldwide.

Subfamily PATULIBRACCHIINAE Pessagno 1971, emend. Baumgartner 1980

Type genus. Patulibracchium Pessagno 1971.

Range. Late Paleozoic-Upper Cretaceous.

Occurrence. Worldwide.

Genus *Crucella* Pessagno 1971, emend. Baumgartner 1980

Type species. Crucella messinae Pessagno 1971.

Range. Upper Triassic (Rhaetian) to Upper Cretaceous.

Occurrence. Worldwide.

Crucella carteri Kozur and Mostler
Plate 12, figure 1

Crucella carteri Kozur and Mostler 1990, p. 246, Pl. 15, fig. 2, 4, 9

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; and Bavaria. Illustrated specimen GSC 107818 from 89-CNA-KUD-16 (upper Hettangian).

Crucella cavata Whalen and Carter n. sp.
Plate 12, figures 15, 18, 19, 21, 22
Species code: CRU10

Description. Test with large central area, four short rays expanded distally, each with a moderately long central spine. Rays wide, subrectangular in axial section with upper and lower planiform surfaces. Rays gradually widening to ray tips. Each ray with one long, massive spine, circular in axial section. Rays with irregularly sized and shaped polygonal pore frames with no development of external lineation; small nodes at pore frame vertices. Prominent circular lacuna in central area variable in size with sides sloping towards centre.

Remarks. The distinctive lacuna distinguishes *Crucella cavata* n. sp. from all other species of *Crucella* Pessagno in the Sandilands fauna.

Etymology. Cavatus, a, um (Latin; adj.) = hollowed out

Measurements (μm).

Number of specimens measured = (n)

Length of longest ray (12)	Maximum width of central area (12)	Maximum width of ray tips (12)	Length of longest spine (7)	
124	82	97	111	Holotype
225	82	122	150	Maximum
124	54	79	94	Minimum
180	69	101	128	Mean

Type locality. 86-OF-KUC-8. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107832 (holotype) from type locality; GSC 107833 (paratype) and GSC 107834 (paratype) from QC-675. See occurrence chart, Figure 16.

Crucella hettangica Kozur and Mostler
Plate 12, figures 3, 4, 5, 7-10, 12, 13, 16, 20, 23
Species code: CRU07

Crucella spp. - Hattori 1989, Pl. 4, fig. K.

Pseudocrucella sp. - Spörli and Aita, 1988, Pl. 4, fig. 3; Aita and Sporli 1992, fig. 5, no. 2.

Crucella hettangica Kozur and Mostler 1990, p. 246, Pl. 15, fig. 7.

Range. *Crucella hettangica* Zone-*Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; Bavaria; Japan; and New Zealand. Illustrated specimens GSC 107820 from 87-CNA-KUD-14; GSC 107821 from 89-CNA-KUH-8; GSC 107822 and GSC 107825 from QC-675; GSC 107823, GSC 107826, and GSC 107828 from 86-OF-KUB-2; GSC 107824 from 87-CNA-KPB-12; GSC 107827 from QC-677. See occurrence chart, Figure 16.

Crucella kaisunensis Whalen and Carter n. sp.
Plate 12, figure 14
Species code: CRU09

Description. Test with small central area and moderately long rays. Rays narrow initially, gradually widening to slightly bulbous ray tips; rays rectangular in axial section with planiform surfaces. Rays with irregularly sized and shaped polygonal pore frames with no development of external lineation; small- to medium-sized nodes at pore frame vertices; pore frames on ray tips smaller than those on arms and central area. Each ray with a long, massive central spine which is circular in axial section.

Remarks. The bulbous ray tips and absence of any lineation of the pore frames distinguish *Crucella kaisunensis* n. sp. from *Crucella hettangica* Kozur and Mostler.

Etymology. This species is named for Kaisun, an old Haida village in Queen Charlotte Islands.

Measurements (μm).

Length of longest ray	Maximum width of rays	Length of longest spine	
178	103	155	Holotype
225	113	281	Maximum, 7 specimens
169	71	130	Minimum, 7 specimens
199	85	173	Mean, 7 specimens

Type locality. 89-CNA-KUH-8. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107831 from type locality. See occurrence chart, Figure 16.

Crucella prisca Kozur and Mostler
Plate 12, figure 2
Species code: CRU06

Crucella spp. - Hattori 1989, Pl. 4, fig. J.

Crucella prisca Kozur and Mostler 1990, p. 246, Pl. 15, fig. 1, 3, 5, 8, 10.

Range. *Parahsuum simplum* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; Bavaria, and Japan. Illustrated specimen GSC 107819 from 87-CNA-KUD-14. See occurrence chart, Figure 16.

Crucella sp. A
Plate 12, figure 6

Crucella sp. 1 - Tipper et al. 1991, p. 225, Pl. 8, fig. 10.

Remarks. The long, twisted, triradiate spines distinguish *Crucella* sp. A from *Crucella kaisunensis* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107829 from 87-CNA-KPB-10 (uppermost Hettangian to lowermost Sinemurian).

Crucella sp. B
Plate 12, figure 11

Remarks. The very fine pore frames and long, triradiate spines of *Crucella* sp. B distinguish it from *Crucella kaisunensis* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107830 from 86-OF-KUB-3 (upper Sinemurian).

Genus *Paronaella* Pessagno 1971, emend. Baumgartner 1980

Type species. *Paronaella solanoensis* Pessagno 1971.

Range. Late Paleozoic? Triassic-Cretaceous.

Paronaella botanyensis Whalen and Carter n. sp.
Plate 13, figures 7, 10, 14
Species code: PAR09

Description. Test large with long, slender rays with widely expanded, wedge-shaped tips. Rays equally spaced, approximately equal in length, narrower and subcircular in axial section in central area. Meshwork composed of small irregularly shaped tetragonal pore frames with small nodes at pore frame vertices. No spines observed on any specimens.

Remarks. The large test with long rays and widely expanded wedge-shaped tips distinguish *Paronaella botanyensis* n. sp. from all other Hettangian and Sinemurian species of *Paronaella.*

Etymology. This species is named for Botany Island, located in the southeast arm of Tasu Sound.

Measurements (μm).

Length of longest ray	Average width of rays at base	Maximum width of ray tips	
240	51	172	Holotype
240	56	172	Maximum, 8 specimens
188	44	140	Minimum, 8 specimens
207	51	155	Mean, 8 specimens

Type locality. 87-CNA-KUD-10. See Locality Descriptions, Appendix 1.

Range. Protokatroma aquila Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; lower Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107845 (holotype) from type locality and GSC 107846 (paratype) from QC-574. See occurrence chart, Figure 16.

Paronaella sp. cf. *P. corpulenta* De Wever
Plate 13, figure 3
Species code: PAR11

Paronaella sp. cf. *P. corpulenta* De Wever 1981b, p. 41, Pl. 3, fig 7.

Range. Lower Jurassic; upper Sinemurian-Pliensbachian.

Occurrence. Taurides Occidentales, Turkey; and Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107840 from 89-CNA-KUH-8. See occurrence chart, Figure 16.

Paronaella jamesi Whalen and Carter n. sp.
Plate 13, figures 18, 19, 22, 23, 24
Species code: PAR10

Description. Test with short equally spaced rays; rays approximately equal in length, narrow proximally, gradually expanding in width distally. Ray tips moderately expanded and bulbous. Meshwork composed mostly of strong, triangular and tetragonal pore frames with small nodes at pore frame vertices; slight lineation of pore frames developed externally on proximal portion of rays. Each ray usually with short, circular, flat-bladed to slightly triradiate central spine; some rays with several smaller spines rather than one primary spine.

Remarks. See remarks under *Paronaella skenaensis* n. sp.

Etymology. This species is named for James Helwig, Dallas, Texas who assisted with fieldwork and construction of plates.

Measurements (μm).

Length of longest ray	Average width of rays at base	Maximum width of ray tips	
174	53	121	Holotype
249	66	184	Maximum, 8 specimens
146	50	113	Minimum, 8 specimens
184	59	139	Mean, 8 specimens

Type locality. 89-CNA-KUH-8. See Locality Descriptions, Appendix 1.

Range. Parahsuum simplum Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107852 (holotype) from type locality, GSC 107849 (paratype) from 86-OF-KUC-6, GSC 107850 (paratype) and GSC 107851 (paratype) from 86-OF-KUC-8, and GSC 107853 (paratype) from 86-OF-KUA-2. See occurrence chart, Figure 16.

Paronaella ravenensis Whalen and Carter n. sp.
Plate 13, figures 1, 2, 6, 9, 12, 16
Species code: PAR06

Description. Test with short, broad rays equally spaced; rays approximately equal in length moderately expanding in width distally; ray tips broadly expanded. Meshwork composed of irregularly shaped triangular and tetragonal pore frames with small nodes at pore frame vertices. Each ray tip usually with several fine spines, flattened to circular in axial section.

Remarks. This species differs from *P. skenaensis* n. sp. in having shorter, more broadly expanded rays with fine multiple spines; it differs from *P. cleopatraensis* Pessagno, Blome and Hull in having fewer, more delicate spines. *P. pessagnoi* Blome differs from *P. ravenensis* n. sp. by having much longer, more strongly bladed spines.

Etymology. This species is named for the raven, a bird sacred to the Haida.

Measurements (μm).

Length of longest ray	Average width of rays at base	Maximum width of ray tips	
214	68	146	Holotype
214	75	188	Maximum, 12 specimens
136	52	118	Minimum, 12 specimens
181	66	140	Mean, 12 specimens

Type locality. 87-CNA-KUD-4. See Locality Descriptions, Appendix 1.

Range. *Canoptum merum* Zone to *Crucella hettangica* Zone. Lower Jurassic; lowermost Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107837 (holotype) from type locality, GSC 107836 (paratype) from 89-CNA-KUD-5, GSC 107838 (paratype) from 89-CNA-SKUD-28, and GSC 107839 (paratype) from QC-545. See occurrence chart, Figure 16.

Paronaella skenaensis Whalen and Carter n. sp.
Plate 13, figures 4, 5, 8, 11, 15
Species code: PAR08

Description. Test with elongate, slender rays composed of very fine meshwork. Rays approximately equal in length, narrow proximally, gradually expanding in width distally to moderately expanded and bulbous ray tips. Meshwork composed of very small, irregularly shaped triangular and tetragonal pore frames with low nodes at pore frame vertices. Each ray normally with a short, delicate central spine circular in axial section; some rays with several spines rather than one main spine.

Remarks. *Paronaella skenaensis* n. sp. differs from *P. jamesi* n. sp. in having much finer meshwork with smaller nodes and more delicate spines.

Etymology. This species is named for Skena, a Haida Village at Cape Chroustcheff, the first point southeast of Sandspit.

Measurements (μm).

Length of longest ray	Average width of rays at base	Maximum width of ray tips	
221	65	146	Holotype
252	73	167	Maximum, 8 specimens
197	44	131	Minimum, 8 specimens
213	59	148	Mean, 8 specimens

Type locality. 89-CNA-KUD-12. See Locality Descriptions, Appendix 1.

Range. *Protokatroma aquila* Zone to *Parahsuum simplum* Zone. Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107841 (holotype) from type locality, GSC 107842 (paratype) from QC-543, GSC 107843 (paratype) from 89-CNA-SKUD-34A, and GSC 107844 (paratype) from 87-CNA-KUD-2. See occurrence chart, Figure 16.

Family QUINQUECAPSULARIIDAE Dumitrica 1995

Type genus. *Quinquecapsularia* Pessagno 1971b

Range. Jurassic-Cretaceous, Cenozoic.

Occurrence. California; Italy; Spain; and Queen Charlotte Islands, British Columbia.

Genus *Empirea* Whalen and Carter n. gen.

Type species. *Empirea hasta* Whalen and Carter n. sp.

Description. Test large, spherical to subspherical in shape, composed of a cortical shell and two medullary shells. Second (innermost or initial) medullary shell a small pentagonal prism composed of delicate bars forming two pentagons united by five short bars. First (outermost) medullary shell a larger but similarly shaped prism composed of stronger bars and arches. Cortical shell two layered, with inner layer a large pentagonal prism composed of massive arches that serve as attachment points for the large, subspherical to irregularly polygonal pore frames of the outer layer. Ten solid, primary radial beams originate from the ten corners of the innermost prism, connect with corresponding positions on the first medullary shell and cortical prism, and extend beyond the surface of test as peripheral spines. Radial beams slender between inner and outer medullary shells becoming more massive towards the perimeter of test. Peripheral spines variable in length and may be either circular or triradiate in axial section.

Remarks. *Empirea* n. gen. is distinguished from *Quinquecapsularia* Pessagno 1971b by having a two layered cortical shell and solid rather than latticed radial beams (latticed buttresses) connecting the first medullary shell to the cortical shell.

Etymology. This genus is named for the trawler *Celestial Empire* that fished for halibut in Queen Charlotte Islands' waters in the early 1900s.

Range. Jurassic; lower Hettangian-upper Sinemurian, upper Tithonian.

Occurrence. Queen Charlotte Islands, British Columbia; Oregon; and Mexico. Undescribed forms of *Empirea* n. gen. have been photographed from sample OR 589, Warm Springs Member, Snowshoe Fromation, Oregon (K.Y. Yeh, pers. comm., 1996).

Empirea hasta n. sp.
Plate 7, figures 6, 9, 10
Species code: EMP01

Description. Test as with genus, possessing a large subspherical cortical shell shaped more or less like a pentagonal prism. Second (initial) medullary shell extremely small, composed of delicate circular bars. First medullary shell slightly larger, also composed of slender circular bars. Cortical shell two layered, composed of large irregularly polygonal (mostly hexagonal and pentagonal) pore frames anchored to the massive arches of the inner layer. Radial beams circular between inner and outer medullary shells, triradiate between outer medullary shell and cortical shell. Peripheral spines (extensions of primary radial beams) short, pyramidal, and strongly triradiate.

Remarks. The more distinct appearance of the outer pentagonal prism within the cortical shell, the larger pore frames of the outer cortical layer, and the short, pyramidal peripheral spines distinguish this species from *Empirea* sp. A.

Etymology. hasta (Latin; noun) = a Macedonian pike.

Measurements (μm).

Maximum diameter of cortical shell	Length of longest spine	
127	35	Holotype
127	60	Maximum, 9 specimens
154	35	Minimum, 9 specimens
142	49	Mean, 9 specimens

Type locality. 87-CNA-KUD-2. See Locality Descriptions, Appendix 1.

Range. Protokatroma aquila Zone to *Canutus rockfishensis-Wrangellium thurstonensis* Zone. Lower Jurassic; lower Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107753 (holotype) and GSC 107754 (paratype) from type locality and GSC 107755 (paratype) from QC-568. See occurrence chart, Figure 16.

Empirea sp. A
Plate 7, figures 1, 2, 5, 17, 20
Species code: EMP02

Remarks. See remarks under *Empirea hasta* n. sp.

Range. Protokatroma aquila Zone to *Crucella hettangica* Zone. Lower Jurassic; lower Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107750 from 89-CNA-SKUE-6 and GSC 107751 and GSC 107752 from QC-568. See occurrence chart, Figure 16.

Empirea sp. B
Plate 7, figures 11, 16, 19

Remarks. The much larger irregular pore frames and large, lanceolate spines distinguish this species from *Empirea hasta* n. sp. and *E*. sp. A.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107756 from QC-568 and GSC 107757 from QC-545 (upper Hettangian).

Family SATURNALIDAE Deflandre 1953, emend. De Wever 1984, emend. Dumitrica 1985

Type genus. Saturnalis Haeckel 1881.

Remarks. This study follows the saturnalid classification of Dumitrica (1995).

Range. Upper Triassic-Recent.

Occurrence. Worldwide.

Subfamily HELIOSATURNALINAE Kozur and Mostler 1972

Type genus. Heliosaturnalis Kozur and Mostler 1972.

Range. Upper Triassic-Jurassic.

Occurrence. Turkey; Bavaria; northeast China; east-central Oregon; and Queen Charlotte Islands, British Columbia.

Genus *Heliosaturnalis* Kozur and Mostler 1972, emend. De Wever 1984

Type species. Heliosaturnalis magnus Kozur and Mostler 1972.

Range. Upper Triassic-Lower Jurassic.

Occurrence. Austria; and Queen Charlotte Islands, British Columbia.

Heliosaturnalis? sp. A
Plate 14, figure 14

Remarks. This species has tentatively been assigned to the genus *Heliosaturnalis* because it possesses a double ring and at least one auxillary ray.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107871 from 86-OF-KUB-3 (upper Sinemurian).

Genus *Palaeosaturnalis* Donofrio and Mostler 1978, emend. De Wever 1984

Type species. Spongosaturnalis triassicus Kozur and Mostler 1972.

Range. Upper Triassic-Lower Jurassic.

Occurrence. Turkey; Bavaria; northeast China; east-central Oregon; and Queen Charlotte Islands, British Columbia.

Palaeosaturnalis liassicus Kozur and Mostler 1990
Plate 14, figures 11, 12, 15, 16, 17
Species code: SAT03

Palaeosaturnalis liassicus Kozur and Mostler 1990, p. 192, Pl. 1, fig. 2, 3; Pl. 12, fig. 1, 3, 4, 6, 8-10; Pl. 13, fig. 1, 2, 6, 7.

Palaeosaturnalis liassicus Kozur and Mostler - Yang and Mizutani 1991, p. 65, Pl. 2, fig. 5, ?10.

Range. Pantanellium browni Zone to *Parahsuum simplum* Zone. Lower Jurassic; middle to upper Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; Bavaria; and northeast China. Illustrated specimens GSC 107866 from 87-CNA-KUD-2, GSC 107867 and GSC 107868 from 87-CNA-KUD-14, GSC 107869 from QC-543, and GSC 107870 from 89-CNA-KUD-11. See occurrence chart, Figure 16.

Palaeosaturnalis prinevillensis (Blome)
Plate 14, figures 19, 23
Species code: SAT04

Acanthocircus largus Blome 1984, p. 23, Pl. 1, fig. 7, 8, 15, 16.

Acanthocircus ochocoensis Blome 1984, p. 24, Pl. 2, fig. 2, 13.

Acanthocircus prinevillensis Blome 1984, p. 24, Pl. 2, fig. 3, 14.

Palaeosaturnalis prinevillensis (Blome) - Yang and Mizutani 1991, p. 66, Pl. 2, fig. 7, 8; Pl. 3, fig. 3, 5, 9.

Range. Upper Triassic, Lower Jurassic; lower Hettangian-upper Sinemurian. This species also exists in the Norian of east-central Oregon but is absent in the Rhaetian of Queen Charlotte Islands. In the Lower Jurassic it is confined to the *Protokatroma aquile* Zone to *Canutus rockfishensis-Wrangellium thurstonensis* Zone.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; Oregon, China. Illustrated specimens GSC 107874 from 89-CNA-KUD-12 and GSC 107875 from 89-CNA-SKUD-34B. See occurrence chart, Figure 16.

Genus *Praehexasaturnalis* Kozur and Mostler 1983, emend. Kozur and Mostler 1990

Type species. Palaeosaturnalis tenuispinosus Donofrio and Mostler 1978

Range. Lower Jurassic, so far as known.

Occurrence. Bavaria; northeast China; Baja California Sur; and Queen Charlotte Islands, British Columbia.

Praehexasaturnalis tetraradiatus Kozur and Mostler 1990
Plate 14, figures 1, 2, 5, 6, 9, 10
Species code: SAT01

Pseudoheliodiscus(?) sp. Whalen and Pessagno 1984, Pl. 3, fig. 12, 13.

Praehexasaturnalis tetraradiatus Kozur and Mostler 1990, p. 195, Pl. 6, fig. 8, 9, 11, 12.

Stauracanthocircus quadratus (Kozur and Mostler) - Yang and Mizutani 1991, p. 73, Pl. 3, fig. ?1, 6.

Range. Protokatroma aquila Zone to *Crucella hettangica* Zone. Lower Jurassic; lower Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; Bavaria; northeast China; and Baja California Sur. Illustrated specimens GSC 107856 from 89-CNA-SKUD-34B, GSC 107857 and GSC 107859 from QC-545, GSC 107858 from 87-CNA-KUD-2, and GSC 107860 from 89-CNA-KUD-12. See occurrence chart, Figure 16.

Praehexasaturnalis poultoni Whalen and Carter n. sp.
Plate 14, figures 3, 4, 7, 8, 13
Species code: SAT02

Description. Large test with moderately wide, flat ring, distinctly hexagonal in outline. Ring surrounded by six long, broad, tapering peripheral spines located in six corners; spines sometimes bifurcated. Shell generally missing but when present, large and spongy with latticed microsphere. Polar rays more robust than auxiliary rays with number of auxiliary rays varying from eight to ten. Centre of ring subcircular in outline.

Remarks. The wider ring and peripheral spines, subcircular outline of centre of ring, and more numerous auxiliary rays distinguish this species from *Praehexasaturnalis tetraradiatus* Kozur and Mostler 1990.

Etymology. This species is named for Terry Poulton, Chief Paleontologist for the Geological Survey of Canada in Calgary, for his studies of Jurassic ammonites and bivalves.

Measurements (μm).

Maximum diameter of ring	Maximum length of peripheral spines	
206	156	Holotype
225	156	Maximum, 10 specimens
159	94	Minimum, 10 specimens
192	113	Mean, 10 specimens

Type locality. 89-CNA-KUD-5. See Locality Descriptions, Appendix 1.

Range. Protokatroma aquila Zone to *Crucella hettangica* Zone. Lower Jurassic; lower Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107861 (holotype) from type locality, GSC 107862 (paratype) and GSC 107865 (paratype) from 87-CNA-KUD-2, GSC 107863 (paratype) from 89-CNA-KUD-12, and GSC 107864 (paratype) from QC-543. See occurrence chart, Figure 16.

Genus *Pseudoheliodiscus* Kozur and Mostler 1972, emend. De Wever 1984.

Type species. Pseudoheliodiscus riedeli Kozur and Mostler 1972.

Range. Upper Triassic-Lower Jurassic.

Occurrence. Austria; Turkey; east-central Oregon; and Queen Charlotte Islands, British Columbia.

Pseudoheliodiscus yaoi Pessagno and Poisson 1981
Plate 14, figure 20
Species Code: SAT07

Pseudoheliodiscus yaoi Pessagno and Poisson 1981, p. 55, Pl. 4, fig. 9; Pl. 5, fig. 1, 4, 7-9; Pl. 13, fig. 2.

Range. Lower Jurassic; upper Sinemurian-Pliensbachian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; and Turkey. Illustrated specimen GSC 107876 from 86-OF-KUA-6. See occurrence chart, Figure 16.

Subfamily SATURNALINAE Deflandre 1953, emend. De Wever 1984

Type genus. Saturnalis Haeckel 1882.

Range. Triassic-Recent.

Occurrence. Worldwide.

Genus *Kozurastrum* De Wever 1984

Type species. Spongosaturnalis minoensis Yao 1972.

Range. Upper Triassic-Middle Jurassic.

Occurrence. Japan; Turkey; Austria; and Queen Charlotte Islands, British Columbia.

Kozurastrum sp. A
Plate 14, figures 21, 25
Species code: SAT08

Remarks. This form is distinguished from *Kozurastrum huxleyense* Carter 1993 by its shorter spines and less circular ring.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107877 from 86-OF-KUC-7 and GSC 107878 from QC-590A. See occurrence chart, Figure 16.

Genus *Mesosaturnalis* Kozur and Mostler 1981, emend. De Wever 1984

Type species. Palaeosaturnalis levis Donofrio and Mostler 1978.

Range. Upper Triassic (Norian)-Upper Cretaceous.

Occurrence. Worldwide.

Mesosaturnalis sp. aff. *M. artus* (Donofrio and Mostler 1978)
Plate 14, figures 18, 22
Species code: SAT05

Palaeosaturnalis artus Donofrio and Mostler 1978, p. 34, Pl. 7, fig. 11.

Remarks. Both specimens figured have a more elliptical central area than *Mesosaturnalis artus* (Donofrio and Mostler) and an unequal number of peripheral spines on each side of the polar rays.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107872 from 86-OF-KUC-7 and GSC 107873 from 86-OF-KUB-3. See occurrence chart, Figure 16.

Genus *Pseudacanthocircus* Kozur and Mostler 1990

Type species. Pseudacanthocircus mediospinosus Kozur and Mostler 1990

Remarks. O'Dogherty (1994) synonymized the Family PSEUDACANTHOCIRCIDAE Kozur and Mostler 1990 with the Family SATURNALIDAE Deflandre; we place the genus Pseudacanthocircis Kozur and Mostler 1990 in the Subfamily SATURNALINAE Deflandre because it lacks centrally placed polar spines.

Range. Upper Triassic (Rhaetian)-Lower Jurassic (upper Hettangian).

Occurrence. Bavaria; and Queen Charlotte Islands, British Columbia.

Pseudacanthocircus sp. aff. *P. pseudosimplex* Kozur and Mostler 1990
Plate 14, figure 24

Pseudacanthocircus pseudosimplex Kozur and Mostler 1990, p. 209, Pl. 11, fig. 2.

Remarks. The presence of three short spines on the ring distinguishes this species from *Pseudacanthocircus pseudosimplex* Kozur and Mostler 1990.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107879 from 87-CNA-KUD-2 (upper Hettangian).

Family TRIPOSPHAERIDAE Vinassa de Regny 1898

Range. Ordovician-Cretaceous.

Occurrence. Worldwide.

Genus *Fontinella* Carter 1993

Type species. Fontinella louisensis Carter 1993.

Range. Upper Triassic (upper Norian)-Lower Jurassic (Hettangian).

Occurrence. Queen Charlotte Islands, British Columbia; New Zealand; and Philippines.

Fontinella habros Carter
Plate 9, figure 9

Fontinella habros Carter 1993, p. 137, Pl. 2, fig. 13, 16.

Range. Upper Triassic (upper Norian and Rhaetian)-Lower Jurassic (Hettangian).

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107778 from 87-CNA-KUD-2.

Family XIPHOSTYLIDAE Haeckel 1881, emend.
Pessango and Yang 1989 in Pessagno, Six & Yang, 1989

Type genus. Xiphostylus Haeckel 1881, emend. Pessagno and Yang 1989 in Pessagno Six & Yang 1989

Range. Mesozoic; Triassic to Cretaceous.

Occurrence. Worldwide.

Genus *Amuria* Whalen and Carter n. gen.

Type species. Amuria impensa Whalen and Carter n. sp.

Description. Test with spherical cortical shell and peripheral spines. Cortical shell consisting of two fused latticed layers with symmetrical polygonal pore frames. Outer latticed layer usually much thicker than inner layer.

Remarks. The presence of peripheral spines on *Amuria* n. gen. distinguishes it from *Archaeocenosphaera* Pessagno and Yang 1989.

Etymology. This genus is named for the ship C.P.R. *Amur* whose captain, Louis P. Locke, took an active interest in the people, mining, and prospecting in the vicinity of Moresby Island, Queen Charlotte Islands.

Range. Triassic, Lower Jurassic; Hettangian and Sinemurian, ?Cretaceous.

Occurrence. Queen Charlotte Islands, British Columbia.

Amuria impensa Whalen and Carter n. sp.
Plate 11, figures 2, 3, 6, 23
Species code: AMU01

Description. Cortical shell large, spherical, with thick outer latticed layer composed of medium-sized, symmetrical, hexagonal pore frames (rarely pentagonal); small nodes at pore frame vertices. Test with eight to twelve short, strong spines evenly distributed over surface of test; spines circular in axial section.

Remarks. The larger test and strong spines (circular in axial section) of *Amuria impensa* n. sp. distinguish it from *A. macfarlanei* n. sp.

Etymology. Impensus, a, um (Latin; adj.) = great, large, strong.

Measurements (µm).

Diameter of cortical shell	Average length of spines	
270	46	Holotype
281	90	Maximum, 21 specimens
206	43	Minimum, 21 specimens
255	67	Mean, 21 specimens

Type locality. 89-CNA-SKUD-32. See Locality Descriptions, Appendix 1.

Range. Canoptum merum Zone to *Crucella hettangica* Zone. Lower Jurassic; lowermost Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107804 (holotype) from type locality, GSC 107805 (paratype) from QC-545, and GSC 107802 (paratype) from 89-CNA-SKUE-6. See occurrence chart, Figure 16.

Amuria macfarlanei Whalen and Carter n. sp.
Plate 11, figure 7
Species code: AMU02

Description. Cortical shell small, spherical to subspherical with thick outer latticed layer composed of small hexagonal pore frames (rarely pentagonal); small nodes at pore frame vertices. Test with approximately six to eight medium-length spines randomly distributed over surface of test; proximal portion of spines triradiate in axial section, distal portion circular.

Remarks. See remarks under *A. impensa* n. sp.

Etymology. This species is named in honor of Bruce MacFarlane for his studies of Sinemurian ammonites at the University of British Columbia.

Measurements (µm).

Number of specimens measured = (n)

Diameter of cortical shell (14)	Average length of spines (7)	
169	60	Holotype
206	77	Maximum
154	37	Minimum
180	61	Mean

Type locality. 87-CNA-KUD-14. See Locality Descriptions, Appendix 1.

Range. Pantanellium browni Zone to *Jacus? sandspitensis* Zone. Lower Jurassic; middle to upper Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107809 (holotype) from type locality. See occurrence chart, Figure 16.

Genus *Archaeocenosphaera* Pessagno and Yang 1989

Type species. Archaeocenosphaera ruesti Pessagno and Yang 1989

Range. ?Paleozoic; Triassic to Cretaceous.

Occurrence. Worldwide.

Archaeocenosphaera laseekensis Pessagno and Yang
Plate 11, figures 1, 5, 9, 21
Species code: ARC04

Archaeocenosphaera laseekensis Pessagno and Yang 1989, p. 203, Pl. 2, fig. 18, 21, 22, 25.

Range. Canoptum merum Zone to *Parahsuum simplum* Zone. Lower Jurassic; lowermost Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107800 from QC-543, GSC 107801 from 89-CNA-SKUD-339, and GSC 107803 from 90-CNA-KPD-5. See occurrence chart, Figure 16.

SPUMELLARIA INCERTAE SEDIS
Genus *Beatricea* Whalen and Carter n. gen.

Type species. Beatricea chistovalensis Whalen and Carter n. sp.

Description. Test small, circular to subrectangular in outline with four long spines in the same plane, 90° apart. Cortical shell thick with planiform upper and lower surfaces each with variably sized central cavity; sides of cortical shell straight. Shell composed of numerous layers of small, irregularly shaped pore frames lacking concentric arrangement. Layers of pore frames much thicker on margins of test. Spines usually triradiate in axial section, rarely circular.

Remarks. Beatricea n. gen. differs from *Praeorbiculiformella* Pessagno by always possessing four strong primary spines at 90° and in lacking concentrically arranged pore frames. *Beatricea* n. gen. differs from *Sophia* n. gen. and *Udalia* n. gen. in possessing irregularly arranged pore frames as well as a central cavity; *Beatricea* n. gen. further differs from *Sophia* n. gen. in lacking a central spicular network.

Etymology. This genus is named for the ship C.P.R. *Princess Beatrice* a sailing vessel in the Queen Charlotte Islands in the early 1900s.

Range. Lower Jurassic; upper Hettangian-lower Pliensbachian.

Occurrence. Queen Charlotte Islands, British Columbia.

Beatricea christovalensis Whalen and Carter n. sp.
Plate 11, figures 13, 14, 16, 17, 18, 19, 20, 22
Species code: SPI03

Description. Test small, subrectangular in outline with four, long prominent spines. Test thick with planiform upper and lower surfaces and straight sides. Cortical shell with irregularly shaped tetragonal and polygonal pore frames with very small nodes at pore frames vertices. Central cavity variable in size but usually about one-half diameter of cortical shell. Central area of test thinner than margins and often missing. Spines usually triradiate (rarely circular) in axial section with narrow longitudinal ridges and broad grooves sometimes showing torsion.

Remarks. This is the first species of *Beatricea* n. gen. described from Lower Jurassic strata of Queen Charlotte Islands. Several morphological features of this species are quite variable: the size and shape of cortical shell, the width of the central cavity, and the length of primary spines. For the present we have included all Hettangian and Sinemurian specimens in one widely variable species, *Beatricea christovalensis* n. sp. We recognize a possible relationship between *B. christovalensis* and Spumellarian indet. B but owing to our incomplete knowledge of the inner structure of both forms, their differences are not addressed in this paper.

Etymology. This species is named for the San Christoval Range in Queen Charlotte Islands.

Measurements (μm).

Diameter of cortical shell	Diameter of central area	Maximum length of primary spines	
225	124	237	Holotype
225	124	329	Maximum, 12 specimens
97	38	84	Minimum, 12 specimens
150	67	193	Mean, 12 specimens

Type locality. 89-CNA-KUG-1A. See Locality Descriptions, Appendix 1.

Range. Crucella hettangica Zone to *Jacus? sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107817 (holotype) from type locality, GSC 107813 (paratype) from 87-CNA-KUD-14, GSC 107814 (paratype) and GSC 107815 (paratype) from QC-676, and GSC 107816 (paratype) from 86-OF-KUC-7. See occurrence chart, Figure 16.

Genus *Praeorbiculiformella* Kozur and Mostler 1978

Type species. Praeorbiculiformella plana Kozur and Mostler 1978.

Range. Triassic-Jurassic.

Occurrence. Worldwide

Praeorbiculiformella? *lomgonensis*
Whalen and Carter n. sp.
Plate 9, figure 8
Species code: ORB03

Description. Test large, circular in outline with a straight-sided periphery; test relatively thick in proportion to diameter. Seven relatively broad grooves radiating from centre of test to margin. Meshwork composed primarily of small, irregularly shaped polygonal pore frames; meshwork generally uniform in size over surface of test.

Remarks. Although the overall characteristics of *Praeorbiculiformella*? *lomgonensis* n. sp. suggest inclusion with *Praeorbiculiformella* Kozur and Mostler, the unusual radiating grooves have not been observed on any other species of this genus.

Etymology. This species is named for Lomgon Bay located on the north side of Tasu Sound.

Measurements (µm).

Maximum diameter of cortical shell	
340	Holotype
347	Maximum, 17 specimens
395	Minimum, 17 specimens
281	Mean, 17 specimens

Type locality. 86-CAA-T-2/3. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 10777 (holotype) from 86-CAA-T-2/3. See occurrence chart, Figure 16.

Praeorbiculiformella robusta Whalen and Carter n. sp.
Plate 9, figures 2, 3, 4, 19
Species code: ORB02

Description. Test large, nearly circular in outline with straight-sided periphery, very thin in proportion relative to diameter. Very broad, shallow depression in centre of test usually destroyed. Three strong, principal spines intersect in centre of test; point of intersection surrounded by dense spongy meshwork with small pores; principal spines usually triradiate in axial section and extend from periphery of feet. Subsidiary spine located between each principal peripheral spine; subsidiary spines extend from margins of test only, not penetrating to centre of test. Meshwork primarily composed of small, irregularly shaped pentagonal and tetragonal pore frames; meshwork generally uniform in size over entire test.

Remarks. The large test and strong spines distinguish *Praeorbiculiformella robusta* n. sp. from *P. yanensis* n. sp.

Etymology. *Robustus, a, um* (Latin; adj.) = hard and strong like oak.

Measurements (µm).

Diameter of cortical shell	Width of central area	Length of longest spine	
325	195	118	Holotype
354	228	125	Maximum, 13 specimens
225	195	52	Minimum, 13 specimens
295	181	92	Mean, 13 specimens

Type locality. 89-CNA-KUG-1A. See Locality Descriptions, Appendix 1.

Range. *Crucella hettangica* Zone-*Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107774 (holotype), GSC 107775 (paratype) and GSC 107776 (paratype), from type locality. See occurrence chart, Figure 16.

Praeorbiculiformella yanensis Whalen and Carter n. sp.
Plate 9, figures 11, 12, 13
Species code: ORB01

Description. Test moderate in size, circular to subtriangular in outline with slightly rounded periphery. Shallow depression in centre of test usually evident; depression wide, about one-half diameter of test. Three principal peripheral spines, very short, triradiate in axial section. Few small subsidiary spines located between principal peripheral spines. Meshwork primarily composed of small, irregularly shaped polygonal pore frames; meshwork generally uniform in size over margins of test becoming slightly denser towards centre of central area.

Remarks. See remarks under *Praeorbiculiformella robusta* n. sp.

Etymology. This species is named for Yan, an old Haida village located on the west side of the entrance to Masset Harbor, Graham Island.

Measurements (µm).

Diameter of cortical shell	Width of central area	Length of longest spine	
284	143	75	Holotype
315	172	94	Maximum, 13 specimens
221	96	23	Minimum, 13 specimens
273	142	64	Mean, 13 specimens

Type locality. 86-CAA-T-2/3. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107779 (holotype), GSC 107780 (paratype), and GSC 107781 (paratype) from type locality. See occurrence chart, Figure 16.

Praeorbiculiformella sp. A
Plate 9, figure 22

Remarks. The very large bladed spines distinguish *Praeorbiculiformella* sp. A from other praeorbiculiformids described in this paper.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107784 from 89-CNA-KUA-6 (upper Sinemurian).

Genus *Pseudoheptacladus* Lahm 1984

Type species. Pseudohaptacladus tener Lahm 1984.

Pseudoheptacladus sp. A
Plate 11, figures 4, 8, 12
Species code: SPI01

Remarks. Cortical shell small and irregularly spherical with seven very long, randomly arranged spines. Shell composed of numerous layers of small spongy pore frames. Centre of test appears to be hollow. Spines very thin, circular in axial section.

Range. Protokatroma aquila Zone to *Parahsuum simplum* Zone. Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107806, GSC 107807, and GSC 107808 from 87-CNA-KUD-2. See occurrence chart, Figure 16.

Genus *Udalia* Whalen and Carter n. gen.

Type species. Udalia dennisoni Whalen and Carter n. sp.

Description. Test square or rectangular in outline, usually quite thick with four prominent spines in the same plane, one at each corner. Upper and lower surfaces of test planiform, sides vertical. Test composed of multiple layers of fine meshwork; meshwork of cortical shell with numerous, irregularly shaped (mostly triangular and tetragonal) pore frames with small nodes at pore frame vertices. Pore frames of inner layers much thinner and lack nodes. Inner structure unknown as centre of test hollow in all specimens observed. Spines circular or triradiate, tapering distally.

Remarks. *Udalia* n. gen. differs from *Sophia* n. gen. by lacking an entactiniid-like inner structure, having a thinner shell, more pore frames, and much smaller nodes at pore frame vertices. We note that *Udalia* n. gen. has ferresiid-like meshwork. It is possible this genus could be assigned to the FERRESIIDAE Carter if that family were revised to include forms with four spines in the cruciform position. Comparison with *Emiluvia* Foreman is difficult because of the absence of information on the inner structure of *Udalia* n. gen.

Etymology. This genus named for the *Udal*, a mission ship built in Sandspit, Queen Charlotte Islands in the early 1900s.

Range. Lower Jurassic; Hettangian-Sinemurian.

Occurrence. Queen Charlotte Islands, British Columbia.

Udalia dennisoni Whalen and Carter n. sp.
Plate 6, figures 11, 13, 14, 17, 18, 19, 21, 22
Species code: UDA03

Description. Cortical shell large, very thick, nearly diamond-shaped in outline (some specimens with slightly incurved or concave sides); upper and lower surfaces planiform, sides vertical. Outer meshwork composed of small- to medium-sized, irregularly shaped triangular and tetragonal pore frames with small nodes at pore frame vertices; pore frame bars very thin in Y direction, much thicker in Z direction (refer to measurement system for Subfamily Charlotteinae, Pl. 4, fig. 11). Test with four, long, strong spines, all equal in length and width; spines tapering distally, triradiate in axial section with narrow, rounded longitudinal ridges and broad, shallow longitudinal grooves.

Remarks. The thick, diamond-shaped test and strong triradiate spines of *Udalia dennisoni* n. sp. distinguish it from *Udalia primaeva* n. sp. In addition, the slightly indented concave sides of some specimens of *U. dennisoni* (see Pl. 6, fig. 13) suggest a resemblance to *Crucella* Pessagno which becomes common at approximately the same time.

Etymology. Named for Shane Dennison who ably assisted with fieldwork at Kennecott Point in 1988.

Measurements (μm).

Maximum diameter of cortical shell	Length of longest spine	
157	133	Holotype
188	283	Maximum, 11 specimens
146	133	Minimum, 11 specimens
164	177	Mean, 11 specimens

Type locality. QC-574. See Locality Descriptions, Appendix 1.

Range. Pantanellium browni Zone to *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; middle to upper Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107746 (holotype), GSC 107744 (paratype), GSC 107748 (paratype), and GSC 107749 (paratype) from type locality. GSC 107745 (paratype) from 87-CNA-KUD-9 and GSC 107747 (paratype) from 87-CNA-KPB-12. See occurrence chart, Figure 16.

Udalia parvacapsa Whalen and Carter n. sp.
Plate 7, figures 3, 4, 7, 8, 12
Species code: UDA04

Description. Cortical shell very small, square to subrectangular in outline, quite thick with planiform upper and lower surfaces and vertical sides. Meshwork composed of small, irregularly shaped triangular and tetragonal pore frames with small- to moderate-sized nodes at pore frame vertices; pore frame bars very thin in Y direction, much thicker in Z direction. Test with four, very long strong spines all equal in length and width and tapering distally; length of spines always twice the maximum diameter of test; spines triradiate in axial section with narrow, rounded longitudinal ridges and broad, shallow longitudinal grooves.

Remarks. Udalia parvacapsa n. sp. differs from *U. plana* n. sp. in having a smaller test and much longer spines.

Etymology. Parvus, a, um (Latin; adj.) = minor, little, small; *Capsa, ae* (Latin; noun) = box or case.

Measurements (µm).

Maximum diameter of cortical shell	Length of longest spine	
126	252	Holotype
154	413	Maximum, 12 specimens
100	169	Minimum, 12 specimens
139	246	Mean, 12 specimens

Type locality. 87-CNA-KUD-9. See Locality Descriptions, Appendix 1.

Range. Pantanellium browni Zone to *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; middle to upper Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107758 (holotype) from type locality, GSC 107759 (paratype) from QC-545, GSC 107760 (paratype) from 87-CNA-KUD-10, and GSC 107761 (paratype) from 87-CNA-KUD-14. See occurrence chart, Figure 16.

Udalia plana Whalen and Carter n. sp.
Plate 5, figures 7, 8, 12, 13; Plate 7, figures 13, 14, 15, 18
Species code: UDA05

Description. Cortical shell diamond-shaped in outline, very thick, with planiform upper and lower surfaces and vertical sides. Meshwork composed of irregularly shaped triangular and tetragonal pore frames with large, rounded nodes at pore frame vertices; pore frame bars thinner in Y direction than in Z direction (refer to Pl. 4, fig. 11 for measurement system). Test with four long spines, all equal in length and width and tapering distally; spines triradiate in axial section with narrow, rounded longitudinal ridges and grooves.

Remarks. See remarks under *Udalia parvacapsa* n. sp.

Etymology. Planus, a, um (Latin; adj.) = even, level, flat.

Measurements (µm).

(n) = number of specimens measured

Maximum diameter of cortical shell (7)	Maximum length of primary spines (6)	
113	131	Holotype
143	131	Maximum
105	79	Minimum
122	93	Mean

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. Protokatroma aquila Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; lower Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107729 (holotype) from type locality, GSC 107762 (paratype) from 89-CNA-KUD-11, GSC 107763 (paratype) from QC-545, and GSC 107764 (paratype) from 87-CNA-KUD-2. See occurrence chart, Figure 16.

Udalia primaeva Whalen and Carter n. sp.
Plate 6, figures 8, 12, 15, 16, 20, 23
Species code: UDA01

Description. Cortical shell large and flattened, nearly square in outline with planiform upper and lower surfaces and straight sides. Outer meshwork composed of small irregularly shaped triangular and tetragonal pore frames with very small nodes at pore frame vertices; pore frame bars very thin in Y direction, much thicker in Z direction. Test with four, very long slim spines all equal in length and width; spines tapering distally, circular in axial section.

Remarks. See remarks under *Sophia dennisoni* n. sp.

Etymology. Primaevus, a, um (Latin; adj.) = young, youthful.

Measurements (µm).

Maximum diameter of cortical shell	Length of longest spine	
175	188	Holotype
206	202	Maximum, 15 specimens
125	118	Minimum, 15 specimens
162	141	Mean, 15 specimens

Type locality. 89-CNA-KUD-5. See Locality Descriptions, Appendix 1.

Range. Canoptum merum Zone to *Parahsuum simplum* Zone. Lower Jurassic; lowermost Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107742 (holotype) from type locality, GSC 107740 (paratype) from 89-CNA-SKUD-27, GSC 107741 (paratype) from 87-CNA-KUD-2, and GSC 107743 (paratype) from QC-543. See occurrence chart, Figure 16.

Spongodiscid indet. A
Plate 9, figure 14

Remarks. The smaller test and coarser meshwork distinguish this species from Spongodiscid indet. B.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107782 from 87-CNA-KUD-2 (upper Hettangian).

Spongodiscid indet. B
Plate 9, figure 18

Remarks. See remarks under Spongodiscid indet. A.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107783 from 89-CNA-KUD-12 (upper Hettangian).

Spumellarian indet. A
Plate 11, figures 10, 11, 15
Species code: SPI02

Remarks. Cortical shell large and irregularly spherical with ten or more moderately long randomly arranged spines. Meshwork dense and spongy throughout test. Spines slim and circular in axial section.

Range. Protokatroma aquila Zone to *Pantanellium browni* Zone. Lower Jurassic; Hettangian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107810 from 89-CNA-SKUD-34A, GSC 107811 from 87-CNA-KUD-2, and GSC 107812 from QC-543. See occurrence chart, Figure 16.

Spumellarian indet. B
Plate 12, figure 17

Remarks. This form has affinities to *Crucella* Pessagno, *Praeorbiculiformella* Kozur and Mostler, and *Beatricea* n. gen. but seems to be a separate form.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107835 from 88-OF-LB-1 (upper Sinemurian).

Spumellarian indet. C
Plate 9, figures 15, 16, 17, 20, 21
Species code: SPI04

Remarks. Cortical shell disc-shaped, hexagonal to subcircular in outline, with six radial spines. Test composed of several layers of meshwork; outer meshwork with small polygonal pore frames with small rounded nodes at vertices. Test appears to have three primary spines at 120° and three intervening secondary spines of variable length. Primary spines long, triradiate in axial section. Length of secondary spines varies from near equal to primary spines (Pl. 9, fig. 16, 17), to very short and almost rudimentary (Pl. 9, fig. 15, 20, 21); secondary spines usually circular in axial section.

This form is somewhat similar to *Pentaspongodiscus dihexacanthus* Carter but lacks polar spines and the radial spines are subequal in length and never twisted.

Range. Protokatroma aquila Zone to *Crucella hettangica* Zone. Lower Jurassic; lower Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107787 and GSC 107786 from 87-CNA-KUD-2, GSC 107785 from 89-CNA-SKUD-38, and GSC 107788 from QC-543. See occurrence chart, Figure 16.

Suborder NASSELLARIINA Ehrenberg 1875

Range. Upper Paleozoic?; Triassic to Recent, worldwide.

Occurrence. Worldwide.

Family BAGOTIDAE Pessagno and Whalen 1982

Type genus. Bagotum Pessagno and Whalen 1982.

Range. Upper Triassic; Rhaetian-Lower to Middle Jurassic.

Occurrence. Queen Charlotte Islands, British Columbia; California; Baja California Sur; and Turkey.

Genus *Bagotum* Pessagno and Whalen 1982

Type species. Bagotum maudense Pessagno and Whalen 1982.

Range. Lower Jurassic; Sinemurian-Pliensbachian.

Occurrence. Queen Charlotte Islands, British Columbia; California; and Baja California Sur.

Bagotum erraticum Pessagno and Whalen
Plate 16, figure 8
Species code: BAG01

Bagotum erraticum Pessagno and Whalen 1982, p. 117; Pl. 1, fig. 10.

Range. Lower Jurassic; Sinemurian-lower Pliensbachian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen USNM 307182 (original holotype) from QC-549. See occurrence chart, Figure 17.

Bagotum helmetense Pessagno and Whalen
Plate 15, figure 1; Plate 26, figure 1
Species code: BAG02

Bagotum? *helmetense* Pessagno and Whalen 1982, p. 118-119; Pl. 1. fig. 11; Pl. 12, fig. 23.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens USNM 307184 (original holotype) from QC-590A, paratype (Pessagno Collection) from QC-590A. See occurrence chart, Figure 17.

Bagotum sp. A
Plate 16, figure 1

Remarks. Bagotum sp. A is more elongate than other species of *Bagotum* from the Sandilands Formation. The very coarse, almost costate, irregularly arranged pore frames distinguish this species from *B. helmetense* Pessagno and Whalen.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107894 from 89-CNA-KUA-6 (upper Sinemurian).

Bagotum sp. B
Plate 15, figure 2

Remarks. Bagotum sp. B is more spindle-shaped (postabdominal chambers increasing more rapidly in width as added) with more regularly arranged pore frames than *B. erraticum* Pessagno and Whalen.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107881 from QC-676 (upper Sinemurian).

Bagotum sp. C
Plate 15, figure 3

Remarks. The pore frames of *Bagotum* sp. C are arranged in a more linear manner and the test is more inflated distally than other species of *Bagotum* from the Sandilands Formation.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107882 from QC-677 (upper Sinemurian).

Genus *Broctus* Pessagno and Whalen 1982

Type species. Broctus selwynensis Pessagno and Whalen 1982.

Range. Lower Jurassic; upper Sinemurian-Pliensbachian.

Occurrence. Queen Charlotte Islands, British Columbia; east-central Oregon; and Baja California Sur.

Broctus kuensis Pessagno and Whalen
Plate 15, figure 4; Plate 26, figure 2
Species code: BRO02

Broctus kuensis Pessagno and Whalen 1982, p. 120-121; Pl. 1, fig. 7; Pl. 2, fig. 17, 21.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens USNM 307192 (original holotype) from QC-590A, USNM 307193 (paratype) from QC-590A. See occurrence chart, Figure 17.

Broctus selwynensis Pessagno and Whalen
Plate 15, figure 5; Plate 26, figure 3
Species code: BRO01

Broctus selwynensis Pessagno and Whalen 1982, p. 121; Pl. 1, fig. 6; Pl. 2, fig. 18, 20; Pl. 12, fig. 10.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens USNM 307190 (original holotype) from QC-590A; USNM 307191 (paratype) from QC-590A. See occurrence chart, Figure 17.

Genus *Droltus* Pessagno and Whalen 1982

Type species. Droltus lyellensis Pessagno and Whalen 1982.

Range. Upper Triassic; Rhaetian-Middle Jurassic; upper Bajocian.

Occurrence. Queen Charlotte Islands, British Columbia; east central Oregon; California; Baja California Sur; and the Russian Far East.

Droltus firmus Whalen and Carter n. sp.
Plate 15, figures 7, 12, 13, 16, 17
Species code: DRO04

Description. Test as with genus, conical, usually with four to five postabdominal chambers. Cephalis dome-shaped, with short horn; imperforate, usually covered by layer of microgranular silica. Thorax, abdomen, and first few postabdominal chambers trapezoidal in outline, increasing gradually in height and width as added; final postabdominal chamber sometimes gradually decreasing in width. Pore frames on outer latticed layer of thorax, abdomen, and first few postabdominal chambers irregularly shaped and sized polygonal pore frames (mostly pentagonal and tetragonal); pore frames on last few postabdominal chambers larger, more uniformly shaped (rectangular), and aligned in distinct horizontal and vertical rows.

Remarks. The very large, irregularly shaped pore frames on the outer latticed layer of the abdomen and first few postabdominal chambers of *Droltus firmus* n. sp. distinguish it from *D. laseekensis* Pessagno and Whalen.

Etymology. Firmus, a, um (Latin; adj.) = firm, strong, stout.

Measurements (µm).

Length (excluding horn)	Maximum width	
188	120	Holotype
195	128	Maximum, 15 specimens
150	98	Minimum, 15 specimens
170	118	Mean, 15 specimens

Type locality. QC-677. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107888 (holotype), GSC 107889 (paratype), and GSC 107890 (paratype) from type locality. See occurrence chart, Figure 17.

Droltus fondrenensis Whalen and Carter n. sp.
Plate 15, figures 9, 18
Species code: DRO05

Description. Test conical, finely costate, with approximately four to six postabdominal chambers. Cephalis medium sized, dome-shaped, sparsely perforate, mostly covered by layer of microgranular silica; cephalis with short, delicate horn, circular in axial section. Thorax, abdomen, and postabdominal chambers trapezoidal in outline, increasing gradually in width and height as added. Pore frames of outer latticed layer on abdomen and postabdominal chambers square to rectangular, aligned in distinct transverse and vertical rows, becoming larger as added. First few postabdominal chambers with about 8 costae visible laterally; number of costae increasing to about 12 on final postabdominal chamber.

Remarks. The much more regularly aligned pore frames of the outer latticed layer, distinguish *Droltus fondrenensis* n. sp. from *D. firmus* n. sp.

Etymology. This species is named for Fondren Science Building at the University of Texas at Dallas where much of the systematic research for this paper was carried out.

Measurements (µm).

Length (excluding horn)	Maximum width	
195	105	Holotype
225	128	Maximum, 6 specimens
150	94	Minimum, 6 specimens
191	112	Mean, 6 specimens

Type locality. QC-677. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107892 (holotype) from type locality. See occurrence chart, Figure 17.

Droltus hecatensis Pessagno and Whalen
Plate 15, figure 14
Species code: DRO02

Droltus hecatensis Pessagno and Whalen 1982, p. 121; Pl. 1, fig. 12, 13, 18, 22; Pl. 4, fig. 1, 2, 6, 10; Pl. 12, fig. 18-19.

Droltus hecatensis Pessagno and Whalen - Hattori 1989, Pl. 12, fig. F.

Range. Lower Jurassic; Hettangian-lower Pliensbachian.

Occurrence. Sandilands and Ghost Creek formations, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107893 from QC-590A. See occurrence chart, Figure 17.

Droltus laseekensis Pessagno and Whalen
Plate 15, figure 8; Plate 26, figure 4
Species code: DRO03

Droltus laseekensis Pessagno and Whalen 1982, p. 122; Pl. 2, fig. 5, 6, 11, 16; Pl. 12, fig. 8, 15.

Range. Crucella hettangica Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens USNM 307196 (original holotype) from QC590A; USNM 307197 (original paratype) from QC-590A. See occurrence chart, Figure 17.

Droltus lyellensis Pessagno and Whalen
Plate 16, figure 9
Species code: DRO06

Droltus lyellensis Pessagno and Whalen 1982, p. 122; Pl. 2, fig. 3, 10; Pl. 12, fig. 7.

Range. Parahsuum simplum Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen USNM 307198 (original holotype) from QC-550. See occurrence chart, Figure 17.

Family CANOPTIDAE Pessagno 1979, (in Pessagno, Finch & Abbott, 1979)

Type genus. Canoptum Pessagno 1979 (in Pessagno, Finch & Abbott, 1979)

Range. Upper Triassic to Lower Jurassic; (?)Middle Jurassic.

Occurrence. Alaska; British Columbia; Washington; Oregon; California; Baja California Sur; Turkey; and Oman.

Genus *Canoptum* Pessagno 1979 in Pessagno, Finch & Abbott 1979

Type species. Canoptum poissoni Pessagno 1979 in Pessagno, Finch & Abbott, 1979.

Range. Upper Triassic; Carnian to Lower Jurassic.

Occurrence. Same as for family.

Canoptum columbiaense Whalen and Carter n. sp.
Plate 15, figures 6, 10, 11, 15, 19
Species code: CAN08

Description. Test conical, usually with 10 to 11 postabdominal chambers. Cephalis and thorax combined steeply conical, almost knob-like, with distinct break in slope from abdomen. Abdomen and postabdominal chambers trapezoidal in outline, gradually increasing in width and height as added. Cephalis and thorax smooth, imperforate, covered by layer of microgranular silica. Postabdominal chambers separated from each other and abdomen by moderately wide circumferential ridges alternating with constrictions. Inner latticed layer of postabdominal chambers consisting of small, irregular polygonal pore frames exposed on circumferential ridges; layer of microgranular silica in constrictions mostly covering polygonal pore frames on proximal part of test; many pore frames exposed within constrictions on distal part of test.

Remarks. *Canoptum columbiaense* n. sp. differs from *C. margaritaense* n. sp. by the absence of pronounced nodes on the circumferential ridges; and from *C. unicum* Pessagno and Whalen by the development of a thicker layer of microgranular silica in the constrictions and the shape of the cephalis.

Etymology. This species is named for the Province of British Columbia.

Measurements (μm).

Length	Maximum width	
218	98	Holotype
259	120	Maximum, 11 specimens
195	90	Minimum, 11 specimens
232	108	Mean, 11 specimens

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. *Protokatroma aquila* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; lower Hettangian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107885 (holotype) from QC-676; GSC 107886 (paratype) and GSC 107887 (paratype) from QC-675. See occurrence chart, Figure 17.

Canoptum dixoni Pessagno and Whalen
Plate 17, figure 1; Plate 26, figure 5
Species code: CAN09

Canoptum dixoni Pessagno and Whalen 1982, p. 124; Pl. 2, fig. 1, 2, 8, 9, 14; Pl. 12, fig. 2.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108553 (specimen destroyed in SEM work) from QC-590A and USNM 307205 (paratype) QC-590A. See occurrence chart, Figure 17.

Canoptum margaritaense Whalen and Carter n. sp.
Plate 17, figures 2, 3
Species code: CAN11

Description. Test conical, lobulate, usually with 11 to 13 postabdominal chambers. Cephalis conical; thorax, abdomen, and postabdominal chambers trapezoidal in outline, increasing gradually in width and height as added. Cephalis and thorax smooth, imperforate, covered by layer of microgranular silica. Postabdominal chambers separated from each other and abdomen by broad, nodose circumferential ridges alternating with constrictions; constrictions covered by thick layer of microgranular silica. Inner latticed layer of postabdominal chambers usually obscured but where exposed, consist of small, polygonal pore frames. H-linked pattern on circumferential ridges formed by raised nodes of microgranular silica surrounded by small polygonal pores.

Remarks. The H-linked pattern on the circumferential ridges distinguish *Canoptum margaritaense* n. sp. from *C. dixoni* Pessagno and Whalen and *C. columbiaense* n. sp.

Etymology. This species is named for Cape St. Margarita, the northern tip of the Queen Charlotte Islands.

Measurements (μm).

Length	Maximum width	
368	128	Holotype
368	128	Maximum, 6 specimens
225	83	Minimum, 6 specimens
287	101	Mean, 6 specimens

Type locality. QC-675. See Locality Descriptions, Appendix 1.

Range. *Crucella hettangica* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108554 (holotype) from QC-675; GSC 108555 (paratype) from QC-590A. See occurrence chart, Figure 17.

Canoptum merum Pessagno and Whalen
Plate 16, figure 3
Species code: CAN06

Canoptum merum Pessagno and Whalen 1982, p. 124; Pl. 1, fig. 1, 15, 16, 20; Pl. 12, fig. 11.

Range. *Canoptum merum* Zone to *Pantanellium browni* Zone. Upper Triassic; (?)Rhaetian Lower Jurassic; lower-middle to upper Hettangian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia and Graylock Formation of east-central Oregon. Illustrated specimen USNM 307206 (original holotype) from QC-543. See occurrence chart, Figure 17.

Canoptum unicum Pessagno and Whalen
Plate 16, figure 2
Species code: CAN10

Canoptum unicum Pessagno and Whalen 1982, p. 125; Pl. 1, fig. 5, 14, 19, 23; Pl. 12, fig. 4.

Range. Pantanellium browni Zone to *Parahsuum simplum* Zone. Lower Jurassic; middle to upper Hettangian-lower Sinemurian

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107895 from 87-CNA-KPB-10. See occurrence chart, Figure 17.

Canoptum sp. A
Plate 17, figure 4

Remarks. The narrower circumferential ridges and lack of microgranular silica in the constrictions distinguish *Canoptum* sp. A from *C. columbiaense* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108556 from QC-568 (upper Hettangian).

Genus *Relanus* Pessagno and Whalen 1982

Type species. Relanus reefensis Pessagno and Whalen 1982.

Range. Lower Jurassic; Hettangian (?)lowest Sinemurian.

Occurrence. Queen Charlotte Islands, British Columbia; and Bavaria.

Relanus reefensis Pessagno and Whalen
Plate 16, figures 4, 5, 10, 11; Plate 26, figure 6
Species code: REL01

Relanus reefensis Pessagno and Whalen 1982, p. 125-126; Pl. 1, fig. 2-4, 17, 21; Pl. 12, fig. 3.

Relanus hettangicus Kozur and Mostler 1990, p. 220; Pl. 16, fig. 1, 4, 5, 7, 11, 14; Pl. 17, fig. 8, 14-16.

Range. Canoptum merum Zone to *Crucella hettangica* Zone. Lower Jurassic; lowest Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; and Bavaria. Illustrated specimens from USNM 307212 (original holotype) from QC-543, USNM 307213 (original paratype) from QC-545, GSC 107897 from 87-CNA-KUD-4, GSC 107899 from 89-CNA-SKUD-39, and GSC 107900 from 90-CNA-KPD-5. See occurrence chart, Figure 17.

Genus *Wrangellium* Pessagno and Whalen 1982

Type species. Wrangellium thurstonense Pessagno and Whalen 1982.

Range. Lower Jurassic; upper Sinemurian to middle Toarcian.

Occurrence. Queen Charlotte Islands, British Columbia; California; east-central Oregon; and Japan.

Wrangellium thurstonense Pessagno and Whalen
Plate 17, figures 5, 6; Plate 26, figure 7
Species code: WNG01

Wrangellium thurstonense Pessagno and Whalen 1982, p. 126; Pl. 2, fig. 7, 13; Pl. 3, fig. 1, 3, 10, 18; Pl. 12, fig. 13.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus? sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens USNM 307214 (original holotype) from QC-590A, USNM 307215 (original paratype) from QC-590A, and GSC 108557 from QC-674. See occurrence chart, Figure 17.

Family CANUTIDAE Pessagno and Whalen 1982

Type genus. Canutus Pessagno and Whalen 1982.

Range. Upper Triassic; (?)Rhaetian, Lower Jurassic; Sinemurian to lower Toarcian.

Occurrence. British Columbia, Oregon, and California.

Genus *Canutus* Pessagno and Whalen 1982

Type species. Canutus tipperi Pessagno and Whalen 1982.

Range. Lower Jurassic; upper Sinemurian to lower Toarcian.

Occurrence. Queen Charlotte Islands, British Columbia; east-central Oregon; California; and Baja California Sur.

Canutus blomei Pessagno and Whalen
Plate 16, figure 7
Species code: CTS04

Canutus blomei Pessagno and Whalen 1982, p. 127; Pl. 3, fig. 13-15; Pl. 12, fig. 20.

Range. Lower Jurassic; upper Sinemurian-Pliensbachian.

Occurrence. Sandilands, Ghost Creek, and Fannin formations, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107902 from 89-CNA-KUH-1. See occurrence chart, Figure 17.

Canutus rockfishensis Pessagno and Whalen
Plate 17, figure 18; Plate 26, figure 8
Species code: CTS03

Canutus rockfishensis Pessagno and Whalen 1982, p. 129; Pl. 2, fig. 4, 12, 15, 19; Pl. 12, fig. 22.

Range. Lower Jurassic; upper Sinemurian-Pliensbachian.

Occurrence. Sandilands, Ghost Creek, and Fannin formations, Queen Charlotte Islands, British Columbia; and Nicely Formation, east-central Oregon. Illustrated specimens USNM 307226 (original holotype) from QC-677; USNM 307227 (original paratype) from QC-590A. <u>See</u> occurrence chart, Figure 17.

Canutus sp. A
Plate 17, figure 19
Species code: CTS05

Remarks. The shorter, more robust test of *Canutus* sp. A distinguishes it from *C. rockfishensis* Pessagno and Whalen, while the structure of the cephalis and the more delicate pore frames of the outer layer distinguish it from *C. blomei* Pessagno and Whalen.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108565 from QC-677. <u>See</u> occurrence chart, Figure 17.

Family CUNICULIFORMIIDAE De Wever 1982

Type genus. Cuniculiformis De Wever 1982.

Range. Lower Jurassic; upper Sinemurian-Pliensbachian, so far as known.

Occurrence. Turkey; New Zealand; and Queen Charlotte Islands, British Columbia.

Genus *Cuniculiformis* De Wever 1982

Type species. Cuniculiformis plinius De Wever 1982.

Range. Lower Jurassic; upper Sinemurian-Pliensbachian.

Occurrence. Turkey; New Zealand; and Queen Charlotte Islands, British Columbia.

Cuniculiformis plinius De Wever
Species code: CUN01
(not illustrated)

Cuniculiformis plinius De Wever 1982, p. 199; Pl. 6, fig. 17-20.

Cuniculiformis plinius De Wever - Spörli and Aita 1988, Pl. 4, fig. 6; Spörli, Aita and Gibson 1989, fig. 5, no. 7; Aita and Spörli 1992, fig. 5, no. 6.

Range. Lower Jurassic; upper Sinemurian-Pliensbachian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; <u>See</u> occurrence chart, Figure 17. Taurides Occidentales, Turkey; and Waipapa Terrane, New Zealand.

Family DEFLANDRECYRTIIDAE Kozur and Mostler 1979

Type genus. Deflandrecyrtium Kozur and Mostler 1979.

Range. Upper Triassic-Lower Jurassic.

Occurrence. European Tethys; Japan; Philippines; and Queen Charlotte Islands, British Columbia.

Genus *Haeckelicyrtium* Kozur and Mostler 1979, emend. Carter 1993

Type species. Haeckelicyrtium austriacum Kozur and Mostler 1979

Range. Triassic-Lower Jurassic.

Occurrence. Austria; Turkey; and Queen Charlotte Islands, British Columbia.

Haeckelicyrtium sp. A
Plate 16, figures 14, 15, 19, 20, 21, 22
Species code: HCK03

Remarks. The smaller more delicate pore frames, shorter, less robust peripheral spines and change in slope of test distinguish *Haeckelicyrtium* sp. A from the Rhaetian form, *H. karcharos* Carter 1993.

Range. Pantanellium browni Zone to *Crucella hettangica* Zone. Lower Jurassic; middle to upper Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107907 and GSC 107908 from QC-545; GSC 107909 from 89-CNA-KUA-3. <u>See</u> occurrence chart, Figure 17.

Family FARCIDAE Pessagno, Whalen, and Yeh 1986

Type genus. Farcus, Pessango, Whalen and Yeh 1986.

Range. Lower Jurassic; upper Sinemurian-upper Toarcian.

Occurrence. Queen Charlotte Islands, British Columbia; east-central Oregon; and Baja California Sur.

Genus *Farcus* Pessagno, Whalen, and Yeh 1986

Type species. Farcus graylockensis Pessagno, Whalen and Yeh 1986.

Range. Lower Jurassic; upper Sinemurian to middle Toarcian.

Occurrence. Queen Charlotte Islands, British Columbia; east-central Oregon; and Baja California Sur.

Farcus sp. A
Plate 16, figure 16
Species code: FAR01

Remarks. The smaller thorax and longer feet of *Farcus* sp. A distinguish it from *Farcus graylockensis* Pessagno, Whalen and Yeh.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 107910 from 86-OF-KUC-8. See occurrence chart, Figure 17.

Family HSUIDAE Pessagno and Whalen 1982

Type genus. Hsuum Pessagno 1977a.

Range. Lower Jurassic; Hettangian-Lower Cretaceous; upper Valanginian-lower Hauterivian.

Occurrence. Alaska, British Columbia, Oregon, California, Baja California, Japan, Sarawak, Oman, Turkey, Romania, Greece, Italy, and Puerto Rico.

Genus *Parahsuum* Yao 1982

Type species. Parahsuum simplum Yao 1982.

Remarks. We tentatively assign *Parahsuum* Yao to the HSUIDAE Pessagno and Whalen. Although there is a linear arrangement of pore frames between costae ridges on *Parahsuum* Yao, there is little evidence of a double-layered test wall.

Range. Lower Jurassic; Hettangian-Middle Jurassic; Bajocian.

Occurrence. Queen Charlotte Islands, British Columbia; Bavaria; Japan; and Russian Far East.

Parahsuum simplum Yao
Plate 16, figure 6
Species code: PHS01

Archaeodictyomitra sp. A - Yao, Matsuda and Isozaki 1980a, Pl. 3, fig. 7-9.

Parahsuum simplum Yao 1982, Pl. 4, fig. 1-4, 6-8.

Parahsuum simplum Yao - Yao, Matsuoka and Nakatani 1982, Pl. 2, fig. 9; Imoto et al., Pl. 1, fig. 1-2; Matsuoka 1983, Pl. 1, fig. 4; Hori 1986, fig. 6, no. 2; Matsuoka and Yao 1986, Pl. 1, fig. 2; Yoshida 1986, Pl. 4, fig. 1-2; Hori and Yao 1988, Pl. 1, fig. 1a-1d; Matsuoka 1988, Pl. 1, fig. 1-2; Sashida 1988, Pl. 1, fig. 1-5, 16-17; Kurimoto and Kuwahara 1991, Pl. 1, fig. 18; Hori 1992, fig. 8, no. 15.

Range. Lower Jurassic; Hettangian? lower Sinemurian-Pliensbachian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; Bavaria; Japan; and Russian Far East. Illustrated specimen GSC 107901 from 89-CNA-KUB-5 (Sinemurian). See occurrence chart, Figure 17.

Family PARVICINGULIDAE Pessagno 1977a

Type genus. Parvicingula Pessagno 1977a.

Range. Late Triassic (Rhaetian)-Upper Cretaceous.

Occurrence. Worldwide.

Genus *Atalanta* Cordey and Carter 1996

Type species. Atalanta emmela Cordey and Carter 1996.

Range. Lower Jurassic; Hettangian-Pliensbachian.

Occurrence. Queen Charlotte Islands and central British Columbia (Intermontane Terrane).

Atalanta emmela Cordey and Carter 1996
Plate 24, figure 13
Species code: ATA02

Gen. indet. Z sp. A, Cordey 1988, p. 291, Pl. 24, fig. 9; Tipper et al. 1991, Pl. 8, fig. 8.

Atalanta emmela Cordey and Carter 1996, p. 447, Pl. 1, fig. 1-3.

Range. Lower Jurassic; Sinemurian-Pliensbachian.

Occurrence. Sandilands Formation, Queen Charlotte Islands; and central British Columbia. Illustrated specimen GSC 110656 (original holotype) from 86-OF-KUB-3. See occurrence chart, Figure 17.

Atalanta epaphrodita Cordey and Carter 1996
Plate 24, figures 8, 9
Species code: ATA01

Gen. indet. M sp. 1 - Tipper et al. 1991, Pl. 8, fig. 18.

Atalanta epaphrodita Cordey and Carter 1996, p. 447, Pl. 1, fig. 6, 7, 10, 11.

Range. Protokatroma aquila Zone to *Parahsuum simplum* Zone. Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 110659 (original holotype) from 87-CNA-KUD-10; GSC 110661 (original paratype) from 87-CNA-KUD-4. See occurrence chart, Figure 17.

Genus *Nitrader* Cordey and Carter 1996

Type species. Nitrader montegufonensis Cordey and Carter 1996

Range. Lower Jurassic; Hettangian-lower Sinemurian.

Occurrence. Queen Charlotte Islands, British Columbia.

Nitrader montegufonensis Cordey and Carter 1996
Plate 24, figures 6, 7
Species code: NIT01

Nitrader montegufonensis Cordey and Carter 1996, p. 449, Pl. 1, fig. 4, 5, 8, 9, 12.

Range. Crucella hettangica Zone to *Parahsuum simplum* Zone. Lower Jurassic; upper Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108639 from QC-574; GSC 110657 (original holotype) from 89-CNA-KUD-17. See occurrence chart, Figure 17.

Nitrader sp. A
Plate 16, figures 12, 13
Species code: NIT02

Remarks. Cone-shaped multicyrtid test with cephalis, thorax, abdomen, and six to nine single layered, postabdominal chambers; each chamber with two rows of irregular polygonal pore frames. Test walls smooth with no circumferential ridges or strictures. Cephalis small and rounded with short, thin, offset horn; short cephalic spine extends outward from base of cephalis.

This species differs from *N. montegufonensis* Cordey and Carter by having more irregularly shaped pores frames between curcumferential ridges.

Range. Protokatroma aquila Zone to *Crucella hettangica* Zone. Lower Jurassic; lower Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 107905 and GSC 107906 from 89-CNA-KUD-5. See occurrence chart, Figure 17.

Family PYLENTONEMIDAE Deflandre 1963

Range. Ordovician-Cretaceous.

Occurrence. Worldwide.

Subfamily POULPINAE De Wever 1981a

Type genus. Poulpus De Wever 1979 in De Wever et al., 1979.

Range. Triassic-Cretaceous.

Occurrence. Queen Charlotte Islands, British Columbia; California; Baja California Sur; Greece; Sicily; and Turkey.

Genus *Saitoum* Pessagno 1977a

Type species. Saitoum pagei Pessagno 1977a.

Range. Lower Jurassic; Hettangian to Cretaceous (upper Barremian-middle Albian).

Occurrence. Lower Jurassic of Queen Charlotte Islands, British Columbia; Baja California Sur; and Turkey; Upper Jurassic of California and Sicily; (?) Lower Cretaceous of East Indies; Cretaceous of the Mediterranean region.

Saitoum coronarium Whalen and Carter n. sp.
Plate 17, figures 8, 9, 12, 13, 16, 17
Species code: SUM01

Description. Test with small cephalis, elliptical to semicircular in outline with prominent long horn. Cephalis with massive cephalic skeletal elements and irregularly shaped (circular, elliptical) and sized (large and small) pore frames. Horn triradiate in axial section with narrow, rounded longitudinal ridges and broad, shallow, longitudinal grooves; horn approximately same length as width of cephalis and positioned slightly off-centre of apex of cephalis. Test with three strong feet, triradiate in axial section with narrow, rounded longitudinal ridges and rounded, broad longitudinal grooves.

Remarks. See remarks under *S. triumphense* n. sp.

Etymology. Coronarius, a, um (Latin; adj.) - relating to a garland, crown.

Measurements (µm).

(n) = number of specimens measured

Length (excluding horn)	Maximum width	Maximum length of feet	Length of horn	
(9)	(9)	(5)	(5)	
41	56	75	60	Holotype
60	75	79	60	Maximum
41	56	45	53	Minimum
53	66	64	56	Mean

Type locality. QC-575. See Locality Descriptions, Appendix 1.

Range. Crucella hettangica Zone to *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108560 (holotype) and GSC 108561 (paratype) from type locality. See occurrence chart, Figure 17.

Saitoum triumphense Whalen and Carter n. sp.
Plate 17, figures 10, 11, 14, 15
Species code: SUM02

Description. Test small with spherical cephalis and long, prominent horn; cephalis with massive cephalic skeletal elements and irregularly sized (mostly large) and shaped (circular, hexagonal, and pentagonal) pore frames. Horn positioned slightly off-centre from apex of cephalis; horn circular in axial section, length approximately equal to diameter of cephalis. Three sturdy feet, longer than diameter of test and circular in axial section.

Remarks. The structure of the horn and feet (both circular in axial section) distinguish *Saitoum triumphense* n. sp. from *S. coronarium* n. sp.

Etymology. This species is named for Triumph Point on Crescent Inlet, west of Kunga Island.

Measurements (µm).

Length (excluding horn)	Maximum width	Maximum length of feet	Length of horn	
56	56	53	60	Holotype
56	60	53	60	Maximum, 5 specimens
49	56	49	49	Minimum, 5 specimens
53	59	50	53	Mean, 5 specimens

Type locality. QC-574. See Locality Descriptions, Appendix 1.

Range. Crucella hettangica Zone to *Parahsuum simplum* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108562 (holotype) from type locality and GSC 108563 (paratype) from QC-575. See occurrence chart, Figure 17.

Saitoum sp. A
Plate 17, figure 7

Remarks. The distinctive ovate shape (somewhat aligned with plane of horn) and numerous small pore frames of *Saitoum* sp. A distinguish it from all other species of *Saitoum*.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108559 from QC-575 (lower Sinemurian).

Family SYRINGOCAPSIDAE Foreman 1973

Type genus. Syringocapsa Neviani 1900.

Range. Triassic to Cretaceous.

Occurrence. Worldwide.

Genus *Katroma* Pessagno and Poisson 1981, emend. De Wever 1982, emend. herein

Type species. Katroma neagui Pessagno and Poisson 1981.

Remarks. The small cephalic spines noted by De Wever (1982) on specimens of *Katroma* from Turkey were not observed on either the Sinemurian or upper Pliensbachian specimens of *Katroma* from British Columbia or Baja California Sur (Whalen, 1985). Due to the vagaries of preservation, these spines are not considered a diagnostic feature of this genus. Transmitted light photography has revealed that on some species of *Katroma*, the final chamber is the postabdominal chamber, while on others it is the abdominal chamber. The genus *Katroma* is hereby emended to accommodate both conditions. In addition, the terminal tube on some species is closed, while on others it remains open. Since this tube is often broken distally, it is not considered morphologically diagnostic whether it is open or closed.

Range. Lower Jurassic; Sinemurian-lower Toarcian.

Occurrence. Queen Charlotte Islands, British Columbia; Oregon; Baja California Sur; and Turkey.

Katroma inflatio Whalen and Carter n. sp.
Plate 19, figures 1, 8, 12, 16
Species code: KAT05

Description. Test with cephalis, thorax, abdomen, postabdominal chamber, and long, terminal tube. Cephalis hemispherical in shape, pore frames mostly obscured by a layer of microgranular silica; small horn on cephalis with short, irregular branches. Thorax and abdomen trapezoidal in outline with mostly pentagonal and hexagonal pore frames becoming larger toward postabdominal chamber. Inflated postabdominal chamber much larger than previous chambers and ellipsoidal in outline. Pore frames on postabdominal chamber hexagonal and pentagonal, larger in medial portion of chamber, gradually decreasing in size toward terminal tube and abdomen. Postabdominal chamber ending in tapered tube; terminal tube usually open with rare circular to elliptical pores.

Remarks. The distinctive ellipsoidal outline of the postabdominal chamber distinguishes *Katroma inflatio* n. sp. from all other species of *Katroma*.

Etymology. *Inflatio, onis* (Latin; noun) = an inflation of the body.

Measurements (µm).

Length (excluding horn)	Maximum width	
255	128	Holotype
330	150	Maximum, 6 specimens
255	128	Minimum, 6 specimens
282	142	Mean, 6 specimens

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. Lower Jurassic; upper Sinemurian-lower Pliensbachian.

Occurrence. Sandilands and Ghost Creek formations, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108589 (holotype) from type locality; GSC 108590 (paratype) from QC-676. See occurrence chart, Figure 17.

Katroma irvingi Whalen and Carter n. sp.
Plate 19, figures 3-6, 10, 14, 18; Plate 26, figures 12-14, 18, 19, 21
Species code: KAT04

Description. Cephalis small, dome-shaped with medium-sized horn having short branches; both horn and branches rounded in axial section. Thorax, abdomen, and first postabdominal chamber trapezoidal in outline with small, polygonal pore frames sometimes obscured by a layer of microgranular silica. Second postabdominal chamber inflated, subspherical, and much larger than previous chambers; medium-sized pentagonal pore frames on inflated postabdominal chamber not much larger than abdominal pore frames. Narrow, terminal tube usually open with rare, randomly distributed, circular and elliptical pores.

Remarks. The subspherical shape of the final postabdominal chamber of *Katroma irvingi* n. sp. distinguishes it from *K. inflatio* n. sp.

Etymology. This species is named in honor of E. Irving (Geological Survey of Canada), whose pioneering studies of the paleomagnetism of the Karmutsen Formation substantially improved our understanding of the geology of the Western Cordillera.

Measurements (µm).

Length (excluding horn)	Maximum width	
300	105	Holotype
450	150	Maximum, 10 specimens
300	105	Minimum, 10 specimens
366	131	Mean, 10 specimens

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. Lower Jurassic; Sinemurian-lower Pliensbachian.

Occurrence. Sandilands and Ghost Creek formations, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108593 (holotype), GSC 108594 (paratype), and transmitted light photographs on Plate 26 from type locality; GSC 108595 (paratype) and GSC 108596 (paratype) from QC-674. See occurrence chart, Figure 17.

Katroma sp. aff. *K. irvingi* Whalen and Carter n. sp.
Plate 19, figures 11, 19

Remarks. The final postabdominal chamber of this species is shorter and wider than that of *K. irvingi* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108597 from QC-676 (upper Sinemurian).

Katroma pinquitudo Whalen and Carter n. sp.
Plate 19, figures 2, 9, 13, 17; Plate 26, figures 9, 15
Species code: KAT03

Description. Cephalis small, dome-shaped, with strong horn; cephalis sparsely perforate, usually covered with layer of microgranular silica. Thorax and abdomen trapezoidal in outline with small pore frames partially obscured by a layer of microgranular silica. Postabdominal chamber inflated, subspherical to ovate, much larger than previous chambers; distinct change in slope between abdomen and postabdominal chamber. Postabdominal chamber with large pentagonal pore frames becoming smaller toward abdomen; terminal tube usually with medially arranged, circumferential spines, rounded in axial section. Narrow terminal tube usually open with small, circular pores.

Remarks. The distinct change in slope between the abdomen and postabdominal chamber, presence of circumferential spines, and smaller pore frames of this species distinguish it from *Katroma westermanni* n. sp. *Katroma pinquitudo* n. sp. differs from *K. inflatio* n. sp. by having a less ellipsoidal postabdominal chamber and circumferential spines.

Etymology. Pinguitudo, inis (Latin; noun) = fatness.

Measurements (µm).

(n) = number of specimens measured

Length (excluding horn) (9)	Maximum width (10)	
296	150	Holotype
296	150	Maximum
210	105	Minimum
247	125	Mean

Type locality. QC-677. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108591 (holotype) and GSC 108592 (paratype); transmitted light photographs on Plate 26 from type locality. See occurrence chart, Figure 17.

Katroma regina Whalen and Carter n. sp.
Plate 19, figures 7, 15; Plate 20, figures 1, 2, 13;
Plate 26, figures 11, 17, 20
Species code: KAT02

Description. Test ovate to spindle-shaped with long, closed, cylindrical terminal tube. Cephalis small, hemispherical in shape with small pores usually covered by layer of microgranular silica. Cephalis with short, broad, branched or single horn. Thorax and abdomen trapezoidal in outline with small pores usually obscured by layer of microgranular silica. Postabdominal chamber ovate, elongated in long axis of test, much larger than previous chambers, with medium-sized pentagonal and hexagonal pore frames; pore frames becoming smaller toward abdomen and terminal tube; no obvious break in slope between abdomen and postabdominal chamber. Terminal tube long, width approximately one-third that of postabdominal chamber; tube with randomly distributed circular pores.

Remarks. The very narrow, elongated postabdominal chamber of *Katroma regina* n. sp. distinguishes it from *K. irvingi* n. sp.

Etymology. Regina, ae (Latin; noun) = queen; this species is named in honour of the Queen Charlotte Islands.

Measurements (μm).

(n) = number of specimens measured

Length (excluding horn) (5)	Maximum width (7)	
278	75	Holotype
349	105	Maximum
244	75	Minimum
288	92	Mean

Type locality. QC-590A. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108599 (holotype), GSC 108600 (paratype), and transmitted light photographs on Plate 26 from type locality; GSC 108598 (paratype) from QC-677. See occurrence chart, Figure 17.

Katroma westermanni Whalen and Carter n. sp.
Plate 20, figures 3, 4, 5, 16, 17, 18;
Plate 26, figures 10, 16
Species code: KAT06

Syringocapsa sp. B - Imoto et al., 1982, Pl. 1, fig. 8.

Description. Cephalis small, hemispherical with short horn; horn rounded in axial section; cephalis with small- to medium-sized polygonal pore frames sometimes covered by a layer of micrograular silica. Thorax and abdomen trapezoidal in outline with medium to large pentagonal and hexagonal pore frames. Postabdominal chamber large, very inflated, subspherical to ovate, with variably sized (mostly large) pentagonal and hexagonal pore frames. Terminal tube circular, usually open, with numerous pores.

Remarks. See remarks under *Katroma pinguitudinis* n. sp.

Etymology. This species is named in honor of G.E.G. Westermann (McMaster University, Ontario) whose studies of Jurassic ammonites have contributed to our geological understanding of the Western Cordillera.

Measurements (μm).

Length (excluding horn)	Maximum width	
270	143	Holotype
345	150	Maximum, 8 specimens
236	135	Minimum, 8 specimens
280	143	Mean, 8 specimens

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108601 (holotype), GSC 108602 (paratype), GSC 108603 (paratype), and transmitted light photographs on Plate 26 from type locality. See occurrence chart, Figure 17.

Genus *Protokatroma* Whalen and Carter n. gen.

Type species. Protokatroma aquila Whalen and Carter n. sp.

Description. Test multicyrtid, spindle-shaped, composed of cephalis, thorax, abdomen, and approximately six postabdominal chambers. Postabdominal chambers terminating in long, cylindrical open or closed tubular extension. Cephalis hemispherical with horn. Thorax and abdomen trapezoidal in outline. Postabdominal chambers trapezoidal in outline with medial chambers larger and wider than proximal and distal postabdominal chambers. Distinct strictures present between some postabdominal chambers.

Remarks. *Protokatroma* n. gen. is distinguished from *Katroma* Pessagno and Poisson by having narrower medial postabdominal chambers and much smaller pore frames throughout. It differs from *Pseudoeucyrtis Pessagno* by having more expanded medial postabdomial chambers and strictures.

Range. Upper Triassic; Rhaetian-Lower Jurassic; lower Sinemurian.

Occurrence. Queen Charlotte Islands, British Columbia; New Zealand; and Japan.

Protokatroma aquila Whalen and Carter n. sp.
Plate 18, figures 6-8, 15
Species code: PTK01

Eucyrtis(?) sp. - Spörli and Aita 1988, Pl. 4, fig. 13.

Eucyrtid gen. and sp. indet.- Carter 1993, p. 114-115, Pl. 20, fig. 15, ?16.

Description. Test multicyrtid with narrow terminal tube. Cephalis small, hemispherical with short horn; horn rounded in axial section, sometimes slightly bifurcated or with short, irregular spines. Cephalis with small, polygonal pore frames usually covered by layer of microgranular silica. Thorax and abdomen trapezoidal in outline with small to medium pentagonal, hexagonal, and irregularly shaped pore frames. Approximately six postabdominal chambers, trapezoidal in outline, with medium-sized, irregularly shaped pore frames; postabdominal chambers gradually increasing in width and height to central part of test, then gradually decreasing in width towards terminal tube. Postabdominal chambers in central part of test about twice as wide as first postabdominal chamber. Terminal tube with numerous circular pores and usually open.

Remarks. See remarks under *Protokatroma* sp. *A* and *P.* sp. aff. *P. aquila* n. sp.

Etymology. Aquila, ae (Latin; noun) = eagle. This species is named for the numerous Bald eagles that inhabit Queen Charlotte Islands.

Measurements (µm).

Length (excluding horn)	Maximum width	
526	150	Holotype
526	150	Maximum, 7 specimens
310	95	Minimum, 7 specimens
410	121	Mean, 7 specimens

Type locality. 89-CNA-SKUD-34B. See Locality Descriptions, Appendix 1.

Range. Protokatroma aquila Zone to *Parahsuum simplum* Zone. Upper Triassic; Rhaetian-Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108571 (holotype) from type locality, GSC 108573 (paratype) from QC-568, and GSC 108572 (paratype) from 87-CNA-KUD-2. See occurrence chart, Figure 17.

Protokatroma sp. aff. *P. aquila* Whalen and Carter n. sp.
Plate 18, figures 2-5

Remarks. This species differs from *P. aquila* n. sp. in having a more elongate, spindle-shaped test. *P.* sp. aff. *P. aquila* n. sp. seems to be an intermediate form between *Pseudoeucyrtis* Pessagno and *Protokatroma* n. gen.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108567 from QC-568, GSC 108568 from 89-CNA-SKUD-34A, GSC 108569 from 89-CNA-KUD-11, and GSC 108570 from 89-CNA-KUD-12. See occurrence chart, Figure 17.

Protokatroma sp. A*
Plate 18, figures 22, 23, 24, 28, 29
Species code: PTK03

Remarks. The more spherical shape of the distal postabdominal chamber and its more abrupt constriction to a terminal tube distinguish *Protokatroma* sp. A from *P. aquila* n. sp.

Range. Lower Jurassic; middle/upper Hettangian-upper Sinemurian, *Pantanellium browni* Zone to *Canutus rockfishensis – Wrangellium thurstonense* Zone.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; Illustrated specimens GSC 108585 from QC-571B; GSC 108586 from 87-CNA-KUD-9; GSC 108587 from 89-CNA-KUD-18; GSC 108588 from QC-575. See Occurrence Chart, Figure 17.

Genus *Teesium* Whalen and Carter n. gen.

Type species. Teesium insignitum Whalen and Carter n. sp.

Description. Test with cephalis, thorax, and large, inflated closed abdominal segment with two, large, porous, cylindrical arms; arms attached to base of abdomen forming an approximate 45° angle with plane extending through cephalis and horn. Cephalis with prominent cylindrical horn, usually porous but pores obscured sometimes by layer of mircogranular silica.

Remarks. The unusual horn and porous, tubular arms of *Teesium* n. gen. distinguish it from all other Lower Jurassic Nassellariina.

Etymology. *Teesium* n. gen. is named after the ship *Tees* which sailed in the Queen Charlotte Islands in the early 1900s under Captain Harry S. Hughes.

Range. Lower Jurassic; upper Sinemurian.

Occurrence. Queen Charlotte Islands, British Columbia.

Teesium insignitum Whalen and Carter n. sp.
Plate 20, figures 7, 8, 9, 10, 11, 12, 14;
Plate 27, figures 13, 17
Species code: TES01

Description. Test with small, hemispherical cephalis with long porous horn. Horn hollow and cylindrical with large, circular, hexagonal, and pentagonal pore frames; pore frames slightly aligned parallel to long axis of horn; diameter of horn approximately half the width of cephalis. Cephalis with irregularly sized and shaped pore frames (pentagonal, elliptical) sometimes completely obscured by a thick layer of microgranular silica. Thorax trapezoidal in outline with medium-sized polygonal pore frames sometimes covered by a layer of microgranular silica. Distinct break in slope between thorax and abdomen. Abdomen

*Please note that on Figure 18 this species is referred to as *Protokatroma coliforme* (H). This change was made following the final drafting of these figures and could not be changed again prior to printing.

inflated, nearly three times larger than cephalis and thorax; abdomen subspherical in shape, sometimes slightly elongated in plane of horn with irregularly sized pentagonal and circular pore frames. Two large, cylindrical arms attached at base of abdomen, tapering distally; each arm forming an approximate 50° angle with plane parallel to axis of horn; arms composed of medium-sized polygonal pore frames with no distinct alignment.

Remarks. See remarks under *Teesium* sp. A.

Etymology. *Insignita, a, um* (Latin, adj.) = marked, conspicuous.

Measurements (µm).

(n) = number of specimens measured

Length (excluding horn) (9)	Maximum length of arms (5)	
120	86	Holotype
139	150	Maximum
105	60	Minimum
125	86	Mean

Type locality. QC-675. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108604 (holotype), GSC 108605 (paratype), GSC 108606 (paratype), and transmitted light photograph on Plate 27 from type locality. See occurrence chart, Figure 17.

Teesium sp. A
Plate 20, figures 6, 15

Remarks. *Teesium* sp. A differs from *T. insignitum* n. sp. by having much smaller pore frames, and the angle formed by the arm and long axis of the test is much smaller.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108607 from QC-675 (upper Sinemurian).

Family THEOPERIDAE Haeckel 1881,
emend. Riedel 1967b

Type genus. *Theopera* Haeckel 1881.

Range. Triassic-Recent.

Occurrence. Worldwide.

Genus *Ectonocorys* Foreman 1968

Type species. *Ectonocorys lampra* Foreman 1968

Range. Lower Jurassic-Upper Cretaceous.

Occurrence. Queen Charlotte Islands, British Columbia; California; and Turkey.

Ectonocorys? sp.
Species code: ECT01
not illustrated

Ectonocorys? sp. De Wever 1982, p. 197; Pl. 5, fig. 14-15.

Remarks. Although not illustrated in this paper, we believe our form is identical to the one illustrated by De Wever (1982).

Range. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-Pliensbachian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; and Taurides Occidentales, Turkey. See occurrence chart, Figure 17.

Genus *Pseudoeucyrtis* Pessagno 1977b

Type species. *Eucyrtis*? *zhamoidai* Foreman 1973b.

Range. Jurassic-Cretaceous.

Occurrence. Worldwide.

Pseudoeucyrtis angusta Whalen and Carter n. sp.
Plate 18, Figures 9-12, 16
Species code: PSE02

aff. *Katroma* sp. 2 - Whalen and Pessagno 1984, Pl. 1, fig. 6.

Description. Test multicyrtid, cylindrical, with narrow terminal tube. Cephalis very small, hemispherical with short horn; horn circular in axial section, sometimes slightly bifurcate; cephalis with small, polygonal pore frames usually covered by layer of microgranular silica. Thorax and abdomen roughly trapezoidal in outline with small irregularly shaped pore frames usually covered by a layer of microgranular silica. Seven to ten postabdominal chambers, rectangular, with medium-sized, irregularly shaped pore frames; chambers very gradually increasing in size to central widest part of test, then gradually decreasing in width; chambers in central part of test just slightly wider than first and last postabdominal chambers; strictures usually weakly developed between postabdominal chambers in central part of test. Terminal tube usually open, with numerous circular pores.

Remarks. *Pseudoeucyrtis angusta* n. sp. differs from *P.* sp. A by possessing weakly developed strictures. The very narrow elongate test of *P. angusta* n. sp. distinguishes it from *Protokatroma aquila* n. sp.

Etymology. *Angustus, a, um* (Latin; adj.) = narrow, tight.

Measurements (µm).

Length (excluding horn)	Maximum width	
592	99	Holotype
592	99	Maximum, 5 specimens
526	86	Minimum, 5 specimens
551	92	Mean, 5 specimens

Type locality. 89-CNA-KUD-16. See Locality Descriptions, Appendix 1.

Range. *Protokatroma aquila* Zone to *Parahsuum simplum* Zone. Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; and Baja California Sur. Illustrated specimens GSC 108575 (holotype) from 89-CNA-KUD-16, GSC 108574 (paratype) from QC-574, GSC 108576 (paratype) from QC-575, and GSC 108577 (paratype) from 87-CNA-KPB-10. See occurrence chart, Figure 17.

Pseudoeucyrtis fullerensis Whalen and Carter n. sp.
Plate 25, figures 2-4, 10, 11, 16, 22, 23
Species code: PSE01

Description. Test elongate, spindle-shaped with approximately eight postabdominal chambers, lacking strictures. Cephalis large, dome-shaped, with medium-sized horn; horn circular in axial section; cephalis and thorax mostly imperforate, almost completely covered by layer of microgranular silica. Thorax, abdomen, and most postabdominal chambers slightly trapezoidal in outline, gradually increasing in width and height as added; last few postabdominal chambers gradually decreasing in width. Pore frames on postabdominal chambers large, mostly hexagonal with small rounded nodes at pore frame vertices; pore frames on test gradually increasing in size as added, aligned in distinct horizontal rows; each row of hexagonal pore frames staggered with respect to flanking rows; two rows of hexagonal pore frames per chamber. Test terminating in tapering, closed tube.

Remarks. See remarks under *Pseudoeucyrtis* sp. B. *Pseudoeucyrtis fullerensis* n. sp. differs from *P. reticularis* Matsuoka by having more fragile pore frames and by lacking a stout basal spine.

Etymology. This species is named for Fuller Point, Queen Charlotte Islands, British Columbia, located to the southeast of the type locality.

Measurements (µm).

(n) = number of specimens measured

Length (excluding horn) (5)	Maximum width (7)	
330 (broken)	116	Holotype
593	128	Maximum
450	90	Minimum
533	111	Mean

Type locality. QC-543. See Locality Descriptions, Appendix 1.

Range. *Protokatroma aquila* Zone to *Crucella hettangica* Zone. Lower Jurassic; lower Hettangian-uppermost Hettangian to lowermost Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108657 (holotype) and GSC 108658 (paratype) from type locality; GSC 108659 (paratype) from QC-568. See occurrence chart, Figure 17.

Pseudoeucyrtis sp. A
Plate 18, figure 1

Remarks. See *Pseudoeucyrtis angusta* n. sp. for comparison.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108566 from QC-571B (lower Sinemurian).

Pseudoeucyrtis sp. B
Plate 25, figures 5, 12

Remarks. The broader horn and larger, more irregularly shaped pore frames of *Pseudoeucyrtis* sp. B distinguish it from *P. fullerensis* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108660 from QC-568 (Hettangian).

Family ULTRANAPORIDAE Pessagno 1977b,
emend. Pessagno, Whalen, and Yeh 1986

Type genus. *Ultranapora* Pessagno 1977b (= Napora Pessagno 1977a).

Range. Lower Jurassic; upper Sinemurian to Upper Cretaceous.

Occurrence. Worldwide.

Genus *Jacus* De Wever 1982

Type species. *Jacus coronatus* De Wever 1982.

Range. Lower Jurassic; middle to upper Hettangian-upper Pliensbachian (?) lower Toarcian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia; and Taurides Occidentales, Turkey.

Jacus? *anatiformis* De Wever 1982
Plate 18, Figures 13, 14, 17, 18, 19, 27
Species code: JAC02

Jacus? *anatiformis* De Wever 1982, Pl. 11, fig. 10-15.

Jacus sp. A - Hattori 1989, Pl. 5, fig. I.

Range. Lower Jurassic; middle to upper Hettangian to Pliensbachian.

Occurrence. Sandilands and Ghost Creek formations, Queen Charlotte Islands, British Columbia; Turkey; and Japan. Illustrated specimens GSC 108578, GSC 108579, GSC 108580 from QC-575 and GSC 108581 from QC-675. See occurrence chart, Figure 17.

Jacus? *sandspitensis* Pessagno, Whalen and Yeh 1986
Species code: JAC01
not illustrated

Jacus(?) *sandspitensis* Pessagno, Whalen and Yeh 1986, p. 33; Pl. 2, fig. 5, 9, 13, 16, 17; Pl. 11, fig. 13.

Range. Lower Jurassic; upper Sinemurian-lower Pliensbachian.

Occurrence. Sandilands and Ghost Creek formations, Queen Charlotte Islands, British Columbia. See occurrence chart, Figure 17.

Genus *Napora* Pessagno 1977a, emend. Pessagno, Whalen and Yeh 1986

Type species. *Napora bukryi* Pessagno 1977a.

Range. Lower Jurassic; upper Sinemurian to Upper Cretaceous.

Occurrence. Worldwide.

Napora? *graybayensis* Pessagno, Whalen and Yeh, 1986
Plate 21, figure 4
Species code: NAP01

Napora(?) *graybayensis* Pessagno, Whalen and Yeh 1986, p. 39; Pl. 2, fig. 1-3, 10, 11, 14; Pl. 11, fig. 3, 4.

Range. *Canutus rockfishensis*-*Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation Queen Charlotte Islands, British Columbia. Illustrated specimen USNM 379327 (original holotype) from QC-675. See occurrence chart, Figure 17.

Napora sp. A
Plate 18, figures 20, 26

Remarks. The much smaller pore frames and shorter horn and feet of *Napora* sp. A distinguish it from *Napora*? *graybayensis* Pessagno, Whalen and Yeh.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108582 and GSC 108583 from QC-575 (lower Sinemurian).

Napora sp. B
Plate 18, figures 21, 25

Remarks. The wider thorax of *Napora* sp. B distinguishes it from *Napora* sp. A; the much smaller pore frames of *Napora* sp. B distinguish it from *Napora*? *graybayensis* Pessagno, Whalen and Yeh.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108584 from QC-675 (upper Sinemurian).

NASSELLARIA INCERTAE SEDIS
Genus *Ares* De Wever 1982

Type species. *Ares armatus* De Wever 1982.

Range. Sinemurian to Pliensbachian.

Occurrence. Queen Charlotte Islands, British Columbia; east-central Oregon; Baja California Sur; and Turkey.

Ares moresbyensis Whalen and Carter n. sp.
Plate 21, figures 1, 2, 11; Plate 27, figures 2, 8
Species code: ARS01

Ares sp. - Whalen and Pessagno 1984, Pl. 1, fig. 11, 12.

Description. Test with small, dome-shaped cephalis and prominent tapering horn; horn approximately equal in length to thorax, triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves; horn not aligned exactly with long axis of test. Cephalis with small to medium polygonal pore frames sometimes obscured by a layer of microgranular silica. Thorax elongate, trapezoidal in outline with large, pentagonal, hexagonal, and circular pore frames. Two prominent spines attached to thorax at base of cephalis at 45° angle with long axis of test; spines tapering distally, triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves; near base of cephalis, longitudinal ridges extend onto thorax forming prominent transverse ridges. One spine slightly longer and more massive than other; longer spine equal to length of thorax.

Remarks. The larger, more regularly shaped thoracic pore frames of *Ares moresbyensis* n. sp. distinguish it from *A. sutherlandi* n. sp.

Etymology. This species is named for Moresby Island, Queen Charlotte Islands, British Columbia, located to the west of the type locality.

Measurements (μm).

(n) = number of specimens measured

Length (excluding horn) (9)	Width of thorax (10)	Maximum length of short arm (9)	
105	71	90	Holotype
120	75	120	Maximum
90	71	68	Minimum
112	75	92	Mean

Type locality. QC-675. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis*-*Wrangellium thurstonense* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108608 (holotype) and transmitted light photograph on Plate 27 from type locality; GSC 108609 (paratype) from QC-674; See occurrence chart, Figure 17.

Ares sutherlandi Whalen and Carter n. sp.
Plate 21, figures 3, 16; Plate 27, figures 1, 7
Species code: ARS02

Description. Test with small, dome-shaped cephalis with prominent broad, tapering horn; horn approximately one-half length of cephalis and thorax combined, triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves. Cephalis with variably-sized pore frames usually partially obscured by layer of microgranular silica. Thorax elongate, cylindrical, with irregularly arranged small- to medium-sized polygonal (mostly pentagonal) pore frames; thoracic pore frames sometimes partially masked by an outer layer of irregular, polygonal pore frames. Two prominent spines attached to thorax at base of cephalis; spines triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves. Larger, more robust spine forming an approximate 55° angle with long axis of test; larger spine bonded to thorax by approximately four narrow, linear ridges which extend from longitudinal ridge of spine and continue obliquely across proximal part of test; smaller spine at 40° to long axis of test.

Remarks. See remarks under *A. moresbyensis* n. sp.

Etymology. This species is named in honor of A. Sutherland Brown (British Columbia Department of Mines and Petroleum Resources, Vancouver, B.C.) who first mapped the entire Queen Charlotte Archipelago and provided a detailed account of the geology.

Measurements (μm).

(n) = number of specimens measured

Length (excluding horn) (6)	Width of thorax (6)	Maximum length of short arm (5)	
109	75	90	Holotype
120	75	90	Maximum
83	75	60	Minimum
97	75	75	Mean

Type locality. QC-675. See Locality Descriptions, Appendix 1.

Range. Parahsuum simplum Zone to *Canutus rockfishensis-Wrangellium thurstonense* Zone. Lower Jurassic; lower-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108610 (holotype) and transmitted light photograph on Plate 27 from type locality. See occurrence chart, Figure 17.

Genus *Bipedis* De Wever 1982

Type species. Bipedis calvabovis De Wever 1982.

Range. Lower Jurassic; Hettangian-upper Pliensbachian.

Occurrence. Queen Charlotte Islands, British Columbia; Turkey; Japan; and Russian Far East.

Bipedis diadema Whalen and Carter n. sp.
Plate 21, figures 7-10, 13, 17; Plate 22, figure 1; Plate 27, figures 11, 12
Species code: BPD05

Description. Test hemi-elliptical in outline with small hemispherical cephalis and medium-sized horn; horn usually triradiate in axial section proximally with narrow, rounded longitudinal ridges and broad grooves becoming rounded in axial section distally. Cephalis mostly smooth, imperforate, covered with thick, irregular layer of microgranular silica; some relict pores observed on cephalis where layer of microgranular silica is thinner. Both cephalis and thorax compressed in plane of feet. Thorax with mostly small, irregularly shaped pore frames with slight development of orientation transverse to long axis of the test. Test with two medium sized feet, triradiate in axial section with narrow rounded ridges and broad grooves; feet curved slightly inward towards centre of test; mouth elliptical in outline with prominent, broad imperforate band.

Remarks. Bipedis diadema n. sp. is distinguished from all other species of *Bipedis* by the very wide imperforate band which rims the mouth, the hemi-elliptical outline, and the compressed thorax and cephalis.

Etymology. Diadema, atis (Latin; neuter) = a royal headband, diadem.

Measurements (μm).

Length (excluding horn)	Maximum width	Maximum length of feet	
105	90	75	Holotype
105	109	75	Maximum, 10 specimens
90	75	45	Minimum, 10 specimens
101	94	65	Mean, 10 specimens

Type locality. QC-675. See Locality Descriptions, Appendix 1.

Range. Canutus rockfishensis-Wrangellium thurstonense Zone to *Jacus? sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108615 (holotype), GSC 108616 (paratype), GSC 108617 (paratype), and transmitted light photograph on Plate 27 from type locality; and GSC 108618 (paratype) and GSC 108619 (paratype) from QC-677. See occurrence chart, Figure 17.

Bipedis douglasi Whalen and Carter n. sp.
Plate 23, figures 1, 5, 9-12; Plate 27, figures 15, 19
Species code: BPD06

Description. Test subtriangular in outline with large, dome-shaped cephalis and strong horn; horn triradiate in axial section with narrow, rounded longitudinal ridges and broad, shallow longitudinal grooves. Cephalis mostly smooth, imperforate; a few pores sometimes exposed at base of horn. Obvious change in slope between the cephalis and thorax. Thorax subcircular in outline, slightly compressed in plane of feet. Thorax with small circular pores; some pore frames formed into narrow, transverse ridges which extend onto feet. Test with two strong feet, triradiate in axial section with broad, rounded longitudinal ridges and grooves; feet widely extended, curving inward slightly toward long axis of test and attached to test part way up thorax. Mouth large, elliptical in outline with prominent broad imperforate band.

Remarks. The narrow, transverse thoracic lineations, widely flaring feet and prominent mouth with downwardly sloping band distinguish *Bipedis douglasi* n. sp. from all other species of *Bipedis*.

Etymology. This species is named for William Douglas, Captain of the *Iphigenia*, a ship which traded in the Queen Charlotte Islands in 1788.

Measurements (µm).

Length (excluding horn)	Maximum width	Maximum length of feet	
120	90	105	Holotype
120	113	116	Maximum, 7 specimens
105	90	83	Minimum, 7 specimens
118	106	102	Mean, 7 specimens

Type locality. QC-676. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108626 (holotype) and transmitted light photograph on Plate 27 from type locality; GSC 108627 (paratype) from QC-677. See occurrence chart, Figure 17.

Bipedis elizabethae Whalen and Carter n. sp.
Plate 24, figures 1, 2, 3
Species code: BPD03

Description. Test slightly inflated, nearly elliptical in outline, with small hemispherical cephalis with short, thin horn; horn circular in axial section with three large pores at base. Cephalis with variably sized and shaped pores with some microgranular silica present proximally. Thorax with small- to medium-sized irregularly shaped pore frames. Test with two very small feet, varying in axial section from bladed to circular to slightly triradiate. Mouth small, round in outline with a broad, prominent imperforate band.

Remarks. This is the oldest Jurassic species of *Bipedis* in our collections. The bladed to very slightly triradiate nature of the feet suggest it may be derived from a form similar to the Rhaetian *Bipedis acrostylus* Bragin.

Etymology. This species is named in memory of Elizabeth (Betty) Pessagno who generously supported the paleontological work of many students at the University of Texas at Dallas.

Measurements (µm).

(n) = number of specimens measured

Length (excluding horn) (8)	Maximum width (8)	Maximum length of feet (4)	
145	142	64	Holotype
153	150	93	Maximum
113	118	56	Minimum
135	138	71	Mean

Type locality. 87-CNA-KUD-4. See Locality Descriptions, Appendix 1.

Range. *Canoptum merum* Zone to *Parahsuum simplum* Zone. Lower Jurassic; lowermost Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108633 (holotype) from type locality, GSC 108634 (paratype) from 89-CNA-SKUD-31, and GSC 108635 (paratype) from 89-CNA-SKUD-36. See occurrence chart, Figure 17.

Bipedis hannai Whalen and Carter n. sp.
Plate 21, figures 5, 6, 12, 14, 15; Plate 22, figures 2, 3, 5, 6, 9, 10, 11, 14, 15
Species code: BPD07

Description. Cephalis large, dome-shaped, with medium-sized horn; horn triradiate in axial section with narrow, rounded longitudinal ridges and grooves. Cephalis mostly covered by layer of microgranular silica; large, elliptical pores at base of horn sometimes pierce cephalis. Obvious change in slope between cephalis and thorax. Thorax subspherical in shape, large, inflated, with irregularly sized and shaped polygonal pore frames with no preferred orientation. Mouth circular in outline with broad, imperforate band. Test with two massive feet (some inwardly curving) attached part way up thorax; feet triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves; feet equal in length to thorax.

Remarks. The triradiate horn and feet of *Bipedis hannai* n. sp. distinguish it from *B. hiberniaensis* n. sp.

Etymology. This species is named for James Hanna, Captain of the ship Sea Otter, who traded in the Queen Charlotte Islands in 1786.

Measurements (µm).

Length (excluding horn)	Maximum width	Maximum length of feet	
131	113	83	Holotype
135	116	105	Maximum, 5 specimens
109	105	60	Minimum, 5 specimens
128	109	87	Mean, 5 specimens

Type locality. QC-571B. See Locality Descriptions, Appendix 1.

Range. Protokatroma aquila Zone to *Parahsuum simplum* Zone. Lower Jurassic; lower Hettangian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108622 (holotype) from type locality, GSC 108620 (paratype) from QC-543, and GSC 108621 (paratype) and GSC 108613 (paratype) from QC-575; GSC 108612 (paratype) and GSC 108614 (paratype) from QC-574. See occurrence chart, Figure 17.

Bipedis helenae Whalen and Carter n. sp.
Plate 23, figures 2, 3, 14, 15; Plate 27, figures 14, 18
Species code: BPD09

Description. Test inflated, subtriangular in outline with medium-sized hemispherical cephalis and circular horn; cephalis with thin coating of microgranular silica near horn, perforate distally. Slight change in slope between cephalis and thorax. Thorax large, subspherical, slightly compressed in plane of feet. Thorax with irregularly shaped polygonal pore frames and small circular pores. Pore frames sometimes developed into low, rounded ridges, transverse to long axis of test. Test with two long, thin feet triradiate in axial section attached at base of thorax; feet widely flaring, curving slightly inward toward long axis of test. Test with medium-sized mouth with imperforate band.

Remarks. The structure of the horn and shape of the test distinguish *Bipedis helenae* n. sp. from *B. rotundus* n. sp.

Etymology. This species is named in memory of Helen Foreman, a distinguished biostratigrapher who led the way for modern radiolarian research in the Paleozoic, Mesozoic, and Cenozoic.

Measurements (μm).

(n) = number of specimens measured

Length (excluding horn) (6)	Maximum width (6)	Maximum length of feet (5)	
135	113	75	Holotype
150	120	90	Maximum
124	105	60	Minimum
132	113	78	Mean

Type locality. QC-677. See Locality Descriptions, Appendix 1.

Range. Crucella hettangica Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108628 (holotype), GSC 108629 (paratype), and transmitted light photograph on Plate 27 from type locality. See occurrence chart, Figure 17.

Bipedis hiberniaensis Whalen and Carter n. sp.
Plate 22, figures 4, 7, 8, 12, 13, 16
Species code: BPD08

Description. Test with large hemispherical cephalis, with medium-sized horn, rounded in axial section. Cephalis almost completely covered by layer of microgranular silica; small elliptical pits (relict pores) commonly seen on cephalis at base of horn. Slight change in slope between cephalis and thorax. Thorax subspherical in shape, large, and inflated, with irregularly sized and shaped polygonal pore frames with no preferred orientation. Mouth large, circular in outline with broad, imperforate band. Test with two small feet attached near base of thorax, approximately one third length of thorax, curving slightly inward toward long axis of test; feet circular in axial section.

Remarks. See remarks under *B. hannai* n. sp.

Etymology. Nova Hibernia was the European name given to the Queen Charlotte Islands by Captain James Hanna in 1786.

Measurements (μm).

(n) = number of specimens measured

Length (excluding horn) (7)	Maximum width (7)	Maximum length of feet (5)	
120	124	49	Holotype
165	143	75	Maximum
120	124	45	Minimum
147	133	56	Mean

Type locality. QC-574. See Locality Descriptions, Appendix 1.

Range. Crucella hettangica Zone to *Parahsuum simplum* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-lower Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108623 (holotype), GSC 108624 (paratype), and GSC 108625 (paratype) from type locality. See occurrence chart, Figure 17.

Bipedis patricki Whalen and Carter n. sp.
Plate 23, figures 6, 7; Plate 24, figures 4, 5, 10
Species code: BPD12

Description. Test hemi-elliptical to subtriangular in outline with small hemispherical cephalis with medium to large horn; horn usually triradiate in axial section. Cephalis mostly smooth, imperforate, covered with thick, irregular layer of microgranular silica; some relict pores observed on cephalis where layer of microgranular silica is thinner. Thorax relatively small with both cephalis and thorax compressed in plane of feet; thorax with mostly small, irregularly shaped pore frames. Test with two very wide, massive feet, triradiate in axial section with narrow rounded ridges and broad grooves; ridge in lateral plane of test particularly strong and bladed; some feet curved slightly inward towards centre of test. Mouth small, elliptical to round in outline, with broad imperforate band.

Remarks. The small thorax and very massive wide feet distinguish *Bipedis patricki* from all other species of *Bipedis*.

Etymology. This species is named in honor of Patrick De Wever, a radiolarist of worldwide reputation.

Measurements (μm).

Length (excluding horn)	Maximum width	Maximum length of feet	
128	119	119	Holotype
152	126	152	Maximum, 5 specimens
126	110	119	Minimum, 5 specimens
138	120	134	Mean, 5 specimens

Type locality. 86-OF-KUB-3. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108636 (holotype) from type locality, GSC 108631 (paratype) and GSC 108632 (paratype) from QC-676, GSC 108637 (paratype) from 89-CNA-KUA-3, and GSC 108638 (paratype) from 86-OF-KUC-6. See occurrence chart, Figure 17.

Bipedis rotundus Whalen and Carter n. sp.
Plate 23, figures 4, 8, 13, 16
Species code: BPD11

Description. Test with large, dome-shaped cephalis with massive horn. Horn triradiate in axial section with narrow, rounded longitudinal ridges and grooves. Cephalis smooth, imperforate at base of horn; large pores formed toward base of cephalis partially masked by layer of microgranular silica. Thorax large, inflated, almost spherical with irregularly sized and shaped polygonal pore frames; some pore frames formed into narrow ridges, transversely aligned to long axis of test; distinct subparallel, oblique alignment of pore frames sometimes seen along sides where thoracic pore frames attach to feet. Test with two massive feet attached at base of thorax but with ridges and grooves of feet visible along side of thorax for most of its length; feet triradiate in axial section with narrow, rounded longitudinal ridges and broad, rounded longitudinal grooves. Mouth large, circular in outline with imperforate band.

Remarks. The very circular outline of *Bipedis rotundus* n. sp., viewed parallel to the plane formed by the two feet, distinguishes it from all other species of *Bipedis*.

Etymology. *Rotundus*, *a*, *um* (Latin, adj.) = round, circular, sometimes spherical.

Measurements (μm).

Length (excluding horn)	Maximum width	Maximum length of feet	
135	113	113	Holotype
173	150	128	Maximum, 6 specimens
135	113	98	Minimum, 6 specimens
145	132	108	Mean, 6 specimens

Type locality. QC-674. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108630 (holotype) from type locality. See occurrence chart, Figure 17.

Genus *Formania* n. gen.

Type species. *Foremania sandilandsensis* n. sp.

Description. Test elongate, cylindrical with single-layered wall. Cephalis large, dome-shaped, with irregularly branching horn. Postabdominal chambers generally rectangular in outline; first few chambers very gradually increasing in size as added; postabdominal chambers gradually decreasing in width producing an open tube. Regularly shaped pore frames on most postabdominal chambers; pore frames more regular in shape (tetragonal) and aligned in distinct horizontal and vertical rows on distal portion of test; pore frames smaller on more proximal part of test, larger and more regularly shaped on distal part of test.

Remarks. The narrow but open tubular extension of the test and the very regularly shaped and aligned pore frames on the distal postabdominal chambers distinguish *Foremania* n. gen. from *Pseudoeucyrtis* Pessagno. The single-layered wall distinguishes *Foremania* n. gen. from *Canutus* Pessagno and Whalen and *Droltus* Pessagno and Whalen.

Etymology. This genus is named in memory of Helen Foreman, a noted scholar of fossil Radiolaria.

Range. Lower Jurassic; Sinemurian-Pliensbachian.

Occurrence. Turkey; Queen Charlotte Islands, British Columbia.

Foremania sandilandsensis n. sp.
Plate 24, figures 14, 15, 18-21, 24, 25, 26
Species code: FRM01

g. sp. indet. 1, 2, 3 - De Wever 1982 , Pl. 13, fig. 10-14.

Description. Test elongate, cylindrical, commonly with ten postabdominal chambers. Cephalis large, dome-shaped with horn; horn irregularly shaped, branching, usually with two or three prongs varying in size. Cephalis and thorax mostly imperforate, almost completely covered by layer of microgranular silica. Thorax and abdomen trapezoidal in outline. Most postabdominal chambers subrectangular to square in outline, very gradually increasing in width and height as added; last few postabdominal chambers gradually decreasing in width. On well preserved specimens, test terminating in a narrow, open tube. Pore frames on initial chambers of test small and irregularly shaped; pore frames on test gradually increasing in size as added, becoming much more regularly tetragonal and aligned in distinct horizontal and vertical rows on distal part of test; small rounded nodes at vertices of all pore frames.

Remarks. *Foremania sandilandsensis* is the only species of *Foremania* yet recognized. Since the test is very large and seldom complete, the observed number of postabdominal chambers depends on preservation.

Etymology. This species is named for Sandilands Island, located in Skidegate Inlet, north of South Bay, Queen Charlotte Islands, British Columbia.

Measurements (μm).

Length	Maximum width	
140	26	Holotype
227	103	Maximum, 5 specimens
140	26	Minimum, 5 specimens
200	80	Mean, 5 specimens

Type locality. QC-590A. See Locality Descriptions, Appendix 1.

Range. *Parahsuum simplum* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; lower to upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108654 (holotype) and GSC 108649 (paratype) from type locality; GSC 108650 and GSC 108651 from QC-674; and GSC 108652 from QC-677. See occurrence chart, Figure 17.

Genus *Laxtorum* Blome 1984, emend. Carter 1993

Type species. *Laxtorum hindei* Blome 1984.

Range. Upper Triassic; upper Norian-Lower Jurassic; Sinemurian (?)Toarcian.

Occurrence. Alaska; California; Queen Charlotte Islands, British Columbia; New Zealand; and Japan.

Laxtorum hemingense Whalen and Carter n. sp.
Plate 25, figures 6, 7, 8, 13, 14, 24, 25;
Plate 27, figures 5, 6, 16, 20
Species code: LAX06

Description. Test conical with approximately eight to nine postabdominal chambers. Cephalis small, steeply dome-shaped with or without a small horn; horn circular in axial section; cephalis imperforate, covered with a thick layer of microgranular silica. Thorax, abdomen, and all postabdominal chambers gradually increasing in width as added. Thorax trapezoidal in outline with medium-sized pores mostly obscured by layer of microgranular silica. Mostly tetragonal pore frames on abdomen and postabdominal chambers subaligned in transverse rows. Circumferential ridges composed of thicker, more irregular pore frame bars (zig-zag structure) on proximal parts of test becoming thinner and straighter distally; circumferential ridges with irregular longitudinal extensions superimposed on adjacent pore frames.

Remarks. *Laxtorum hemingense* n. sp. is distinguished from *Laxtorum* sp. A and *Laxtorum* sp. B by the absence of a prominent horn. It differs from all Rhaetian species of *Laxtorum* in having larger, open, more regularly aligned pore frames and in lacking a terminal tube.

Etymology. This species is named for Heming Head, located on the east side of Talunkwan Island, northwest of the type locality.

Measurements (μm).

Length (excluding horn)	Maximum width	
240	105	Holotype
240	109	Maximum, 5 specimens
218	98	Minimum, 5 specimens
229	104	Mean, 5 specimens

Type locality. QC-549. See Locality Descriptions, Appendix 1.

Range. *Crucella hettangica* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108661 (holotype) and GSC 108662 (paratype) from type locality, GSC 108663 (paratype) from QC-674, and GSC 108664 and GSC 108665 (both paratypes) and transmitted light photographs on Plate 27 from QC-590A. See occurrence chart, Figure 17.

Laxtorum sp. A
Plate 25, figure 17

Remarks. The more massive horn and finer pore frames of *Laxtorum* sp. A distinguish it from *L. hemingense* n. sp. and *L.* sp. B.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108666 from QC-568 (upper Hettangian).

Laxtorum sp. B
Plate 25, figures 18, 19, 20

Remarks. The more spindle-shaped test, prominent longer horn, and finer pore frames distinguish *Laxtorum* sp. B. from *L. hemingense*.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108668 from 87-CNA-KUD-4; GSC 108667 and GSC 108669 from QC-568 (all upper Hettangian).

Genus *Solidea* Whalen and Carter n. gen.

Type species. *Solidea hillhousei* Whalen and Carter n. sp.

Description. Test tricyrtid, spindle-shaped, with tubular extension (velum?); tubular extension nearly as long as cephalis, thorax, and abdomen combined. Cephalis with small, broad horn. Single layered wall construction throughout test; cephalis, thorax, and abdomen with uniformly sized pentagonal and hexagonal pore frames. Tubular extension with larger, more irregularly sized and shaped polygonal pore frames; pores on tubular extension usually ovate, with slight orientation parallel to long axis of the test.

Remarks. The shape of the cephalis, thorax, and abdomen and distinctive tubular extension distinguish *Solidea* n. gen. from all other tricyrtid Nassellariina. This genus is strongly similar to *Dicanthocapsa* Squinabol emend. Dumitrica, but in our specimens there is no evidence of a sutural pore which seems to be strongly characteristic of *Diacanthocapsa*. In addition, *Dicanthocapsa* does not show such a wide, strong tubular extension as is present on *Solidea* n. gen.

Etymology. The genus is named after the French ship *La Solide* which visited the Queen Charlotte Islands in 1791, in the course of a round-the-world voyage under Captain Etienne Marchand.

Range. Lower Jurassic; upper Sinemurian, so far as known.

Occurrence. Queen Charlotte Islands, British Columbia.

Solidea hillhousei Whalen and Carter n. sp.
Plate 25, figures 1, 9, 15, 21; Plate 27, figures 3, 4, 9, 10
Species code: SOL01

Description. Cephalis hemispherical with short horn; horn sharply tapering, usually circular in axial section but sometimes triradiate, with narrow, longitudinal ridges and deep, broad grooves with a short distal spine. Thorax trapezoidal in outline. Abdomen subspherical in shape with tubular extension (velum?). Tubular extension circular in axial section, slightly tapering distally. Pore frames on cephalis, thorax, and abdomen small, uniformly sized, mostly pentagonal and hexagonal in outline. Polygonal pore frames on tubular extension irregularly shaped (circular and elliptical) and sized (large and small) with some suggestion of alignment with long axis of test; large elliptical pores positioned at junction between thorax and terminal tube.

Remarks. *Solidea hillhousei* n. sp. is distinguished from other Jurassic tricyrtid single-walled Nassellariina by the long and wide tubular extension attached to the abdomen.

Etymology. This species is named in honor of J. W. Hillhouse (United States Geological Survey, Menlo Park, California) whose paleomagnetic studies of the Nicola Greenstone in Alaska have aided our understanding of allochthonous terranes such as Wrangellia.

Measurements (μm).

(n) = number of specimens measured

Length (excluding horn) (6)	Maximum width (6)	Length of tubular extension (5)	
90	64	68	Holotype
105	83	101	Maximum
90	64	45	Minimum
98	72	76	Mean

Type locality. QC-677. See Locality Descriptions, Appendix 1.

Range. *Canutus rockfishensis-Wrangellium thurstonense* Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108656 (holotype), GSC 108655 (paratype), and transmitted light photographs on Plate 27 from type locality. See occurrence chart, Figure 17.

Genus *Trexus* Whalen and Carter n. gen.

Type species. *Trexus dodgensis* Whalen and Carter n. sp.

Description. Robust, inflated, dome-shaped multicyrtid, with small horn. Test lacks strictures. Thick multilayered wall: inner layer composed of large, fragile, irregularly polygonal pore frames; outer layers more massive, composed of irregularly sized and shaped polygonal pore frames; outer layers connected by irregularly sized and shaped pillars; small nodes at pore frame vertices on outer latticed layer.

Remarks. *Trexus* n. gen. differs from *Canutus* Pessagno and Whalen by possessing irregularly polygonal pore frames rather than square to rectangular, linearly arranged pore frames on both the inner and outer layers (see Pl. 24, fig. 22).

Canutus? *beehivensis* and *C.*? *ingrahamensis* described by Carter from the Rhaetian part of the Sandilands Formation in Queen Charlotte Islands, are herein reassigned to the genus *Trexus* Whalen and Carter n. gen.

Etymology. *Trexus* n. gen. is a name formed by an arbitrary combination of letters (ICZN, 1985, Appendix D, pt. VI, Recommendation 40, p. 201).

Range. Upper Triassic (Rhaetian) to Lower Jurassic (upper Hettangian-upper Pliensbachian) so far as known.

Occurrence. Queen Charlotte Islands, British Columbia.

Trexus dodgensis Whalen and Carter n. sp.
Plate 24, figures 11, 12, 16, 22, 23
Species code: TRX01

Description. Test large, dome-shaped, inflated with three to four postabdominal chambers. Cephalis small, hemispherical to dome-shaped, with short horn. Thorax and abdomen trapezoidal in outline. Postabdominal chambers subrectangular in outline, increasing very gradually in width, more rapidly in height as added. Outer latticed layer consisting of irregularly sized and shaped polygonal pore frames (mostly pentagonal and hexagonal) with small nodes at pore frame vertices. Inner latticed layer composed of delicate, polygonal pore frames.

Remarks. The irregularly sized and shaped pore frames of the outer layers of *T. dodgensis* n. sp. distinguish it from all other Jurassic multicyrtid Nassellariina with multiwalled construction. *T. dodgensis* n. sp. differs from *T. beehivensis* (Carter) and *T. ingrahamensis* (Carter) by having a more dome-shaped test and it lacks a terminal tube.

Etymology. This species is named for Dodge Point, Queen Charlotte Islands, British Columbia, located to the southeast of the type locality.

Measurements (µm).

Length (excluding horn)	Maximum width	
150	120	Holotype
173	143	Maximum, 7 specimens
150	120	Minimum, 7 specimens
155	132	Mean, 7 specimens

Type locality. QC-574. See Locality Descriptions, Appendix 1.

Range. Crucella hettangica Zone to *Jacus*? *sandspitensis* Zone. Lower Jurassic; uppermost Hettangian to lowermost Sinemurian-upper Sinemurian.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108646 (holotype) and GSC 108645 (paratype) from type locality, GSC 108644 (paratype) from QC-676, and GSC 108647 (paratype) from QC-575. See occurrence chart, Figure 17.

Trexus sp. A
Plate 24, fig. 17

Remarks. The finer pore frames of *Trexus* sp. A distinguish it from *Trexus dodgensis* n. sp.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimen GSC 108648 from 87-CNA-KUD-2 (upper Hettangian).

Nassellarian indet. A
Plate 16, figures 17, 18, 25

Remarks. Spindle-shaped, multicyrtid test with approximately eight postabdominal chambers; irregular meshwork double layered with thick outer layer. Circumferential ridges developed on all but final chambers. Cephalis very small with long, thin, offset horn. Short cephalic spine extends outward near base of cephalis.

Occurrence. Sandilands Formation, Queen Charlotte Islands, British Columbia. Illustrated specimens GSC 108549 from 89-CNA-SKUD-34B and GSC 108550 from 87-CNA-KUD-2 (upper Hettangian).

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PLATES 1-27

PLATE 1

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 7, 8, 13, 14, 18, 23, 24
Tozerium nascens Whalen and Carter n. sp.
Species code: TOZ01
Figures 1, 24. GSC 107675 (holotype) from 89-CNA-SKUD-27, scale bar = 134 and 66 μm.
Figure 7. GSC 107676 (paratype) from 89-CNA-SKUD-27, scale bar = 103 μm.
Figure 8. GSC 107677 (paratype) from 89-CNA-SKUD-32, scale bar = 135 μm.
Figure 13. GSC 107678 (paratype) from QC-545, scale bar = 75 μm.
Figure 14. GSC 107679 (paratype) from 89-CNA-SKUE-6, scale bar = 128 μm.
Figure 18. GSC 107680 (paratype) from 89-CNA-SKUD-34A, scale bar = 67 μm.
Figure 23. GSC 107681 (paratype) from 89-CNA-SKUD-27, scale bar = 67 μm.

Figure 2
Tozerium sp. A
GSC 107682 from 90-CNA-KPD-5, scale bar = 131 μm.

Figures 3, 9, 10, 15, 19, 20, 25
Charlottea weedensis Whalen and Carter n. sp.
Species code: CHA01
Figure 3. GSC 107683 (paratype) from 89-CNA-SKUD-31, scale bar = 135 μm.
Figure 9. GSC 107684 (paratype) from 89-CNA-SKUD-34B, scale bar = 139 μm.
Figure 10. GSC 107685 (paratype) from 87-CNA-KUD-2, scale bar = 140 μm.
Figures 15, 19, 25. GSC 107686 (holotype) from QC-545, scale bar = 150, 100, and 60 μm.
Figure 20. GSC 107687 (paratype) from QC-543, scale bar = 100 μm.

Figures 4, 11, 26
Pantanellium tanuense Pessagno and Blome
Species code: PAN08
Figure 4. GSC 107688 from 89-CNA-SKUE-6, scale bar = 126 μm.
Figure 11. GSC 107689 from QC-543, scale bar = 100 μm.
Figure 26. GSC 99430 from 87-CNA-KUD-2, scale bar = 78 μm.

Figures 5, 22
Pantanellium kluense Pessagno and Blome
Species code: PAN09
Figure 5. GSC 107691 from 89-CNA-SKUD-34A, scale bar = 136 μm.
Figure 22. GSC 107692 from 87-CNA-KUD-2, scale bar = 61 μm.

Figures 6, 16
Pantanellium browni Pessagno and Blome
Species code: PAN10
GSC 107693 from 87-CNA-KPB-10, scale bar = 136 and 78 μm.

Figure 12
Pantanellium skedansense Pessagno and Blome
Species code: PAN16
GSC 107694 from 86-OF-KUC-8, scale bar = 127 μm.

Figures 17, 21, 27
Pantanellium freboldi Whalen and Carter, n. sp.
Species code: PAN12
Figure 17. GSC 107695 (paratype) from 87-CNA-KPB-12, scale bar = 135 μm.
Figures 21, 27. GSC 107696 (holotype) from 87-CNA-KPB-12, scale bar = 136 and 77 μm.

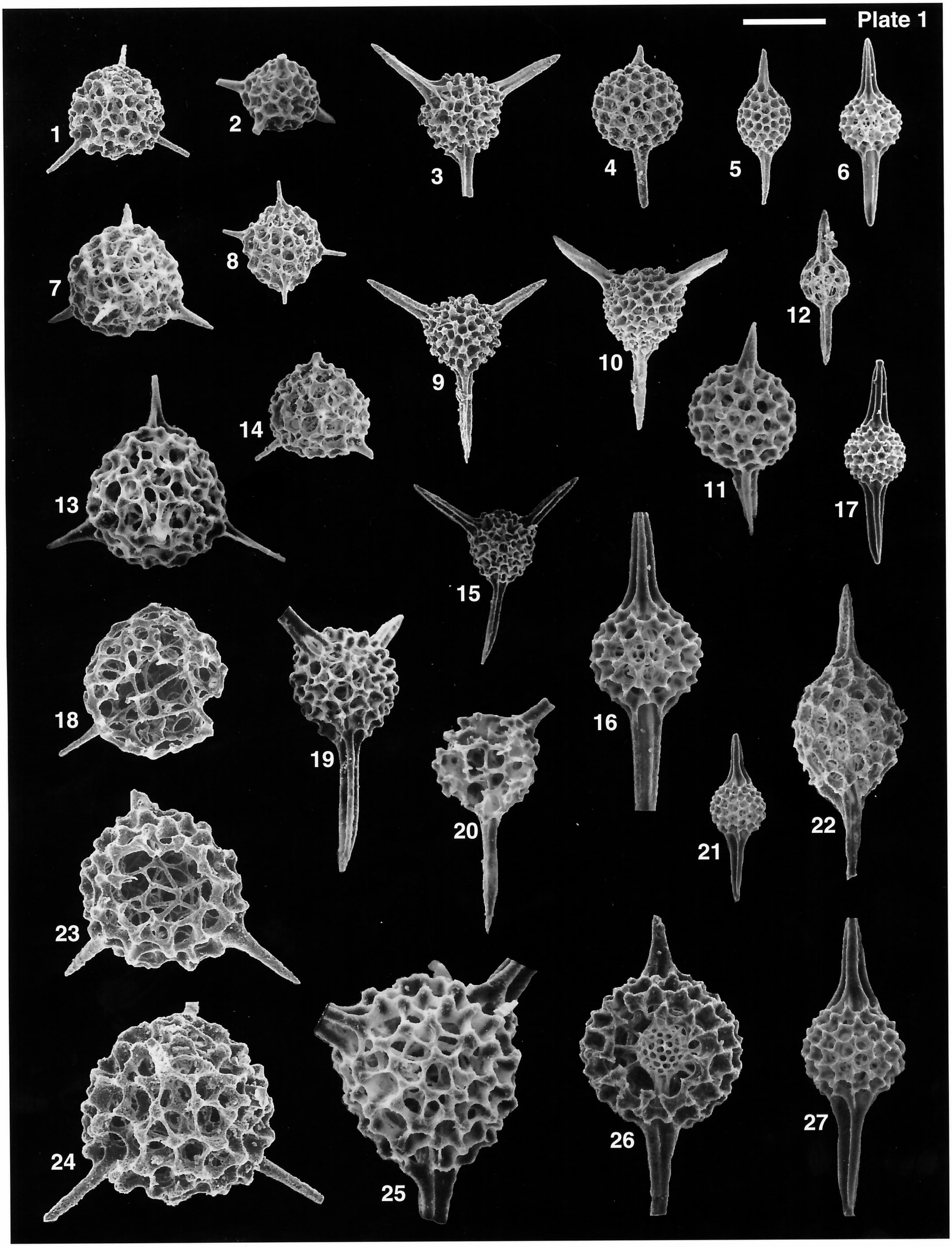
Plate 1
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PLATE 2

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 2, 13, 14, 17, 18
Pantanellium carlense Whalen and Carter n. sp.
Species code: PAN14
Figures 1, 13, 17. GSC 107697 (holotype) from QC-675, scale bar = 93, 40, and 31.5 μm.
Figures 2, 14, 18. GSC 107698 (paratype) from QC-675, scale bar = 86, 31.5, and 31.5 μm.

Figure 3
Pantanellium sp. cf. *P. browni* Pessagno and Blome
GSC 107699 from QC-571B, scale bar = 81 μm.

Figures 4, 5
Pantanellium danaense Pessagno and Blome
Species code: PAN11
Figure 4. GSC 107700 from QC-674, scale bar = 67 μm.
Figure 5. GSC 107701 from QC-675, scale bar = 63 μm.

Figure 6
Pantanellium kungaense Pessagno and Blome
Species code: PAN17
GSC 107702 from QC-674, scale bar = 67 μm.

Figures 7, 11, 15, 16
Pantanellium sixi Whalen and Carter n. sp.
Species code: PAN13
Figures 7, 16. GSC 107703 (holotype) from QC-676, scale bar = 100 and 31.5 μm.
Figures 11, 15. GSC 107704 (paratype) from QC-675, scale bar = 89 and 31.5 μm.

Figures 12, 20
Pantanellium sp. aff. *P. sixi* Whalen and Carter n. sp.
GSC 107705 from QC-677, scale bar = 84 and 30 μm

Figures 8-10, 19
Charlottea amurensis Whalen and Carter n. sp.
Species code: CHA02
Figures 8, 9. GSC 107706 (holotype) from QC-676, scale bar = 102 and 102 μm.
Figure 10. GSC 107707 (paratype) from QC-674, scale bar = 93 μm.
Figure 19. GSC 107708 (paratype) from 86-OF-KUB 2, scale bar = 85 μm.

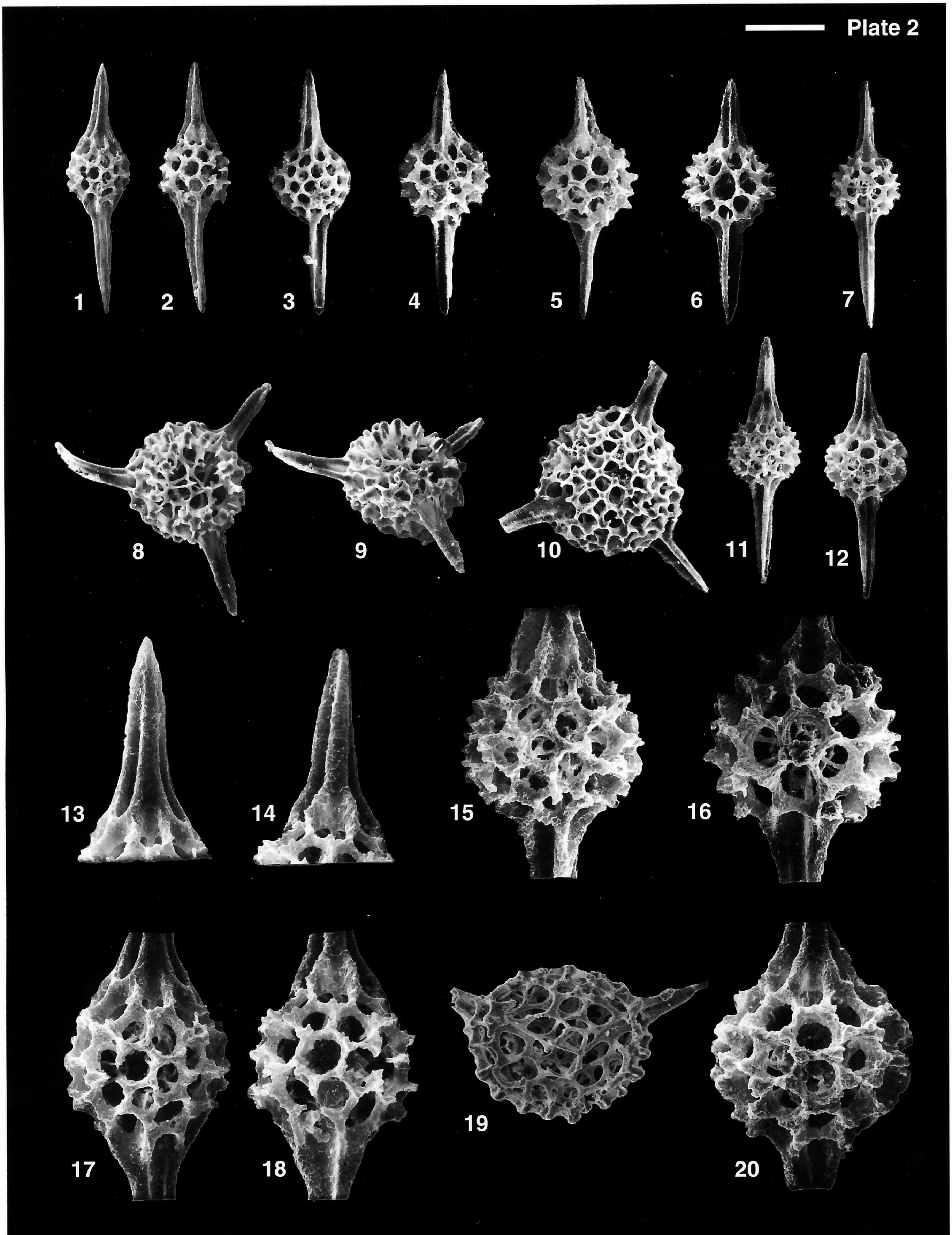
Plate 2
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PLATE 3

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 2, 9
Charlottea amurensis Whalen and Carter n. sp.
Species code: CHA02
GSC 107709 (paratype) from QC-676, scale bar = 100, 105, and 55 μm.

Figures 3, 4, 6-8, 11, 12, 15
Charlottea harbridgensis Whalen and Carter n. sp.
Species code: CHA04
Figures 3, 4, 12. GSC 107710 (holotype) from QC-676, scale bar = 93, 92, and 36 μm.
Figures 6, 7, 11. GSC 107711 (paratype) from QC-676, scale bar = 100, 100, and 38 μm.
Figures 8, 15. GSC 107712 (paratype) from QC-676, scale bar = 89 and 36 μm.

Figures 5, 10, 13, 14
Charlottea johnsoni Whalen and Carter n. sp.
Species code: CHA06
Figures 5, 13. GSC 107713 (holotype) from QC-574, scale bar = 75 and 46 μm.
Figures 10, 14. GSC 107714 (paratype) from QC-574, scale bar = 60 and 40 μm.

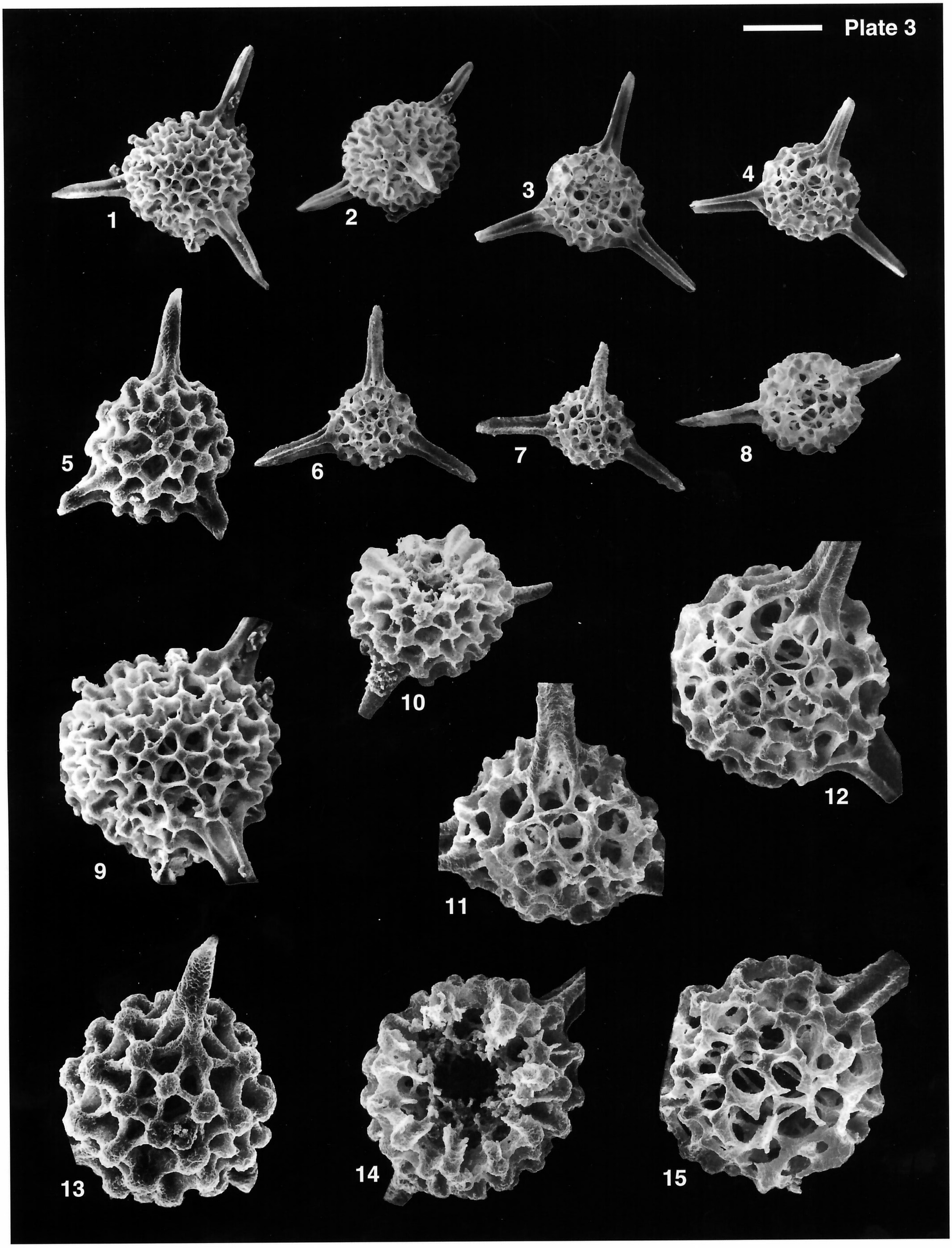
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PLATE 4

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 6-10, 13
Charlottea proprietatis Whalen and Carter n. sp.
Species code: CHA03
Figures 1, 10, 13. GSC 107715 (holotype) from QC-675, scale bar = 100, 69, and 55 μm.
Figure 6. GSC 107716 (paratype) from QC-675, scale bar = 100 μm.
Figure 7. GSC 107717 (paratype) from 89-CNA-KUB-4, scale bar = 87 μm.
Figure 8. GSC 107718 (paratype) from QC-675, scale bar = 102 μm.
Figure 9. GSC 107719 (paratype) from QC-675, scale bar = 84 μm.

Figures 2-5, 11, 14, 15
Charlottea triquetra Whalen and Carter n. sp.
Species code: CHA05
Figures 2, 3, 11, 14. GSC 107720 (holotype) from QC-677, scale bar = 72, 73, 30, and 30 μm.
Figures 4, 5, 15. GSC 107721 (paratype) from QC-677, scale bar = 69, 66, and 31.5 μm.

Figure 12
Charlottea sp. A.
GSC 107722 from QC-675, scale bar = 84 μm.

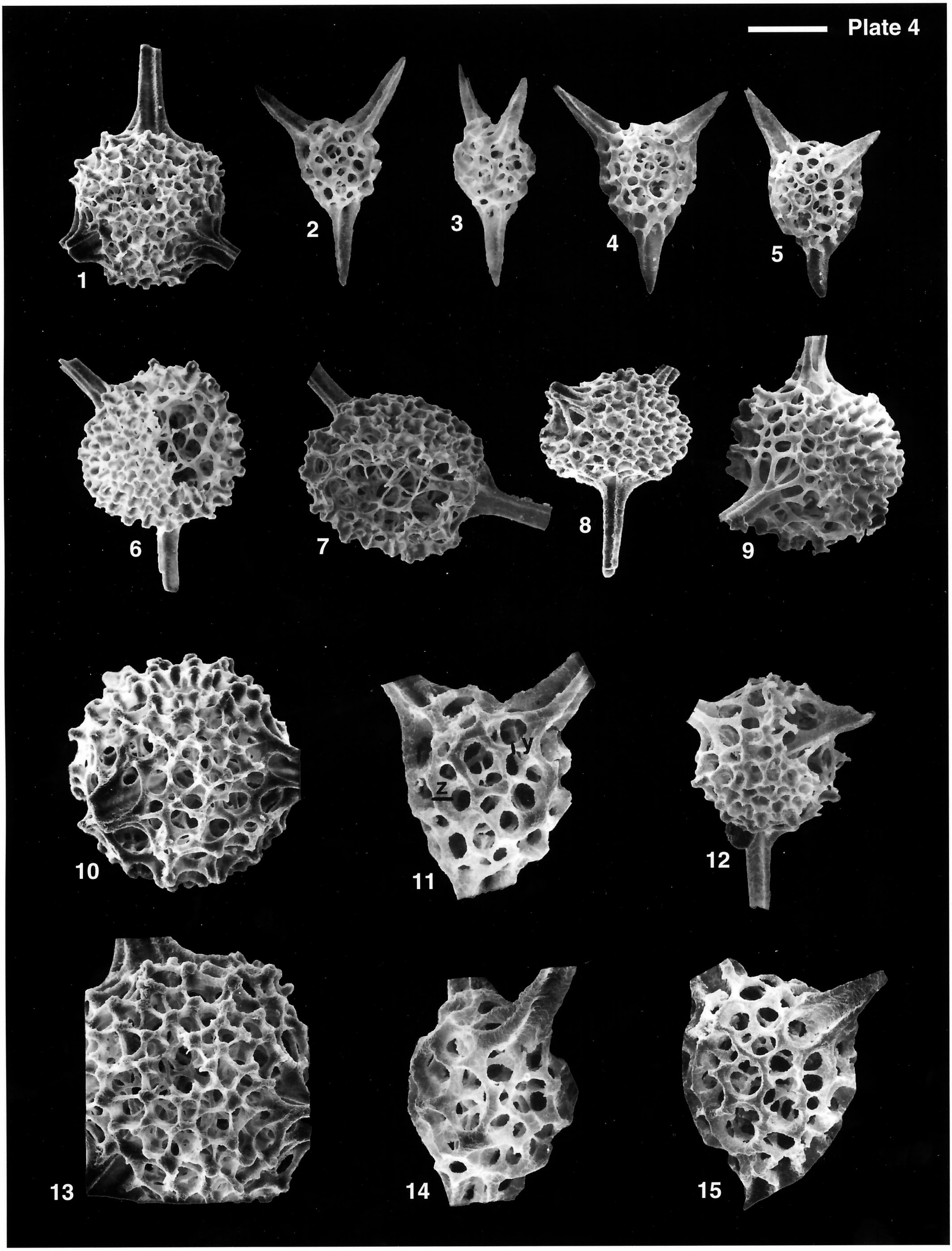
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PLATE 5

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 17
Charlottea sp. B.
GSC 107723 from QC-574, scale bar = 100 and 43 μm.

Figures 2-4, 14, 18
Danubea howardi Whalen and Carter n. sp.
Species code: DAN01
Figures 2, 14, 18. GSC 107724 (holotype) from QC-571B, scale bar = 114, 42, and 46 μm.
Figure 3. GSC 107725 (paratype) from QC-545, scale bar = 150 μm.
Figure 4. GSC 107726 (paratype) from QC-545, scale bar = 150 μm.

Figures 5, 11, 16
Danubea sp. aff. *D. howardi* Whalen and Carter n. sp.
GSC 107727 from QC-571B, scale bar = 84, 31.5, and 31.5 μm.

Figures 6, 15
Charlottea sp. C.
GSC 107728 from QC-674, scale bar = 86 and 46 μm.

Figures 7, 8, 12, 13
Udalia plana Whalen and Carter n. sp.
Species code: UDA05
GSC 107729 (holotype) from QC-676, scale bar = 114, 105, 43, and 40 μm.

Figures 9, 10, 19
Sophia tuberis Whalen and Carter n. sp.
Species code: SOP06
GSC 107730 (holotype) from QC-675, scale bar = 100, 100, and 38 μm.

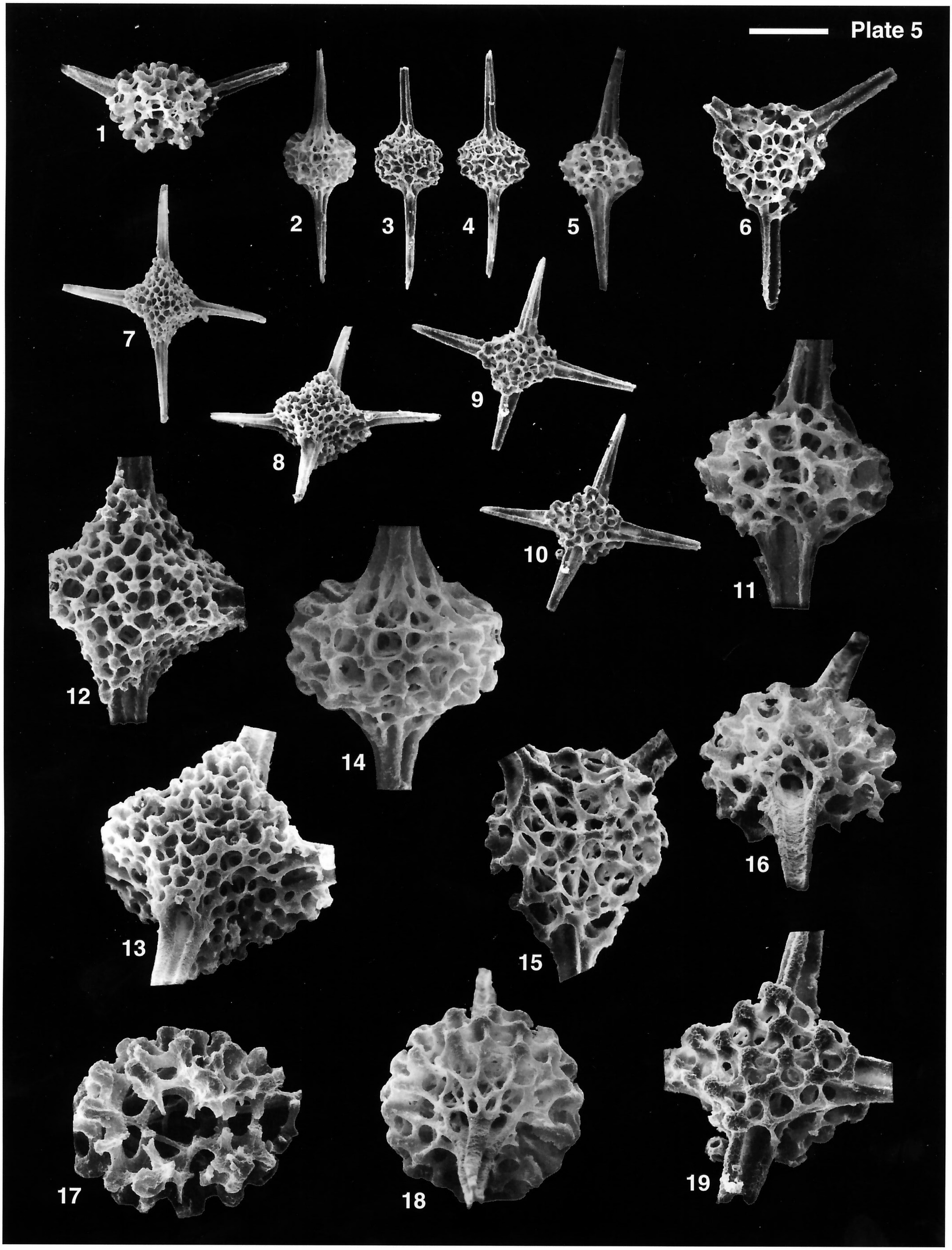
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PLATE 6

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 2
Thurstonia gibsoni Whalen and Carter n. sp.
Species code: THU01
Figure 1. GSC 107731 (holotype) from 89-CNA-SKUD-27, scale bar = 135 μm.
Figure 2. GSC 107732 (paratype) from 89-CNA-SKUD-27, scale bar = 137 μm.

Figures 3-5, 10
Thurstonia timberensis Whalen and Carter n. sp.
Species code: THU04
Figure 3. GSC 107733 (holotype) from 87-CNA-KUD-14, scale bar = 130 μm.
Figure 4. GSC 107734 (paratype) from 87-CNA-KUD-14, scale bar = 130 μm.
Figure 5. GSC 107735 (paratype) from 87-CNA-KUD-14, scale bar = 130 μm.
Figure 10. GSC 107736 (paratype) from 87-CNA-KUD-14, scale bar = 129 μm.

Figure 6
Thurstonia sp. A
GSC 107737 from QC-677, scale bar = 72 μm.

Figures 7, 9
Thurstonia minutaglobus Whalen and Carter n. sp.
Species code: THU05
Figure 7. GSC 107738 (paratype) from 89-CNA-SKUD-27, scale bar = 102 μm.
Figure 9. GSC 107739 (paratype) from 89-CNA-KUD-18, scale bar = 130 μm.

Figures 8, 12, 15, 16, 20, 23
Udalia primaeva Whalen and Carter n. sp.
Species code: UDA01
Figure 8. GSC 107740 (paratype) from 89-CNA-SKUD-27, scale bar = 136 μm.
Figure 12. GSC 107741 (paratype) from 87-CNA-KUD-2, scale bar = 135 μm.
Figure 15. GSC 107742 (holotype) from 89-CNA-KUD-5, scale bar = 150 μm.
Figures 16, 20, 23. GSC 107743 (paratype) from QC-543, scale bar = 120, 75, and 60 μm.

Figures 11, 13, 14, 17-19, 21, 22
Udalia dennisoni Whalen and Carter n. sp.
Species code: UDA03
Figure 11. GSC 107744 (paratype) from QC-574, scale bar = 88.5 μm.
Figure 13. GSC 107745 (paratype) from 87-CNA-KUD-9, scale bar = 143 μm.
Figures 14, 21. GSC 107746 (holotype) from QC-574, scale bar = 105 and 60 μm.
Figure 17. GSC 107747 (paratype) from 87-CNA-KPB-12, scale bar = 136 μm.
Figure 18. GSC 107748 (paratype) from QC-574, scale bar = 85.5 μm.
Figures 19, 22. GSC 107749 (paratype) from QC-574, scale bar = 81 and 51 μm.

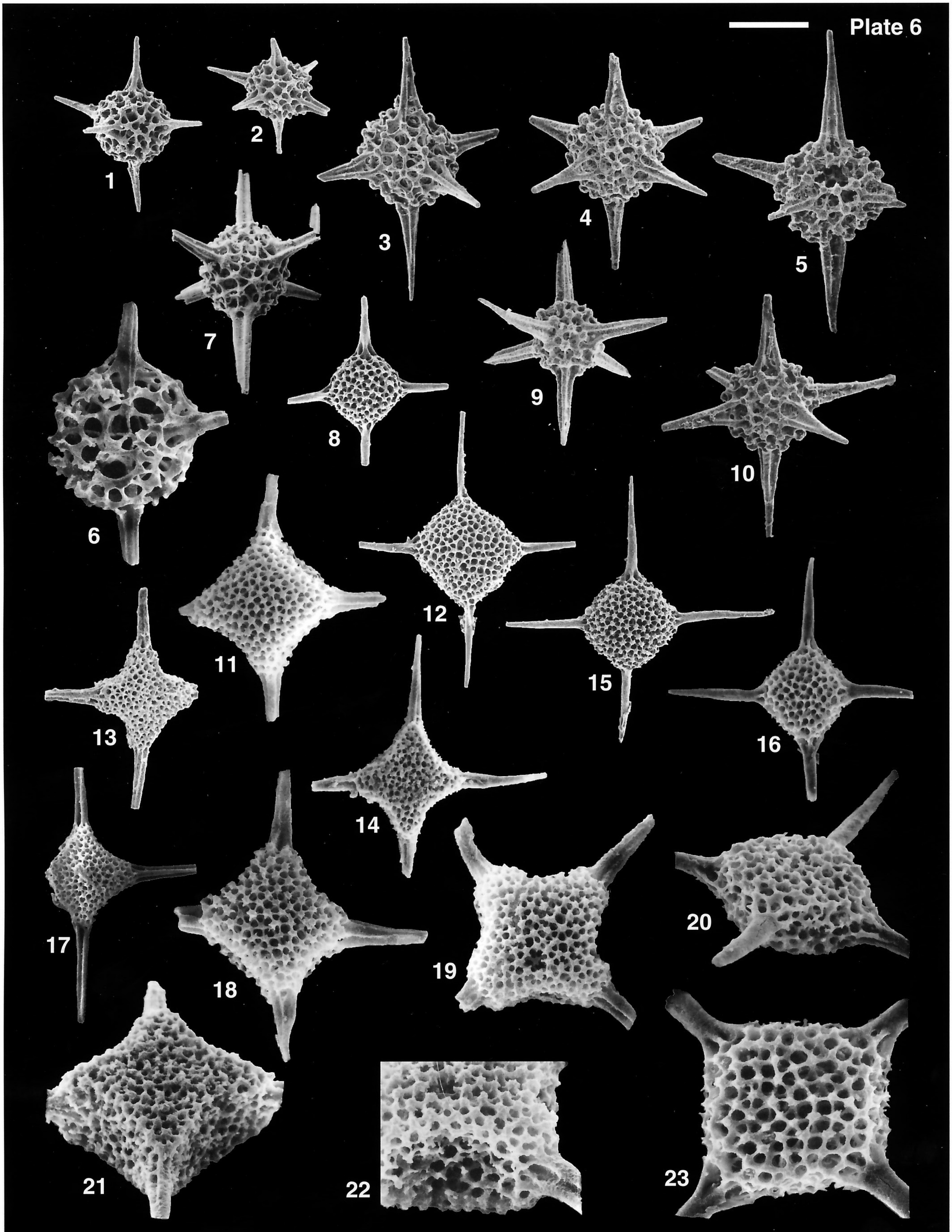
Plate 6
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PLATE 7

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 2, 5, 17, 20
Empirea sp. A
Species code: EMP02
Figure 1. GSC 107750 from 89-CNA-SKUE-6, scale bar = 136 μm.
Figures 2, 5. GSC 107751 from QC-568, scale bar = 54 and 60 μm.
Figures 17, 20. GSC 107752 from QC-568, scale bar = 60 and 40.5 μm.

Figures 6, 9, 10
Empirea hasta Whalen and Carter n. sp.
Species code: EMP01
Figure 6. GSC 107753 (holotype) from 87-CNA-KUD-2, scale bar = 69 μm.
Figure 9. GSC 107754 (paratype) from 87-CNA-KUD-2, scale bar = 92 μm.
Figure 10. GSC 107755 (paratype) from QC-568, scale bar = 72 μm.

Figures 11, 16, 19
Empirea sp. B
Figure 11, 16. GSC 107756 from QC-568, scale bar = 52.5 and 51 μm.
Figure 19. GSC 107757 from QC-545, scale bar = 75 μm.

Figures 3, 4, 7, 8, 12
Udalia parvacapsa Whalen and Carter n. sp.
Species code: UDA04
Figure 3. GSC 107758 (holotype) from 87-CNA-KUD-9, scale bar = 172 μm.
Figures 4, 12. GSC 107759 (paratype) from QC-545, scale bar = 201 and 51 μm.
Figure 7. GSC 107760 (paratype) from 87-CNA-KUD-10, scale bar = 172 μm.
Figure 8. GSC 107761 (paratype) from 87-CNA-KUD-14, scale bar = 172 μm.

Figures 13-15, 18
Udalia plana Whalen and Carter n. sp.
Species code: UDA05
Figure 13. GSC 107762 (paratype) from 89-CNA-KUD-11, scale bar = 135 μm.
Figures 14, 18. GSC 107763 (paratype) from QC-545, scale bar = 120 and 60 μm.
Figure 15. GSC 107764 (paratype) from 87-CNA-KUD-2, scale bar = 134 μm.

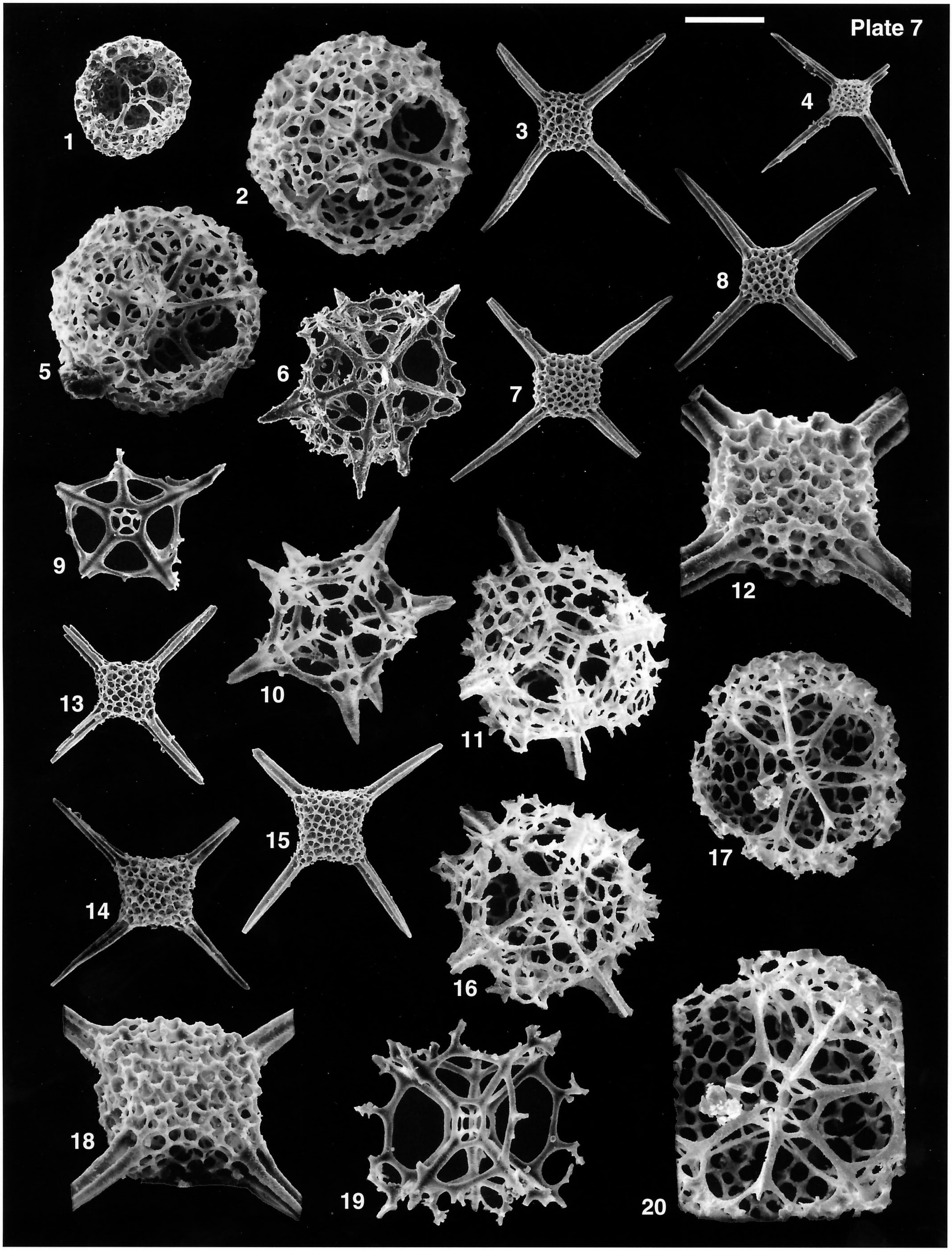
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PLATE 8

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 12
Thurstonia magnaglobus Whalen and Carter n. sp.
Species code: THU03
GSC 107765 (holotype) from QC-574, scale bar = 73 and 43 μm.

Figures 2, 5-7, 9, 10, 13
Thurstonia minutaglobus Whalen and Carter n. sp.
Species code: THU05
Figures 2, 6, 13. GSC 107766 (holotype) from QC-574, scale bar = 93, 86, and 40 μm.
Figures 5, 9. GSC 107767 (paratype) from QC-574, scale bar = 60 and 33 μm.
Figures 7, 10. GSC 107768 (paratype) from QC-574, scale bar = 60 and 60 μm.

Figures 3, 4, 8, 11, 14
Parentactinia carteri Whalen and Carter n. sp.
Species code: PET01
Figures 4, 8. GSC 107769 (holotype) from QC-543, scale bar = 86 μm.
Figures 3, 11, 14. GSC 107770 (paratype) from QC-545, scale bar = 100, 60, and 60 μm.

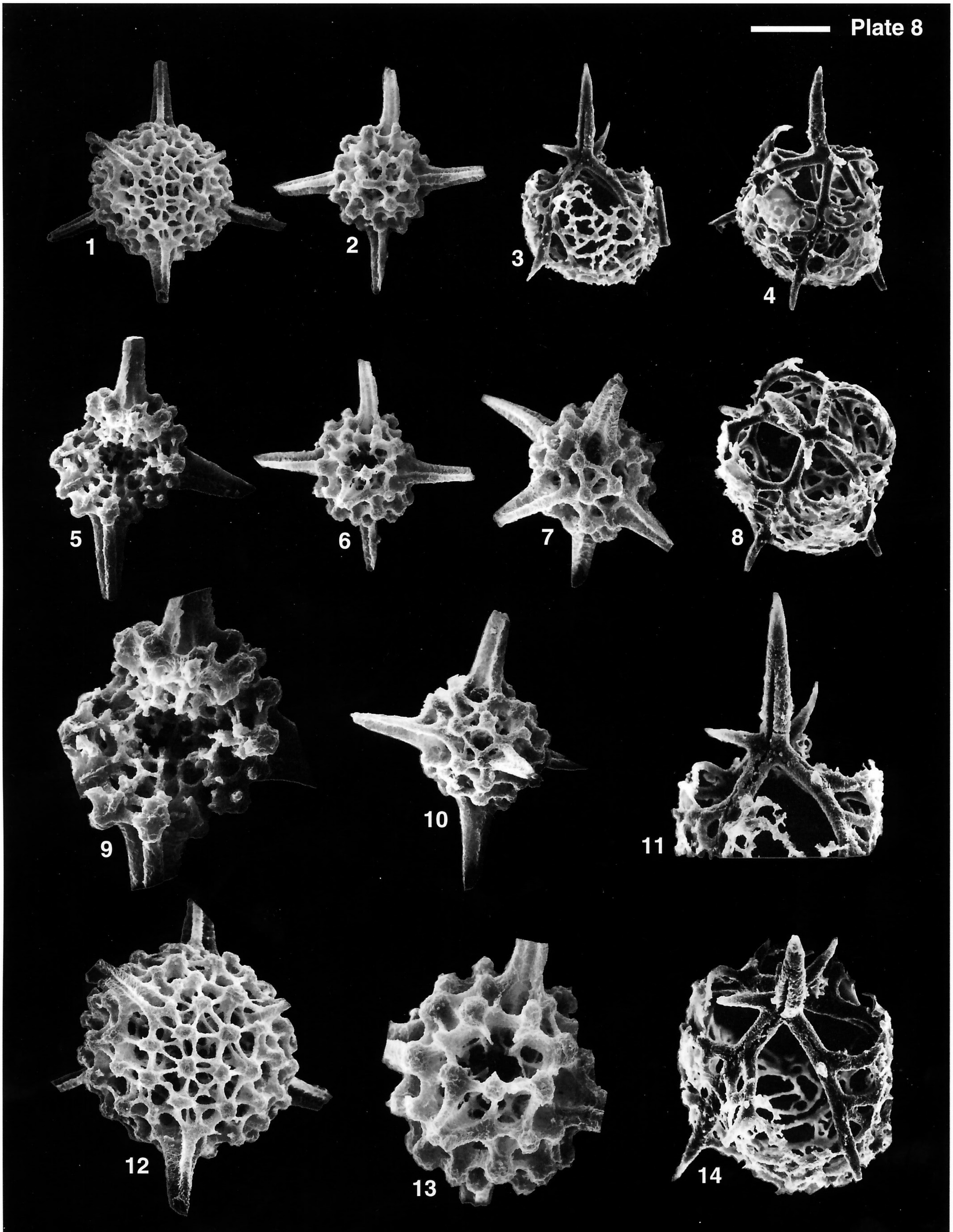
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PLATE 9

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 5-7, 10
Sophia palfyi Whalen and Carter n. sp.
Species code: SOP07
Figure 1. GSC 107771 (paratype) from 87-CNA-KUD-15, scale bar = 172 μm.
Figures 5, 6. GSC 107772 (holotype) from 87-CNA-KUD-14, scale bar = 65 and 172 μm.
Figures 7, 10. GSC 107773 (paratype) from QC-549, scale bar = 150 and 54 μm.

Figures 2-4, 19
Praeorbiculiformella robusta Whalen and Carter n. sp.
Species code: ORB02
Figures 2, 19. GSC 107774 (holotype) from 89-CNA-KUG-1A, scale bar = 177.5 and 86 μm.
Figure 3. GSC 107775 (paratype) from 89-CNA-KUG-1A, scale bar = 172 μm.
Figure 4. GSC 107776 (paratype) from 89-CNA-KUG-1A, scale bar = 180 μm.

Figure 8
Praeorbiculiformella? lomgonensis Whalen and Carter n. sp.
Species code: ORB03
GSC 107777 (holotype) from 86-CAA-T-2/3, scale bar = 176 μm.

Figure 9
Fontinella habros Carter
GSC 107778 from 87-CNA-KUD-2, scale bar = 136 μm.

Figures 11-13
Praeorbiculiformella yanensis Whalen and Carter n. sp.
Species code: ORB01
Figure 11. GSC 107779 (holotype) from 86-CAA-T-2/3, scale bar = 172 μm.
Figure 12. GSC 107780 (paratype) from 86-CAA-T-2/3, scale bar = 171 μm.
Figure 13. GSC 107781 (paratype) from 86-CAA-T-2/3, scale bar = 172 μm.

Figure 14
Spongodiscid indet. A
GSC 107782 from 87-CNA-KUD-2, scale bar = 135 μm.

Figure 18
Spongodiscid indet. B
GSC 107783 from 89-CNA-KUD-12, scale bar = 151 μm.

Figure 22
Praeorbiculiformella sp. A
GSC 107784 from 89-CNA-KUA-6, scale bar = 130 μm.

Figures 15-17, 20, 21
Spumellarian indet. C
Species code: SPI04
Figure 15. GSC 107785 from 89-CNA-SKUD-38, scale bar = 134 μm.
Figure 16. GSC 107786 from 87-CNA-KUD-2, scale bar = 182 μm.
Figure 17. GSC 107787 from 87-CNA-KUD-2, scale bar = 137 μm.
Figures 20, 21. GSC 107788 from QC-543, scale bar = 99 and 75 μm.

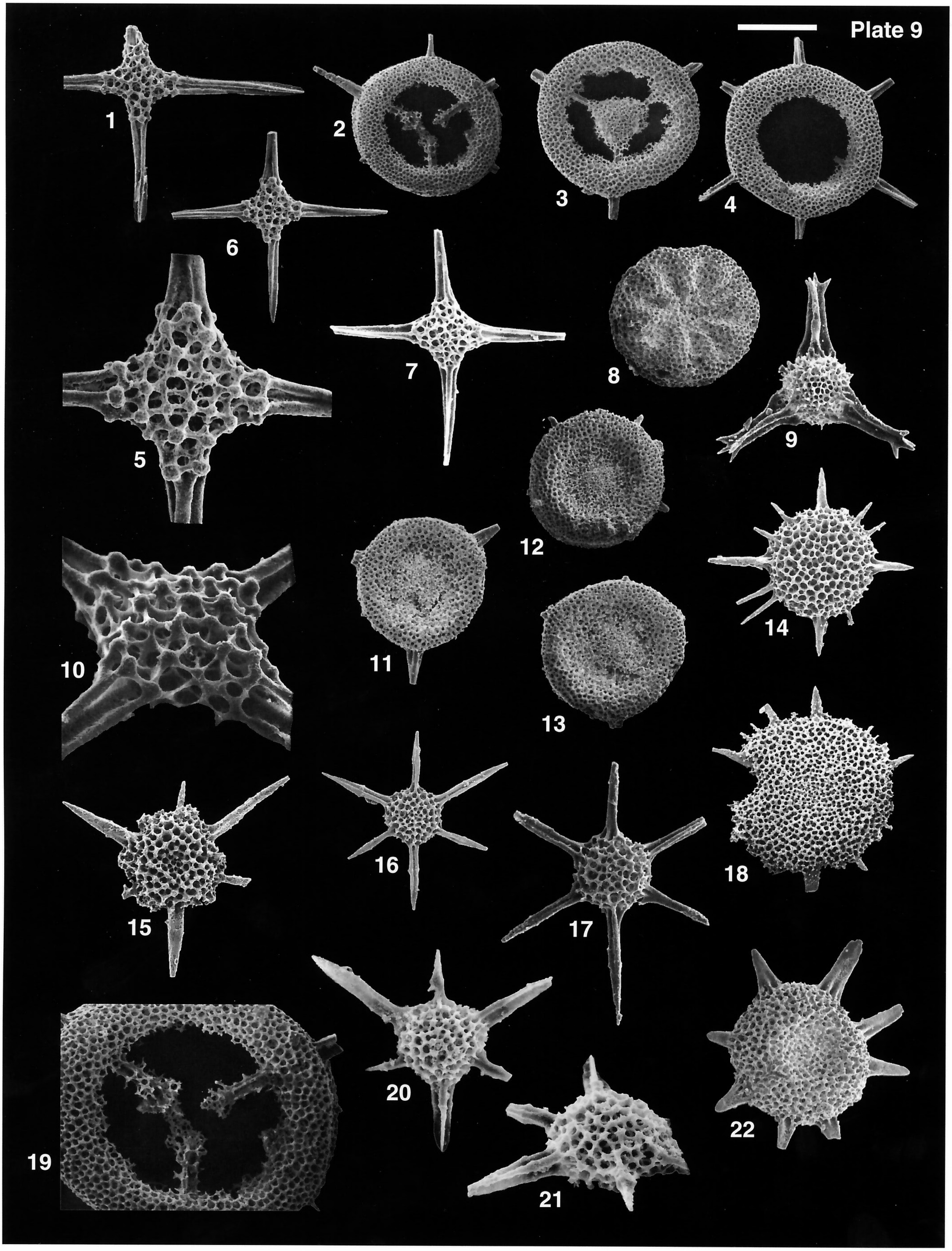
Plate 9
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PLATE 10

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 6, 10, 13, 17
Archaeohagiastrum sp. aff. *A. pobi* Whalen and Carter n. sp.
Species code: HAG01
Figure 1. GSC 107789 from 87-CNA-KUD-14, scale bar = 173 μm.
Figures 6, 10, 13, 17. GSC 107790 from QC-549, scale bar = 201, 85.5, 43.5, and 75 μm.

Figures 2, 7, 8, 18, 19
Hagiastrum rudimentum Whalen and Carter n. sp.
Species code: HAG04
Figures 2, 18, 19. GSC 107791 (holotype) from QC-675, scale bar = 126, 43.5, and 31. 5 μm.
Figure 7. GSC 107792 (paratype) from 86-OF-KUC-8, scale bar = 167 μm.
Figure 8. GSC 107793 (paratype) from 86-OF-KUC-6, scale bar = 173 μm.

Figures 3-5, 9
Archaeohagiastrum pobi Whalen and Carter n. sp.
Species code: HAG02
Figures 3, 9. GSC 107794 (holotype) from 89-CNA-KUH-8, scale bar = 214 and 99 μm.
Figure 4. GSC 107795 (paratype) from 86-OF-KUA-2, scale bar = 178 μm.
Figure 5. GSC 107796 (paratype) from 86-OF-KUA-2, scale bar = 178.5 μm.

Figures 11, 12, 14-16
Hagiastrum majusculum Whalen and Carter n. sp.
Species code: HAG03
Figure 11. GSC 107797 (holotype) from 86-OF-KUB-2, scale bar = 178 μm.
Figures 12, 15, 16. GSC 107798 (paratype) from QC-676, scale bar = 162, 51, and 43. 5 μm
Figure 14. GSC 107799 (paratype) from 86-OF-KUA-2, scale bar = 178 μm.

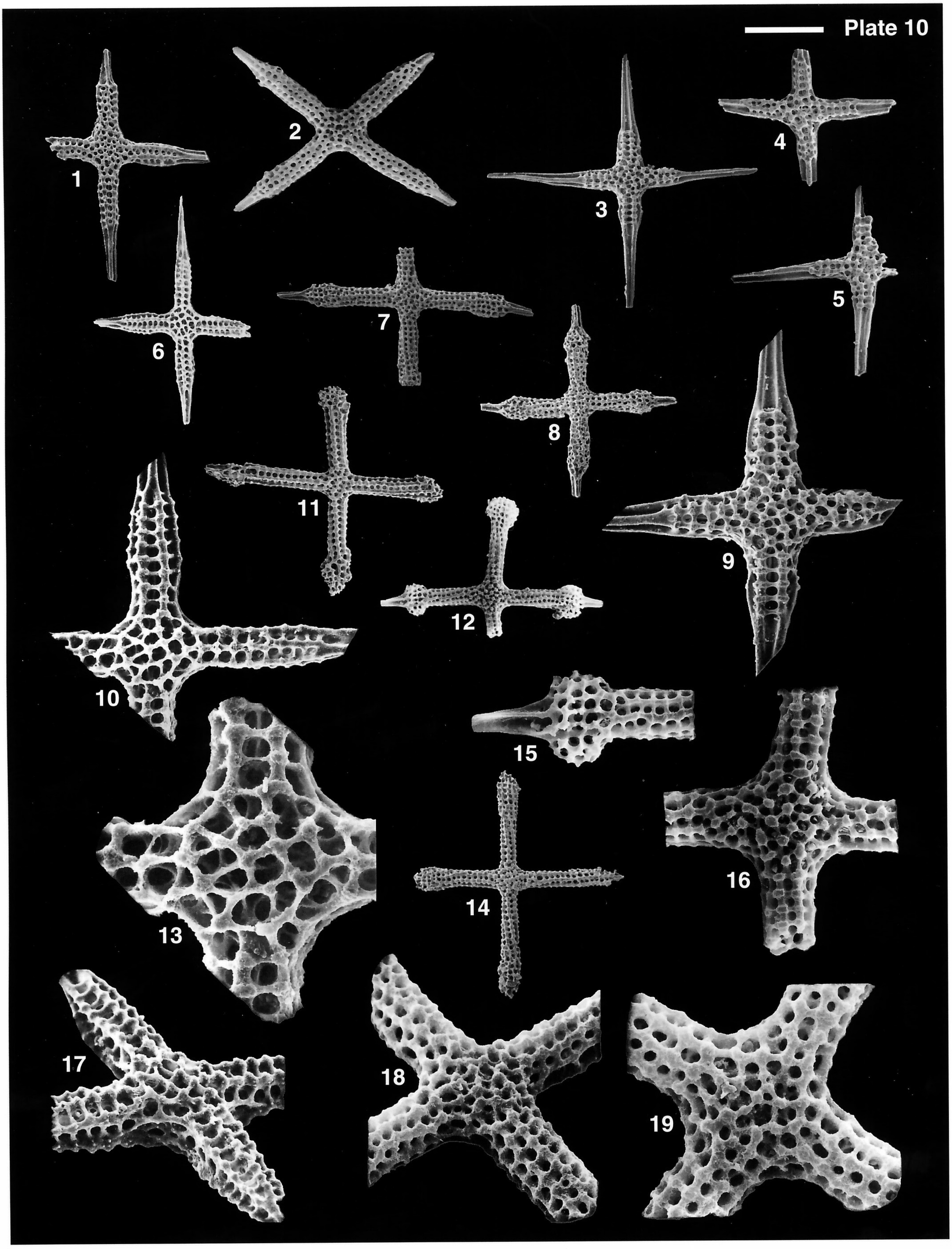
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PLATE 11

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 5, 9, 21
Archaeocenosphaera laseekensis Pessagno and Yang
Species code: ARC04
Figures 1, 21. GSC 107800 from QC-543, scale bar = 85.5 and 43.5 μm.
Figure 5. GSC 107801 from 89-CNA-SKUD-339, scale bar = 136 μm.
Figure 9. GSC 107803 from 90-CNA-KPD-5, scale bar = 81.5 μm.

Figures 2, 3, 6, 23
Amuria impensa Whalen and Carter n. sp.
Species code: AMU01
Figure 2. GSC 107804 (holotype) from 89-CNA-SKUD-32, scale bar = 139.5 μm.
Figures 3, 23. GSC 107805 (paratype) from QC-545, scale bar = 120 and 66 μm.
Figure 6. GSC 107802 (paratype) from 89-CNA-SKUE-6, scale bar = 136 μm.

Figures 4, 8, 12
Pseudoheptacladus sp. A
Species code: SPI01
Figure 4. GSC 107806 from 87-CNA-KUD-2, scale bar = 146 μm.
Figure 8. GSC 107807 from 87-CNA-KUD-2, scale bar = 135 μm.
Figure 12. GSC 107808 from 87-CNA-KUD-2, scale bar = 135 μm.

Figure 7
Amuria macfarlanei Whalen and Carter n. sp.
Species code: AMU02
GSC 107809 (holotype) from 87-CNA-KUD-14, scale bar = 121 μm.

Figures 10, 11, 15
Spumellarian indet. A
Species code: SPI02
Figure 10. GSC 107810 from 89-CNA-SKUD-34A, scale bar = 139 μm.
Figure 11. GSC 107811 from 87-CNA-KUD-2, scale bar = 134.5 μm.
Figure 15. GSC 107812 from QC-543, scale bar = 120 μm.

Figures 13, 14, 16-20, 22
Beatricea christovalensis Whalen and Carter n. sp.
Species code: SPI03
Figure 13. GSC 107813 (paratype) from 87-CNA-KUD-14, scale bar = 173 μm.
Figure 14. GSC 107817 (holotype) from 89-CNA-KUG-1A, scale bar = 177.5 μm.
Figures 16, 20. GSC 107814 (paratype) from QC-676, scale bar = 84 and 88.5 μm.
Figures 17, 18, 22. GSC 107815 (paratype) from QC-676, scale bar = 94, 66, and 33 μm.
Figure 19. GSC 107816 (paratype) from 86-OF-KUC-7, scale bar = 127 μm.

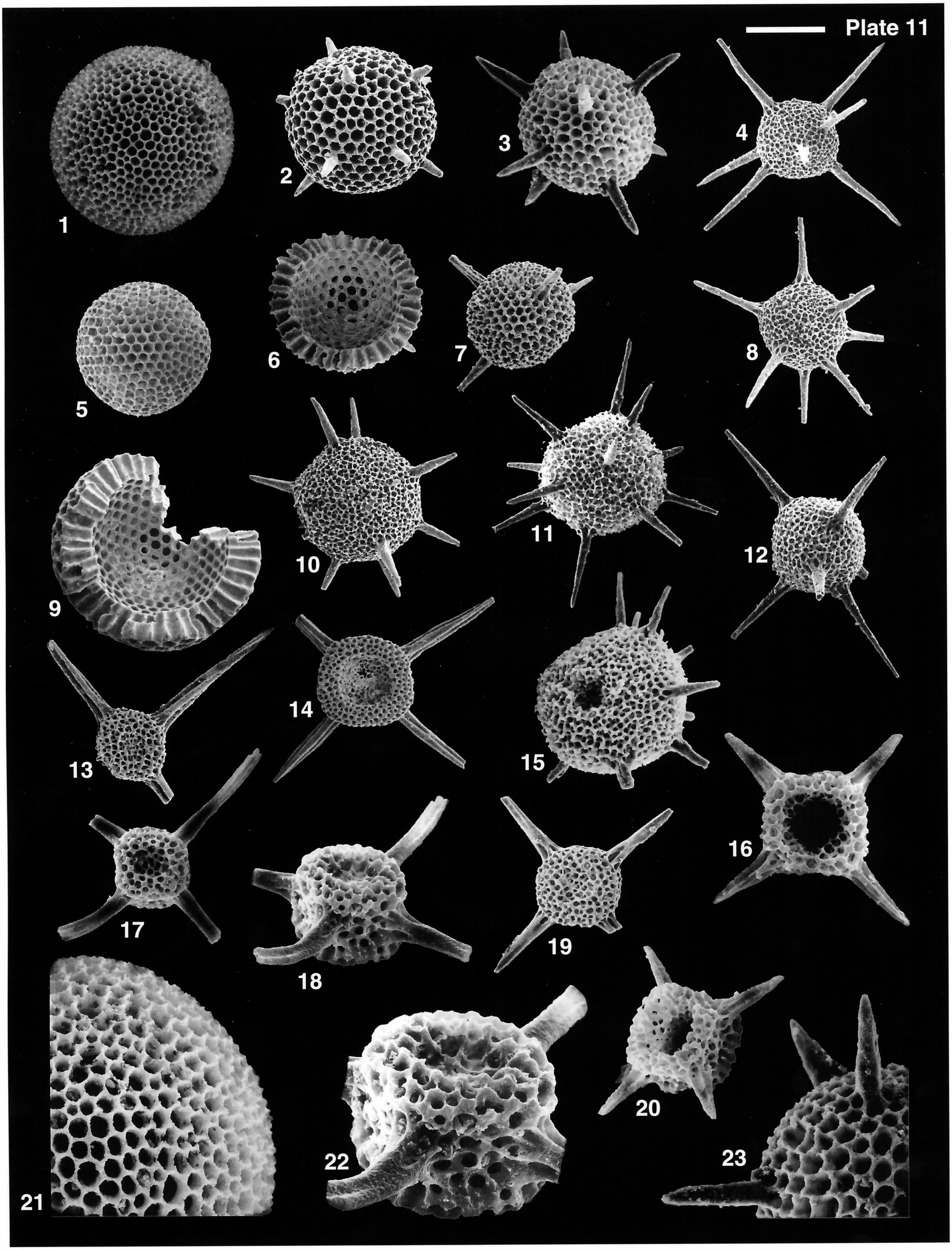
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PLATE 12

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figure 1
Crucella carteri Kozur and Mostler
GSC 107818 from 89-CNA-KUD-16, scale bar = 128 μm.

Figure 2
Crucella prisca Kozur and Mostler
Species code: CRU06
GSC 107819 from 87-CNA-KUD-14, scale bar = 173 μm.

Figures 3-5, 7-10, 12, 13, 16, 20, 23
Crucella hettangica Kozur and Mostler
Species code: CRU07
Figure 3. GSC 107820 from 87-CNA-KUD-14, scale bar = 173 μm.
Figure 4. GSC 107821 from 89-CNA-KUH-8, scale bar = 173 μm.
Figure 5. GSC 107822 from QC-675, scale bar = 114 μm.
Figure 7. GSC 107823 from 86-OF-KUB-2, scale bar = 168.5 μm.
Figure 8. GSC 107824 from 87-CNA-KPB-12, scale bar = 170 μm.
Figures 9, 10. GSC 107825 from QC-675, scale bar = 105 and 46.5 μm.
Figure 12. GSC 107826 from 86-OF-KUB-2, scale bar = 177.5 μm.
Figures 13, 23. GSC 107827 from QC-677, scale bar = 120 and 40.5 μm.
Figures 16, 20. GSC 107828 from 86-OF-KUB-2, scale bar = 172 and 86 μm.

Figure 6
Crucella sp. A
GSC 107829 from 87-CNA-KPB-10, scale bar = 136 μm.

Figure 11
Crucella sp. B
GSC 107830 from 86-OF-KUB-3, scale bar = 252 μm.

Figure 14
Crucella kaisunensis Whalen and Carter n. sp.
Species code: CRU09
GSC 107831 (holotype) from 89-CNA-KUH-8, scale bar = 172 μm.

Figures 15, 18, 19, 21, 22
Crucella cavata Whalen and Carter n. sp.
Species code: CRU10
Figure 15. GSC 107832 (holotype) from 86-OF-KUC-8, scale bar = 170.5 μm.
Figure 18. GSC 107833 (paratype) from QC-675, scale bar = 102 m.
Figures 19, 21, 22. GSC 107834 (paratype) from QC-675, scale bar = 162, 54, 136.5 μm.

Figure 17
Spumellarian indet. B
GSC 107835 from 88-OF-LB-1, scale bar = 177 μm.

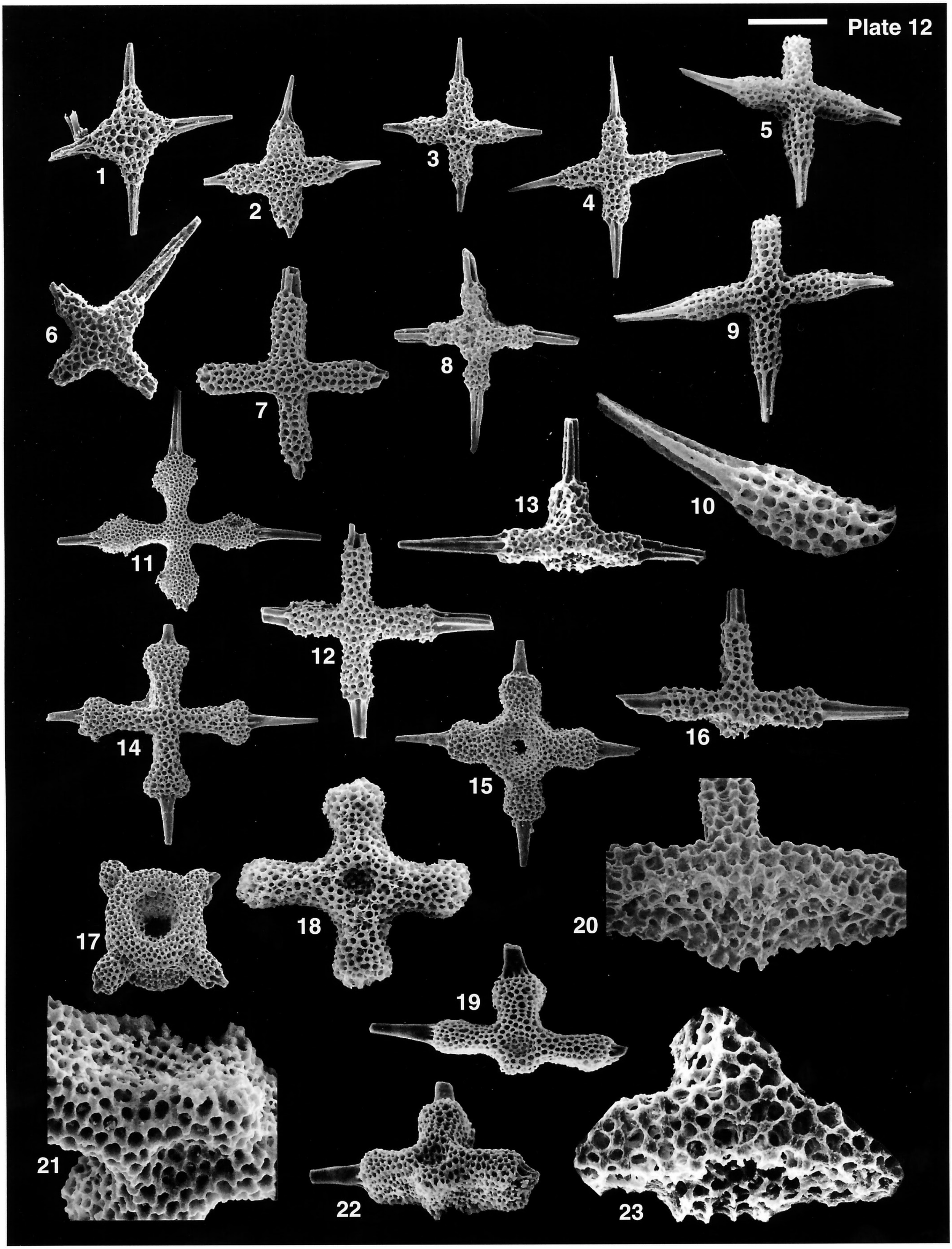
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PLATE 13

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 2, 6, 9, 12, 16
Paronaella ravenensis Whalen and Carter n. sp.
Species code: PAR06
Figure 1. GSC 107836 (paratype) 89-CNA-KUD-5, scale bar = 136 μm.
Figure 2. GSC 107837 (holotype) 87-CNA-KUD-4, scale bar = 146 μm.
Figure 6. GSC 107838 (paratype) 89-CNA-SKUD-28, scale bar = 136 μm.
Figures 9, 12, 16. GSC 107839 (paratype) QC-545, scale bar = 120, 120, and 60 μm.

Figure 3
Paronaella sp. cf. *P. corpulenta* De Wever
Species code: PAR11
GSC 107840 from 89-CNA-KUH-8, scale bar = 172.5 μm.

Figures 4, 5, 8, 11, 15
Paronaella skenaensis Whalen and Carter n. sp.
Species code: PAR08
Figure 4. GSC 107841 (holotype) from 89-CNA-KUD-12, scale bar = 162 μm.
Figures 5, 11. GSC 107842 (paratype) from QC-543, scale bar = 171 and 99 μm.
Figure 8. GSC 107843 (paratype) from 89-CNA-SKUD-34A, scale bar = 168 μm.
Figure 15. GSC 107844 (paratype) from 87-CNA-KUD-2, scale bar = 162 μm.

Figures 7, 10, 14
Paronaella botanyensis Whalen and Carter n. sp.
Species code: PAR09
Figure 7. GSC 107845 (holotype) from 87-CNA-KUD-10, scale bar = 171.5 μm.
Figures 10, 14. GSC 107846 (paratype) from QC-574, scale bar = 129 and 63 μm.

Figures 13, 17
Homoeoparonaella sp. A
Species code: PAR12
Figure 13. GSC 107847 from 89-CNA-KUH-1, scale bar = 171.5 μm.
Figure 17. GSC 107848 from 86-OF-KUC-7, scale bar = 172.5 μm.

Figures 18, 19, 22-24
Paronaella jamesi Whalen and Carter n. sp.
Species code: PAR10
Figure 18. GSC 107849 (paratype) from 86-OF-KUC-6, scale bar = 158 μm.
Figure 19. GSC 107850 (paratype) from 86-OF-KUC-8, scale bar = 178 μm.
Figure 22. GSC 107851 (paratype) from 86-OF-KUC-8, scale bar = 167 μm.
Figure 23. GSC 107852 (holotype) from 89-CNA-KUH-8, scale bar = 176.5 μm.
Figure 24. GSC 107853 (paratype) from 86-OF-KUA-2, scale bar = 171 μm.

Figures 20, 21
Leugeonidae indet. A
Species code: SPI05
Figure 20. GSC 107854 from 89-CNA-KUG-1, scale bar = 132 μm.
Figure 21. GSC 107855 from 86-OF-KUB-2, scale bar = 138 μm.

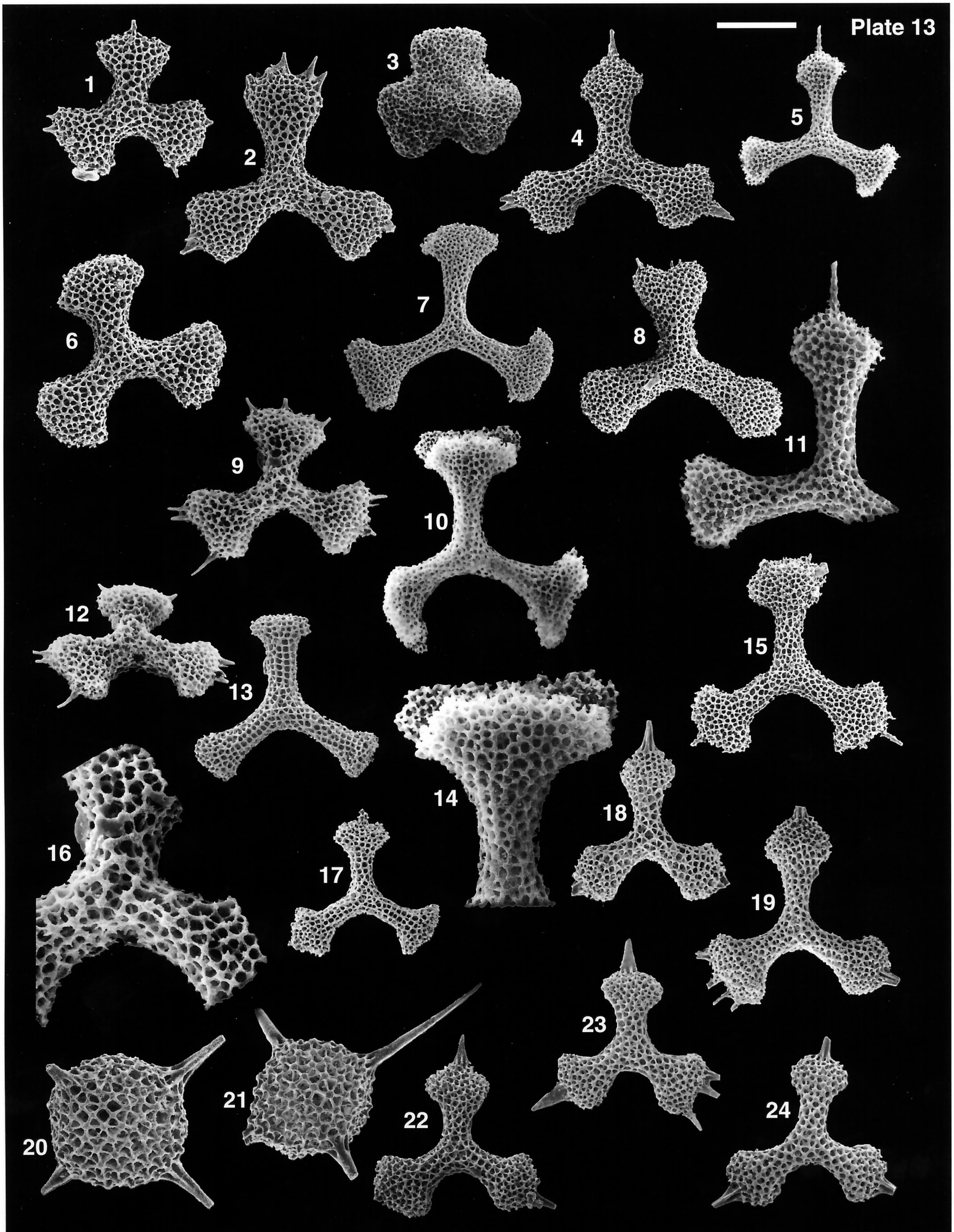
Plate 13
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PLATE 14

All figures are scanning electron micrographs of early Jurassic Spumellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (µm) cited for each illustration.

Figures 1, 2, 5, 6, 9, 10
Praehexasaturnalis tetraradiatus Kozur and Mostler
Species code: SAT01
Figure 1. GSC 107856 from 89-CNA-SKUD-34B, scale bar = 186 µm.
Figure 2. GSC 107857 from QC-545, scale bar = 201 µm.
Figure 5. GSC 107858 from 87-CNA-KUD-2, scale bar = 182 µm.
Figure 6. GSC 107859 from QC-545, scale bar = 171 µm.
Figures 9, 10. GSC 107860 from 89-CNA-KUD-12, scale bar = 28 and 186 µm.

Figures 3, 4, 7, 8, 13
Praehexasaturnalis poultoni Whalen and Carter n. sp.
Species code: SAT02
Figure 3. GSC 107861 (holotype) from 89-CNA-KUD-5, scale bar = 187.5 µm.
Figure 4. GSC 107862 (paratype) from 87-CNA-KUD-2, scale bar = 183 µm.
Figure 7. GSC 107863 (paratype) from 89-CNA-KUD-12, scale bar = 133 µm.
Figure 8. GSC 107864 (paratype) from QC-543, scale bar = 150 µm.
Figure 13. GSC 107865 (paratype) from 87-CNA-KUD-2, scale bar = 136 µm.

Figures 11, 12, 15-17
Palaeosaturnalis liassicus Kozur and Mostler
Species code: SAT03
Figure 11. GSC 107866 from 87-CNA-KUD-2, scale bar = 187.5 µm.
Figure 12. GSC 107867 from 87-CNA-KUD-14, scale bar = 259 µm.
Figure 15. GSC 107868 from 87-CNA-KUD-14, scale bar = 258 µm.
Figure 16. GSC 107869 from QC-543, scale bar = 99 µm.
Figure 17. GSC 107870 from 89-CNA-KUD-11, scale bar = 176.5 µm.

Figure 14
Heliosaturnalis? sp. A
GSC 107871 from 86-OF-KUB-3, scale bar = 179 µm.

Figures 18, 22
Mesosaturnalis sp. aff. *M. artus* (Donofrio and Mostler)
Species code: SAT05
Figure 18. GSC 107872 from 86-OF-KUC-7, scale bar = 172.5 µm.
Figure 22. GSC 107873 from 86-OF-KUB-3, scale bar = 180 µm.

Figures 19, 23
Palaeosaturnalis prinevillensis (Blome)
Species code: SAT04
Figure 19. GSC 107874 from 89-CNA-KUD-12, scale bar = 178 µm.
Figure 23. GSC 107875 from 89-CNA-SKUD-34B, scale bar = 186 µm.

Figure 20
Pseudoheliodiscus yaoi Pessagno and Poisson
Species code: SAT07
GSC 107876 from 86-OF-KUA-6, scale bar = 174 µm.

Figures 21, 25
Kozurastrum sp. A
Species code: SAT08
Figure 21. GSC 107877 from 86-OF-KUC-7, scale bar = 172 µm.
Figure 25. GSC 107878 from QC-590A, scale bar = 133 µm.

Figure 24
Pseudacanthocircus sp. aff. *P. pseudosimplex* Kozur and Mostler
GSC 107879 from 87-CNA-KUD-2, scale bar = 185 µm.

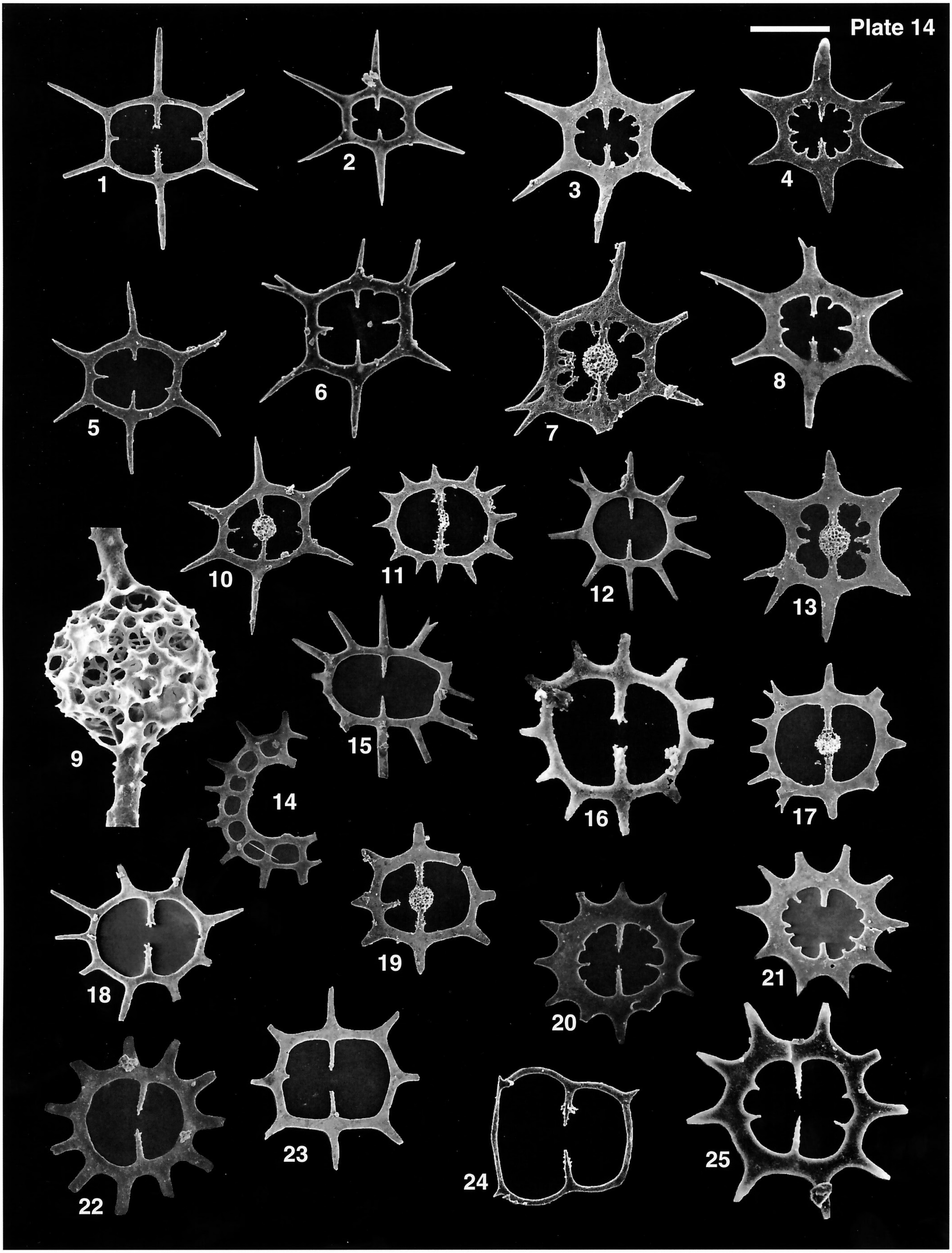
Plate 14
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PLATE 15

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figure 1
Bagotum helmetense Pessagno and Whalen
Species code: BAG02
USNM 307184 (original holotype) from QC-590A, scale bar = 55 μm.

Figure 2
Bagotum sp. B
GSC 107881 from QC-676, scale bar = 55 μm.

Figure 3
Bagotum sp. C
GSC 107882 from QC-677, scale bar = 60 μm.

Figure 4
Broctus kuensis Pessagno and Whalen
Species code: BRO02
USNM 307192 (original holotype) from QC-590A, scale bar = 62 μm.

Figure 5
Broctus selwynensis Pessagno and Whalen
Species code: BRO01
USNM 307190 (original holotype) from QC-590A, scale bar = 84 μm.

Figures 6, 10, 11, 15, 19
Canoptum columbiaense Whalen and Carter n. sp.
Species code: CAN08
Figure 6. GSC 107885 (holotype) from QC-676, scale bar = 72 μm.
Figures 10, 15. GSC 107886 (paratype) from QC-675, scale bar = 111 and 48 μm.
Figures 11, 19. GSC 107887 (paratype) from QC-675, scale bar = 108 and 40 μm.

Figures 7, 12, 13, 16, 17
Droltus firmus Whalen and Carter n. sp.
Species code: DRO04
Figures 7, 12. GSC 107888 (holotype) from QC-677, scale bar = 67 and 36 μm.
Figures 13, 16. GSC 107889 (paratype) from QC-677, scale bar = 63 and 38 μm.
Figure 17. GSC 107890 (paratype) from QC-677, scale bar = 38 μm.

Figure 8
Droltus laseekensis Pessagno and Whalen
Species code: DRO03
USNM 307196 (original holotype) from QC-590A, scale bar = 86 μm.

Figures 9, 18
Droltus fondrenensis Whalen and Carter n. sp.
Species code: DRO05
GSC 107892 (holotype) from QC-677, scale bar = 80 and 43 μm.

Figure 14
Droltus hecatensis Pessagno and Whalen
Species code: DRO02
GSC 107893 from QC-590A, scale bar = 72 μm.

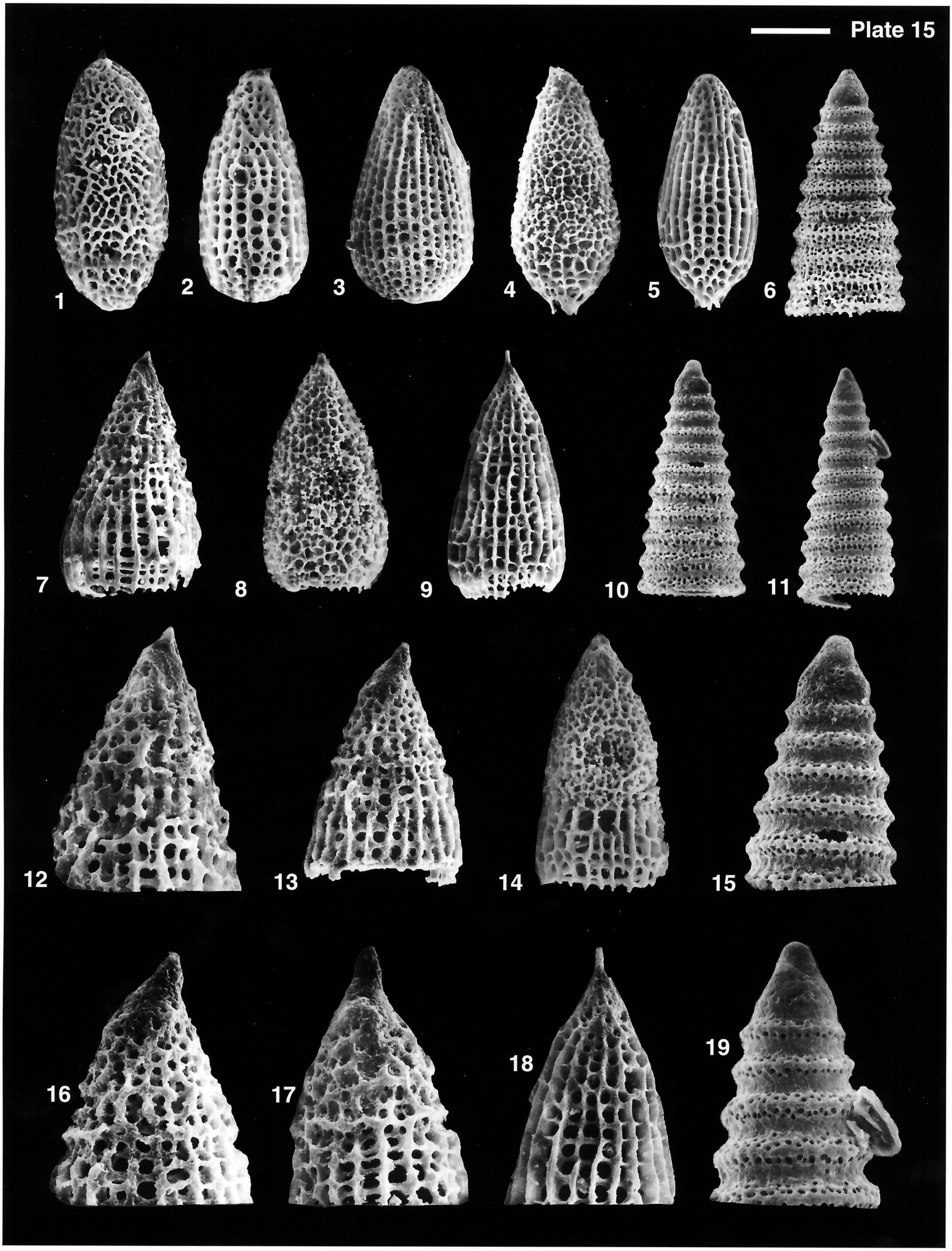
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PLATE 16

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figure 1
Bagotum sp. A
GSC 107894 from 89-CNA-KUA-6, scale bar = 130.5 μm.

Figure 2
Canoptum unicum Pessagno and Whalen
Species code: CAN10
GSC 107895 from 87-CNA-KPB-10, scale bar = 136 μm.

Figure 3
Canoptum merum Pessagno and Whalen
Species code: CAN06
USNM 307206 (original holotype) from QC-543, scale bar = 85.5 μm.

Figures 4, 5, 10, 11
Relanus reefensis Pessagno and Whalen
Species code: REL01
Figure 4. GSC 107897 from 87-CNA-KUD-4, scale bar = 136 μm.
Figure 5. USNM 307212 (original holotype) from QC-543, scale bar = 120 μm.
Figure 10. GSC 107899 from 89-CNA-SKUD-39, scale bar = 138 μm.
Figure 11. GSC 107900 from 90-CNA-KPD-5, scale bar = 76.5 μm.

Figure 6
Parahsuum simplum Yao
Species code: PHS01
GSC 107901 from 89-CNA-KUB-5, scale bar = 90 μm.

Figure 7
Canutus blomei Pessagno and Whalen
Species code: CTS04
GSC 107902 from 89-CNA-KUH-1, scale bar = 129 μm.

Figure 8
Bagotum erraticum Pessagno and Whalen
Species code: BAG01
USNM 307182 (original holotype) from QC-549, scale bar = 75 μm.

Figure 9
Droltus lyellensis Pessagno and Whalen
Species code: DRO06
USNM 307198 (original holotype) from QC-550, scale bar = 60 μm.

Figures 12, 13
Nitrader sp. A
Species code: NIT02
Figure 12. GSC 107905 from 89-CNA-KUD-5, scale bar = 134.5 μm.
Figure 13. GSC 107906 from 89-CNA-KUD-5, scale bar = 137 μm.

Figures 14, 15, 19-22
Haeckelicyrtium sp. A
Species code: HCK03
Figures 14, 19. GSC 107907 from QC-545, scale bar = 150 and 120 μm.
Figures 15, 20, 22. GSC 107908 from QC-545, scale bar = 150, 120, and 60 μm.
Figure 21. GSC 107909 from 89-CNA-KUA-3, scale bar = 173 μm.

Figure 16
Farcus sp. A.
Species code: FAR01
GSC 107910 from 86-OF-KUC-8, scale bar = 132 μm.

Figures 17, 18, 25
Nassellarian indet. A
Figure 17. GSC 108549 from 89-CNA-SKUD-34B, scale bar = 139.5 μm.
Figures 18, 25. GSC 108550 from 87-CNA-KUD-2, scale bar = 136 and 78.5 μm.

Figure 23
Spirillina orbicula Terquem and Berthelin
GSC 108551 from QC-674, scale bar = 66 μm.

Figure 24
Spirillina orbicula Terquem and Berthelin
GSC 108552 from 89-CNA-KUD-18, scale bar = 255 μm.

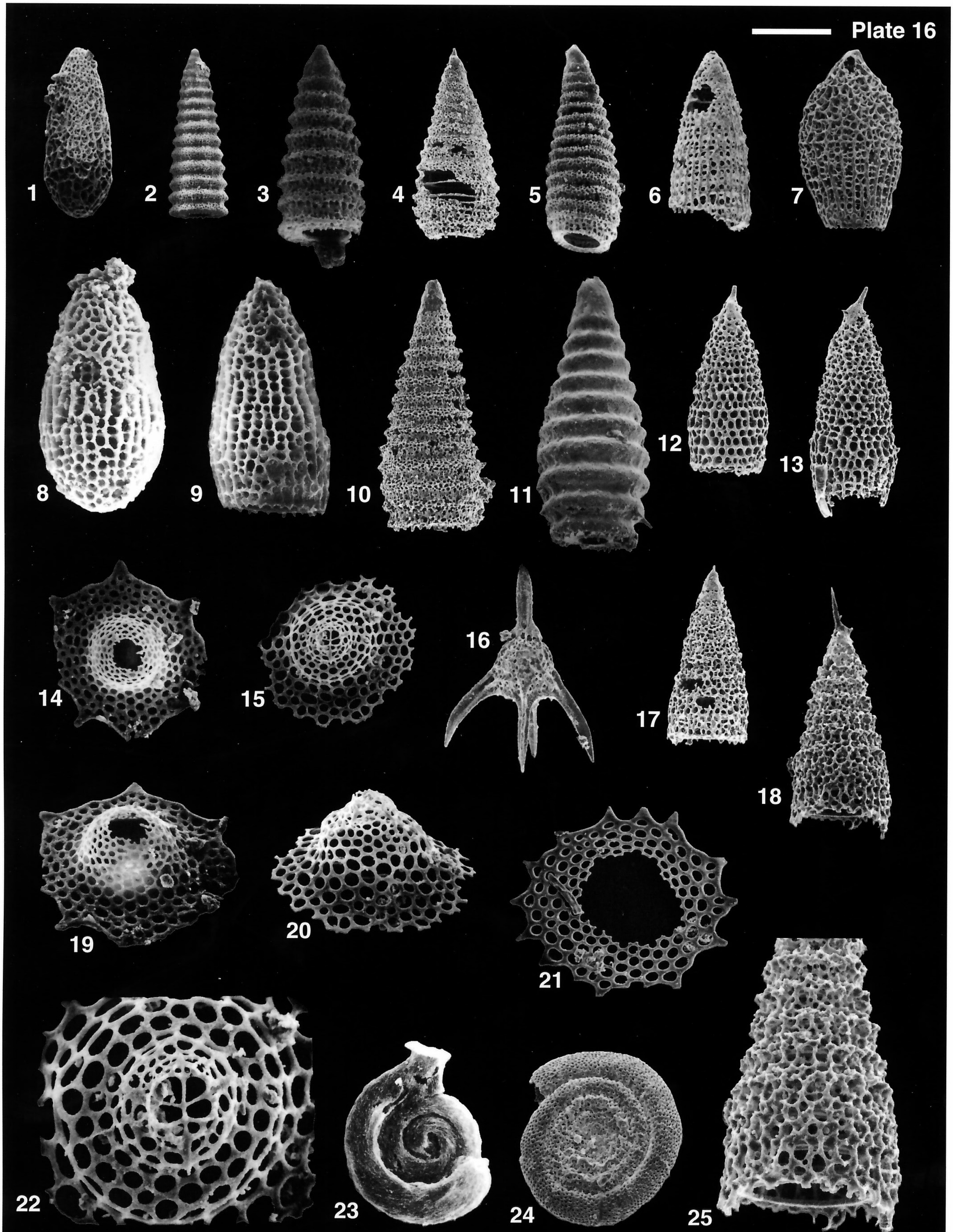
Plate 16
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PLATE 17

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figure 1
Canoptum dixoni Pessagno and Whalen
Species code: CAN09
GSC 108553 (specimen destroyed) from QC-590A, scale bar = 137 μm.

Figures 2, 3
Canoptum margaritaense Whalen and Carter n. sp.
Species code: CAN11
Figure 2. GSC 108554 (holotype) from QC-675, scale bar = 120 μm.
Figure 3. GSC 108555 (paratype) from QC-590A, scale bar = 96 μm.

Figure 4
Canoptum sp. A.
GSC 108556 from QC-568, scale bar = 94 μm.

Figures 5, 6
Wrangellium thurstonense Pessagno and Whalen
Species code: WNG01
Figure 5. GSC 108557 from QC-674, scale bar = 99 μm.
Figure 6. USNM 307214 (original holotype) from QC-590A, scale bar = 105 μm.

Figure 7
Saitoum sp. A
GSC 108559 from QC-575, scale bar = 81 μm.

Figures 8, 9, 12, 13, 16, 17
Saitoum coronarium Whalen and Carter n. sp.
Species code: SUM01
Figures 8, 12, 16. GSC 108560 (holotype) from QC-575, scale bar = 46, 30, and 30 μm.
Figures 9, 13, 17. GSC 108561 (paratype) from QC-575, scale bar = 46, 31.5, and 31.5 μm.

Figures 10, 11, 14, 15
Saitoum triumphense Whalen and Carter n. sp.
Species code: SUM02
Figures 10, 14. GSC 108562 (holotype) from QC-574, scale bar = 56 and 27.5 μm.
Figures 11, 15. GSC 108563 (paratype) from QC-575, scale bar = 46 and 31.5 μm.

Figure 18
Canutus rockfishensis Pessagno and Whalen
Species code: CTS03
USNM 307226 (original holotype) from QC-590A, scale bar = 69 μm.

Figure 19
Canutus sp. A
Species code: CTS05
GSC 108565 from QC-677, scale bar = 57 μm.

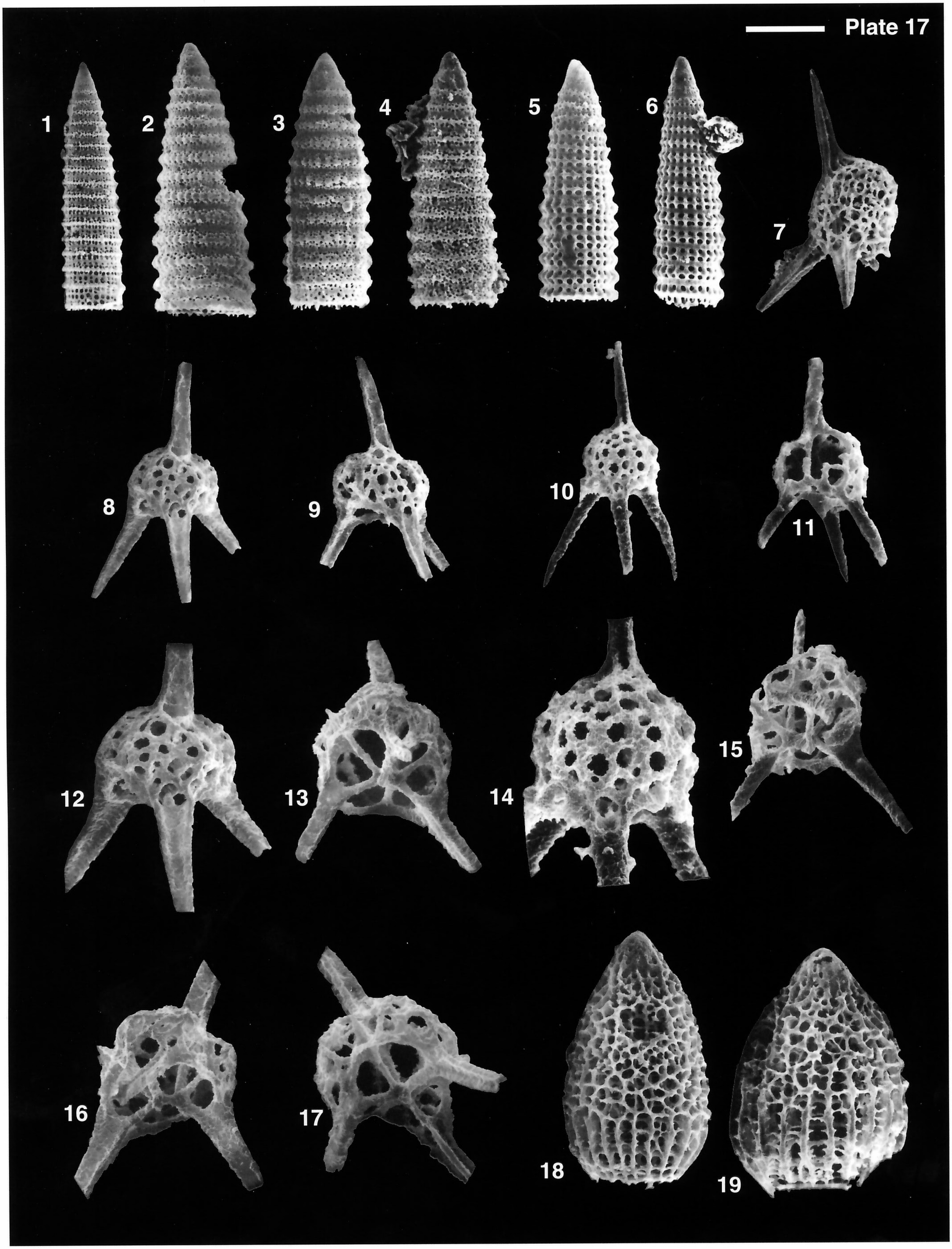
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PLATE 18

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figure 1
Pseudoeucyrtis sp. A
GSC 108566 from QC-571B, scale bar = 142.5 μm.

Figures 2-5
Protokatroma sp. aff. *P. aquila* Whalen and Carter n. sp.
Figure 2. GSC 108567 from QC-568, scale bar = 102 μm.
Figure 3. GSC 108568 from 89-CNA-SKUD-34A, scale bar = 136 μm.
Figure 4. GSC 108569 from 89-CNA-KUD-11, scale bar = 138 μm.
Figure 5. GSC 108570 from 89-CNA-KUD-12, scale bar = 133 μm.

Figures 6-8, 15
Protokatroma aquila Whalen and Carter n. sp.
Species code: PTK01
Figure 6. GSC 108571 (holotype) from 89-CNA-SKUD-34B, scale bar = 136 μm.
Figure 7. GSC 108572 (paratype) from 87-CNA-KUD-2, scale bar = 135.5 μm.
Figures 8, 15. GSC 108573 (paratype) from QC-568, scale bar = 66 and 69 μm.

Figures 9-12, 16
Pseudoeucyrtis angusta Whalen and Carter n. sp.
Species code: PSE02
Figures 9, 16. GSC 108574 (paratype) from QC-574, scale bar = 126 and 39 μm.
Figure 10. GSC 108575 (holotype) from 89-CNA-KUD-16, scale bar = 172.5 μm.
Figure 11. GSC 108576 (paratype) from QC-575, scale bar = 126 μm.
Figure 12. GSC 108577 (paratype) from 87-CNA-KPB-10, scale bar = 136 μm.

Figures 13, 14, 17-19, 27
Jacus? *anatiformis* De Wever
Species code: JAC02
Figure 13. GSC 108578 from QC-575, scale bar = 57 μm.
Figures 14, 19. GSC 108579 from QC-575, scale bar = 46.5 and 37.5 μm.
Figures 17, 27. GSC 108580 from QC-575, scale bar = 61.5 and 31.5 μm.
Figure 18. GSC 108581 from QC-675, scale bar = 52.5 μm.

Figures 20, 26
Napora sp. A
Figure 20. GSC 108582 from QC-575, scale bar = 63 μm.
Figure 26. GSC 108583 from QC-575, scale bar = 43.5 μm.

Figures 21, 25
Napora sp. B
GSC 108584 from QC-675, scale bar = 72 and 40.5 μm.

Figures 22-24, 28, 29
Protokatroma sp. A
Species code: PTK03
Figure 22. GSC 108585 from QC-571B, scale bar = 139.5 μm.
Figure 23. GSC 108586 from 87-CNA-KUD-9, scale bar = 130.5 μm.
Figure 24. GSC 108587 from 89-CNA-KUD-18, scale bar = 130.5 μm.
Figures 28, 29. GSC 108588 from QC-575, scale bar = 114 and 60 μm.

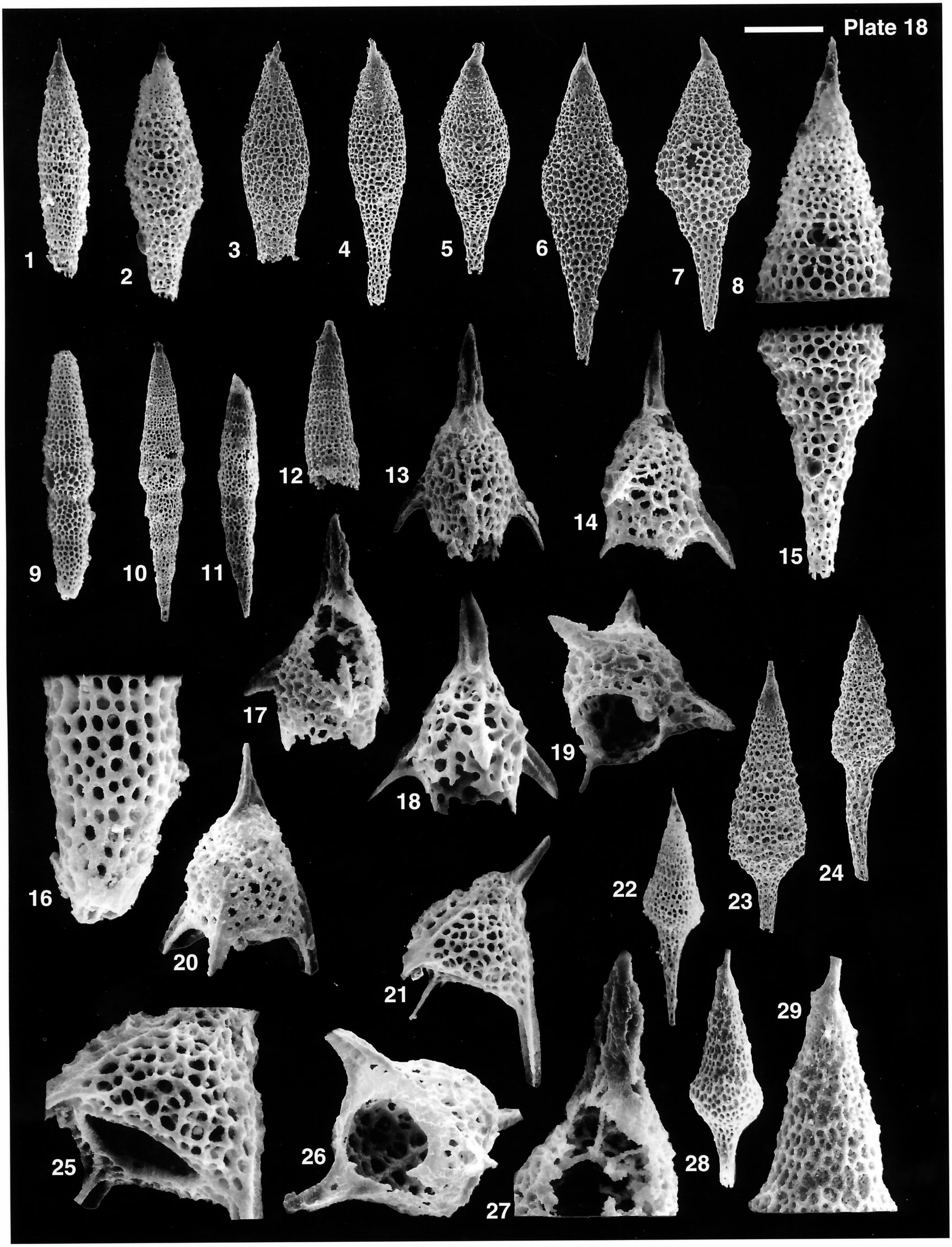
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PLATE 19

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 8, 12, 16
Katroma inflatio Whalen and Carter n. sp.
Species code: KAT05
Figures 1, 12. GSC 108589 (holotype) from QC-676, scale bar = 93 and 42 μm.
Figures 8, 16. GSC 108590 (paratype) from QC-676, scale bar = 126 and 44 μm.

Figures 2, 9, 13, 17
Katroma pinquitudo Whalen and Carter n. sp.
Species code: KAT03
Figures 2, 13. GSC 108591 (holotype) from QC-677, scale bar = 100 and 46 μm.
Figures 9, 17. GSC 108592 (paratype) from QC-677, scale bar = 74 and 38 μm.

Figures 3-6, 10, 14, 18
Katroma irvingi Whalen and Carter n. sp.
Species code: KAT04
Figures 3, 10. GSC 108596 (paratype) from QC-674, scale bar = 150 and 50 μm.
Figure 4. GSC 108595 (paratype) from QC-674, scale bar = 126 μm.
Figures 5, 14. GSC 108593 (holotype) from QC-676, scale bar = 120 and 42 μm.
Figures 6, 18. GSC 108594 (paratype) from QC-676, scale bar = 167 and 59 μm.

Figures 7, 15
Katroma regina Whalen and Carter n. sp.
Species code: KAT02
GSC 108598 (paratype) from QC-677, scale bar = 75 and 38 μm.

Figures 11, 19
Katroma sp. aff. *K. irvingi* Whalen and Carter n. sp.
GSC 108597 from QC-676, scale bar = 93 and 42 μm.

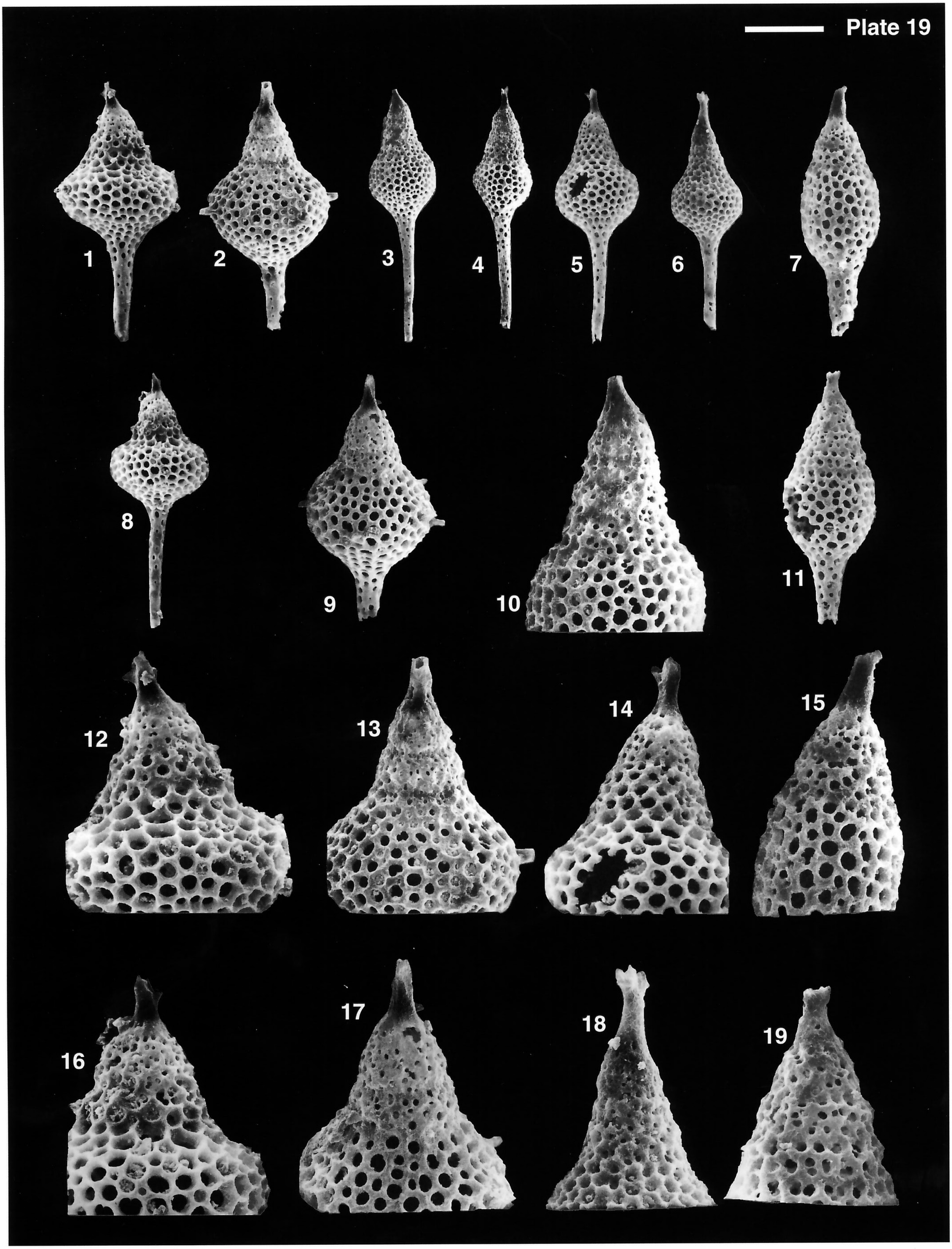
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PLATE 20

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 2, 13
Katroma regina Whalen and Carter n. sp.
Species code: KATK02
Figure 1. GSC 108599 (holotype) from QC-590A, scale bar = 100 μm.
Figures 2, 13. GSC 108600 (paratype) from QC-590A, scale bar = 86 and 50 μm.

Figures 3-5, 16-18
Katroma westermanni Whalen and Carter n. sp.
Species code: KAT06
Figures 3, 16. GSC 108601 (holotype) from QC-676, scale bar = 102 and 42 μm.
Figures 4, 17. GSC 108602 (paratype) from QC-676, scale bar = 102 and 44 μm.
Figures 5, 18. GSC 108603 (paratype) from QC-676, scale bar = 150 and 44 μm.

Figures 6, 15
Teesium sp. A.
GSC 108607 from QC-675, scale bar = 86 and 46 μm.

Figures 7-12, 14
Teesium insignitum Whalen and Carter n. sp.
Species code: TES01
Figures 7, 8, 12. GSC 108604 (holotype) from QC-675, scale bar = 89, 55, and 40 μm.
Figures 9, 14. GSC 108605 (paratype) from QC-675, scale bar = 60 and 31. 5 μm.
Figures 10, 11. GSC 108606 (paratype) from QC-675. scale bar = 46 and 43 μm.

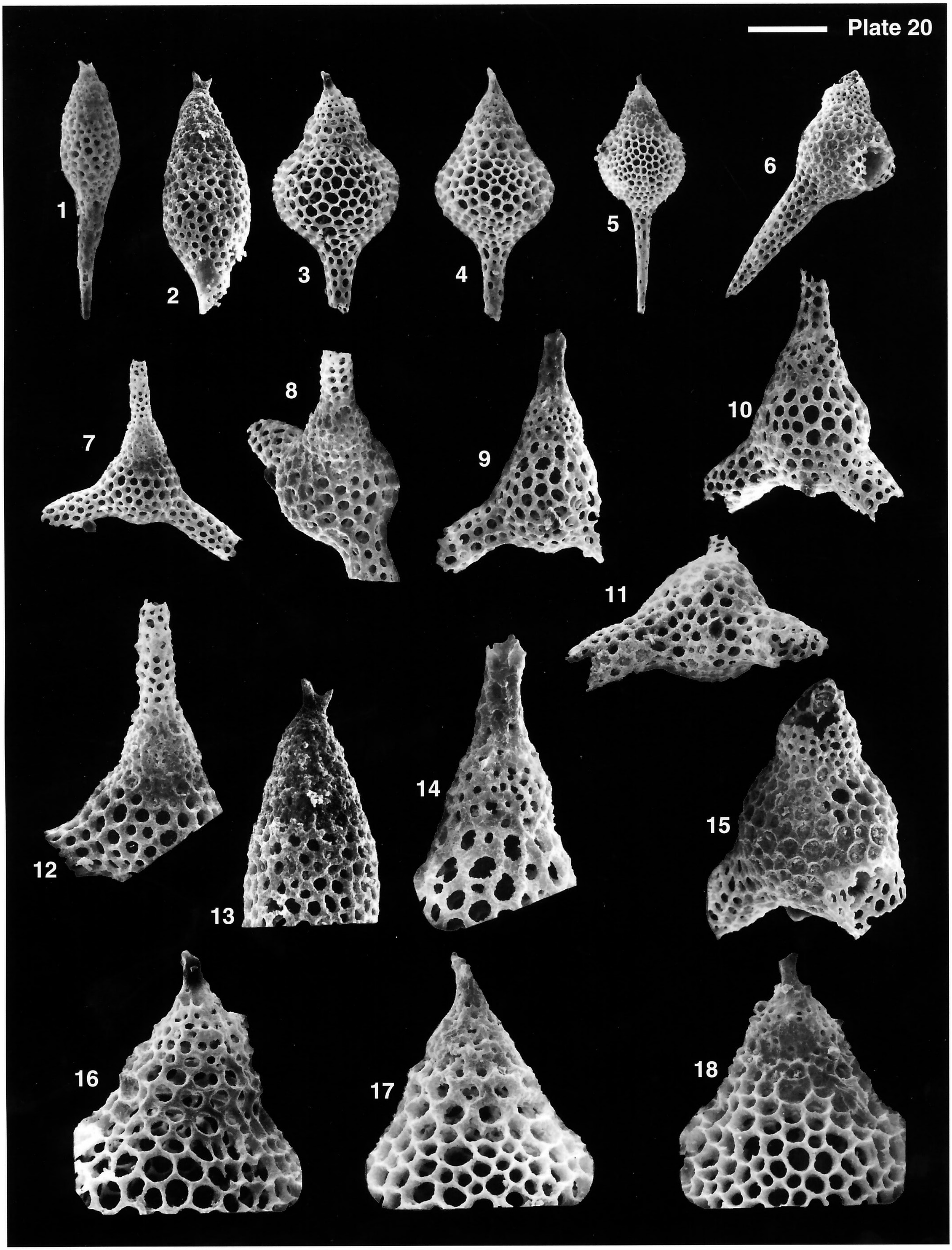
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PLATE 21

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 2, 11
Ares moresbyensis Whalen and Carter n. sp.
Species code: ARS01
Figures 1, 11. GSC 108608 (holotype) from QC-675, scale bar = 86 and 50 μm.
Figure 2. GSC 108609 (paratype) from QC-674, scale bar = 75 μm.

Figures 3, 16
Ares sutherlandi Whalen and Carter n. sp.
Species code: ARS02
GSC 108610 (holotype) from QC-675, scale bar = 72 and 42 μm.

Figure 4
Napora? *graybayensis* Pessagno, Whalen and Yeh
Species code: NAP01
USNM 379327 (original holotype) from QC-675, scale bar = 48 μm.

Figures 5, 6, 12, 14, 15
Bipedis hannai Whalen and Carter n. sp.
Species code: BPD07
Figures 5, 14. GSC 108612 (paratype) from QC-574, scale bar = 74 and 36 μm.
Figures 6, 15. GSC 108613 (paratype) from QC-575, scale bar = 89 and 50 μm.
Figure 12. GSC 108614 (paratype) from QC-574, scale bar = 59 μm.

Figures 7-10, 13, 17
Bipedis diadema Whalen and Carter n. sp.
Species code: BPD05
Figures 7, 17. GSC 108615 (holotype) from QC-675, scale bar = 63 and 36 μm.
Figure 8. GSC 108616 (paratype) from QC-675, scale bar = 60 μm.
Figure 9. GSC 108617 (paratype) from QC-675, scale bar = 50 μm.
Figures 10, 13. GSC 108618 (paratype) from QC-677, scale bar = 46 and 33 μm.

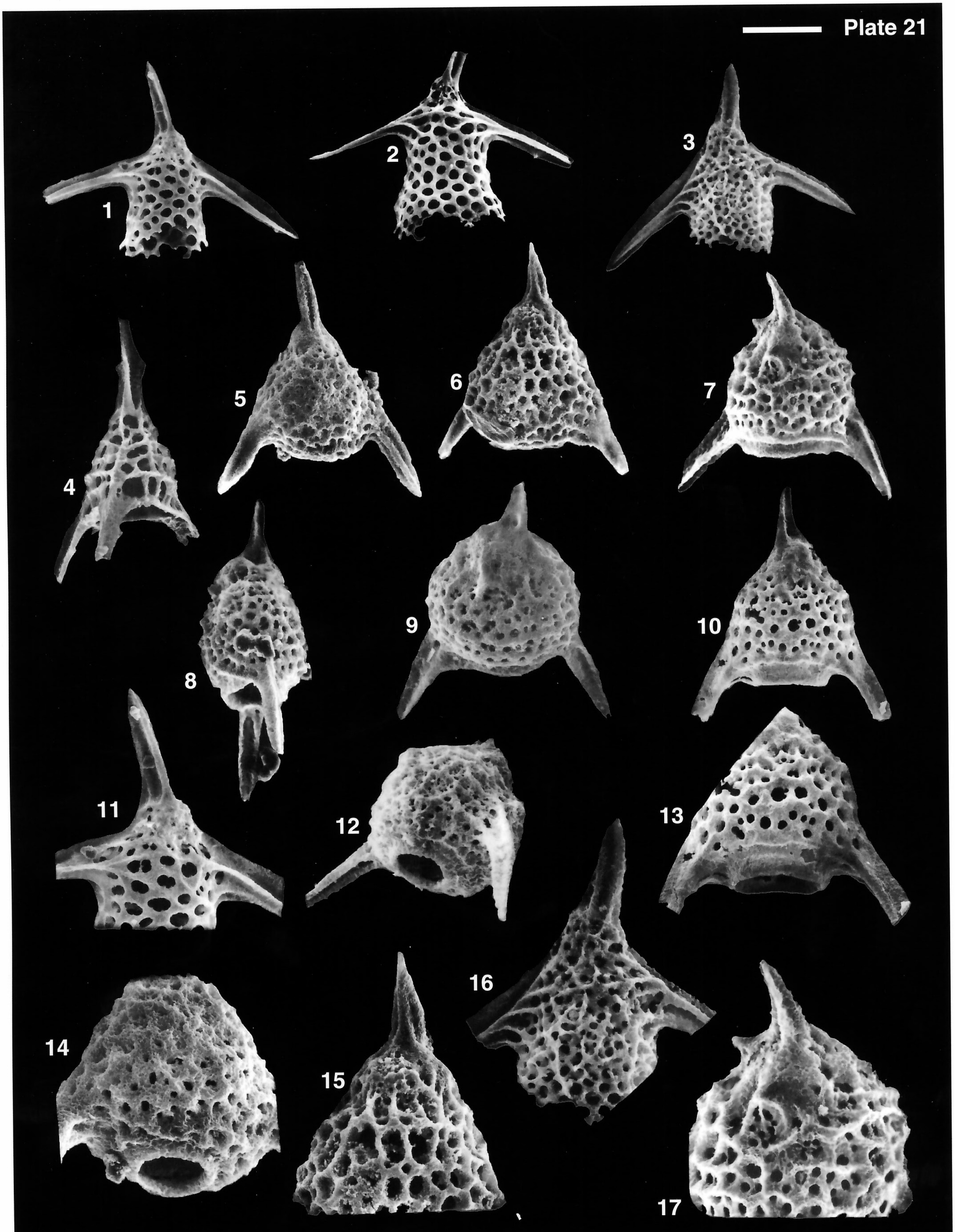
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PLATE 22

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figure 1
Bipedis diadema Whalen and Carter n. sp.
Species code: BPD05
GSC 108619 (paratype) from QC-677, scale bar = 57 μm.

Figures 2, 3, 5, 6, 9-11, 14, 15
Bipedis hannai Whalen and Carter n. sp.
Species code: BPD07
Figures 2, 6. GSC 108620 (paratype) from QC-543, scale bar = 100 and 67 μm.
Figures 3, 11, 15. GSC 108621 (paratype) from QC-575, scale bar = 75, 43, and 50 μm.
Figures 5, 9, 10, 14. GSC 108622 (holotype) from QC-571B, scale bar = 80, 72, 38, and 60 μm.

Figures 4, 7, 8, 12, 13, 16
Bipedis hiberniaensis Whalen and Carter n. sp.
Species code: BPD08
Figures 4, 13, 16. GSC 108623 (holotype) from QC-574, scale bar = 65, 38, and 33 μm.
Figures 7, 12. GSC 108624 (paratype) from QC-574, scale bar = 69 and 33 μm.
Figure 8. GSC 108625 (paratype) from QC-574, scale bar = 75 μm.

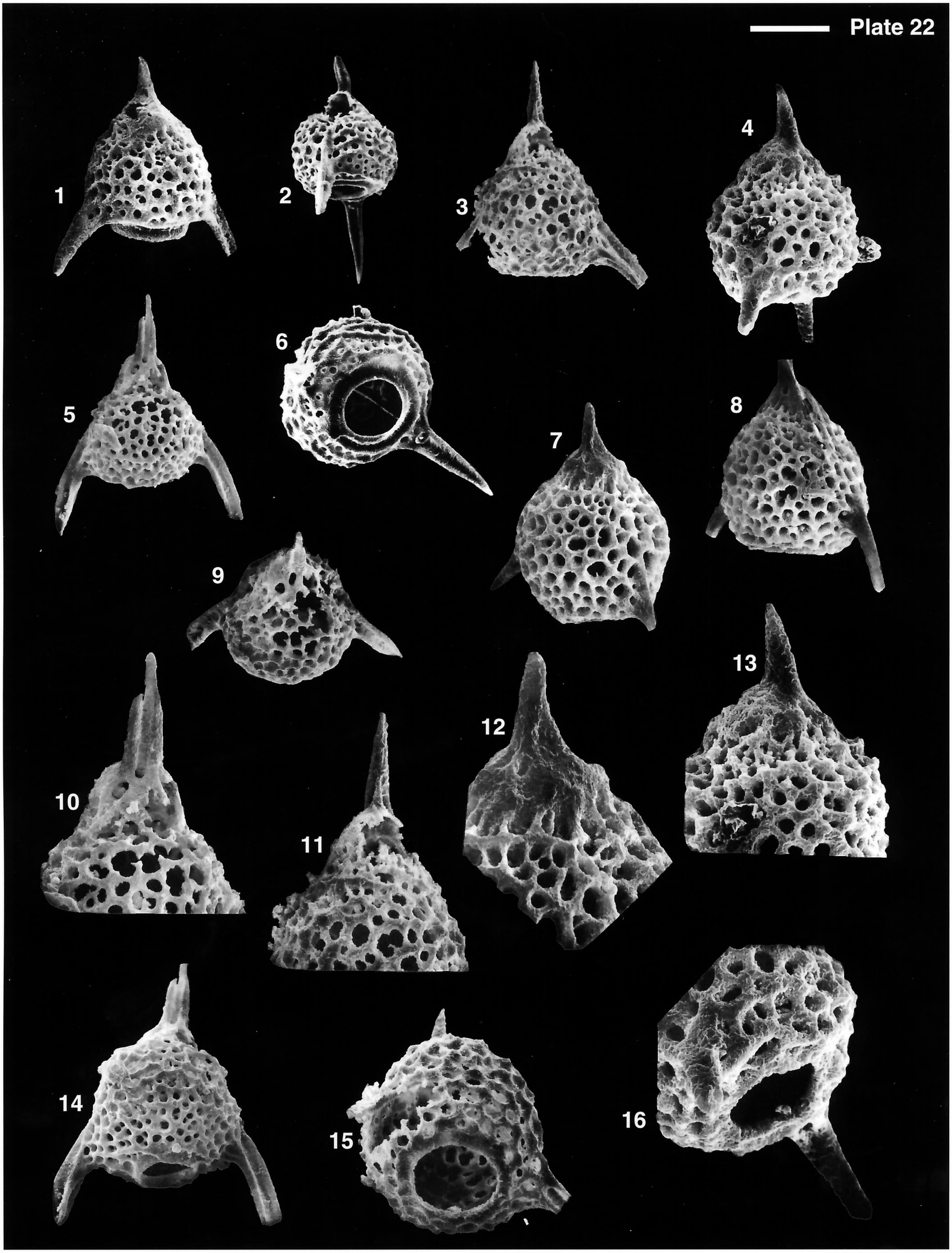
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PLATE 23

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 5, 9, 10-12
Bipedis douglasi Whalen and Carter n. sp.
Species code: BPD06
Figures 1, 5, 9. GSC 108626 (holotype) from QC-676, scale bar = 108, 48, and 48 μm.
Figures 10, 11, 12. GSC 108627 (paratype) from QC-677, scale bar = 47, 93, and 38 μm.

Figures 2, 3, 14, 15
Bipedis helenae Whalen and Carter n. sp.
Species code: BPD09
Figures 2, 14, 15. GSC 108628 (holotype) from QC-677, scale bar = 84, 36, and 24 μm.
Figure 3. GSC 108629 (paratype) from QC-677, scale bar = 89 μm.

Figures 4, 8, 13, 16
Bipedis rotundus Whalen and Carter n. sp.
Species code: BPD11
GSC 108630 (holotype) from QC-674, scale bar = 100, 43, 55, and 46 μm.

Figures 6, 7
Bipedis patricki Whalen and Carter n. sp.
Species code: BPD12
Figure 6. GSC 108631 (paratype) from QC-676, scale bar = 111 μm.
Figure 7. GSC 108632 (paratype) from QC-676, scale bar = 108 μm.

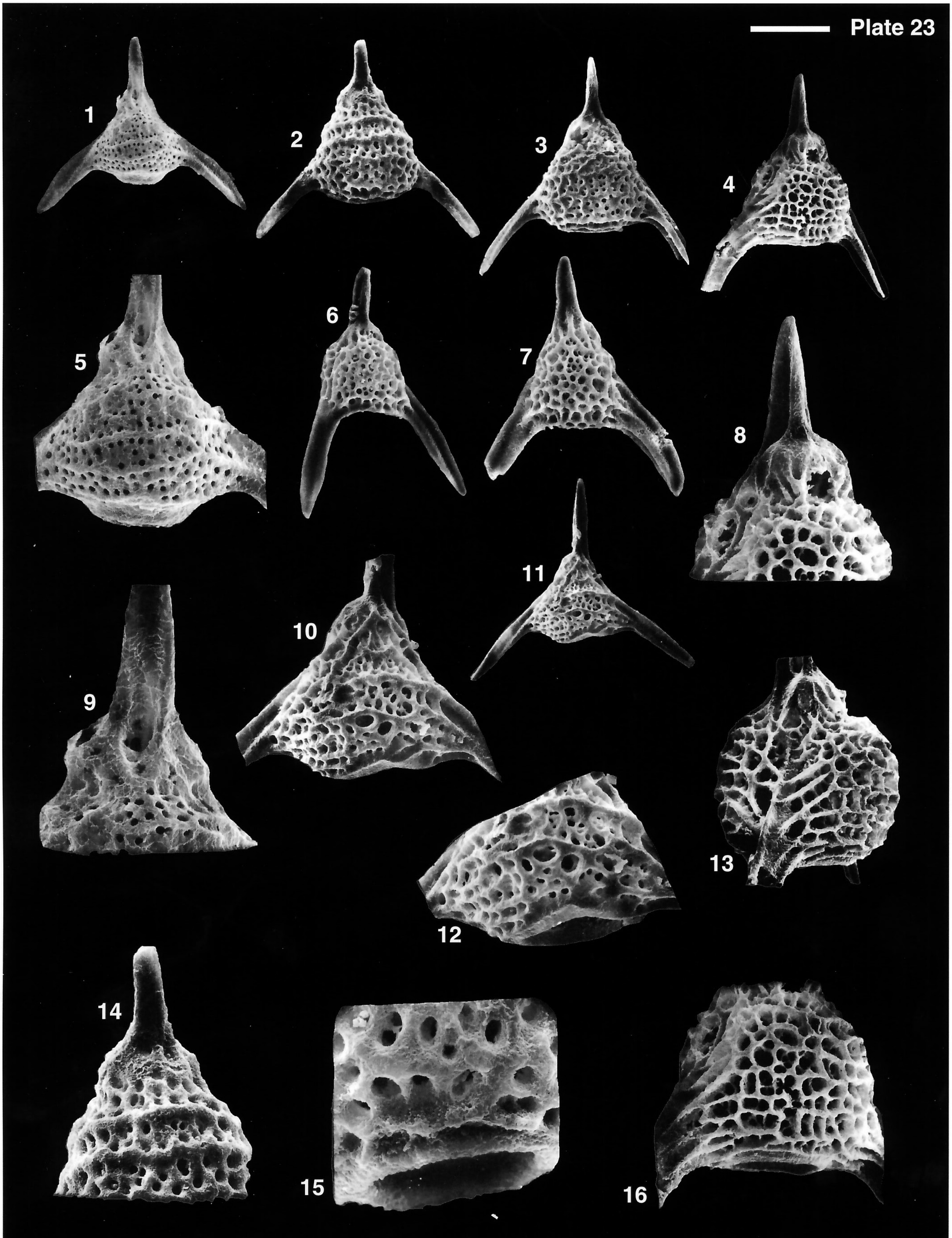
Plate 23
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PLATE 24

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1-3
Bipedis elizabethae Whalen and Carter n. sp.
Species code: BPD03
Figure 1. GSC 108633 (holotype) from 87-CNA-KUD-4, scale bar = 109 μm.
Figure 2. GSC 108634 (paratype) from 89-CNA-SKUD-31, scale bar = 107 μm.
Figure 3. GSC 108635 (paratype) from 89-CNA-SKUD-36, scale bar = 112 μm.

Figures 4, 5, 10
Bipedis patricki Whalen and Carter n. sp.
Species code: BPD12
Figure 4. GSC 108636 (holotype) from 86-OF-KUB-3, scale bar = 128 μm.
Figure 5. GSC 108637 (paratype) from 89-CNA-KUA-3, scale bar = 136 μm.
Figure 10. GSC 108638 (paratype) from 86-OF-KUC-6, scale bar = 132 μm.

Figures 6, 7
Nitrader montegufonensis Cordey and Carter
Species code: NIT01
Figure 6. GSC 108639 from QC-574, scale bar = 99 μm.
Figure 7. GSC 110657 (original holotype) from 89-CNA-KUD-17, scale bar = 100 μm.

Figures 8, 9
Atalanta epaphrodita Cordey and Carter
Species code: ATA01
Figure 8. GSC 110659 (original holotype) from 87-CNA-KUD-10, scale bar = 100 μm.
Figure 9. GSC 110661 from 87-CNA-KUD-4, scale bar = 100 μm.

Figures 11, 12, 16, 22, 23
Trexus dodgensis Whalen and Carter n. sp.
Species code: TRX01
Figure 11. GSC 108644 (paratype) from QC-676, scale bar = 63 μm.
Figure 12. GSC 108645 (paratype) from QC-574, scale bar = 99 μm.
Figure 16. GSC 108646 (holotype) from QC-574, scale bar = 69 μm.
Figures 22, 23. GSC 108647 (paratype) from QC-575, scale bar = 51 and 99 μm.

Figure 13
Atalanta emmela Cordey and Carter
Species code: ATA02
GSC 110656 (original holotype) from 86-OF-KUB-3, scale bar = 100 μm.

Figures 14, 15, 18-21, 24-26
Foremania sandilandsensis Whalen and Carter n. sp.
Species code: FRM01
Figure 14. GSC 108649 (paratype) from QC-590A, scale bar = 72 μm.
Figure 15. GSC 108650 (paratype) from QC-674, scale bar = 84 μm.
Figures 18, 24. GSC 108651 (paratype) from QC-674, scale bar = 85.5 and 43.5 μm.
Figures 19, 25. GSC 108652 (paratype) from QC-677, scale bar = 74.5 and 37.5 μm.
Figures 20, 21, 26. GSC 108654 (holotype) from QC-590A, scale bar = 46.5, 60, and 60 μm.

Figure 17
Trexus sp. A.
GSC 108648 from 87-CNA-KUD-2, scale bar = 135 μm.

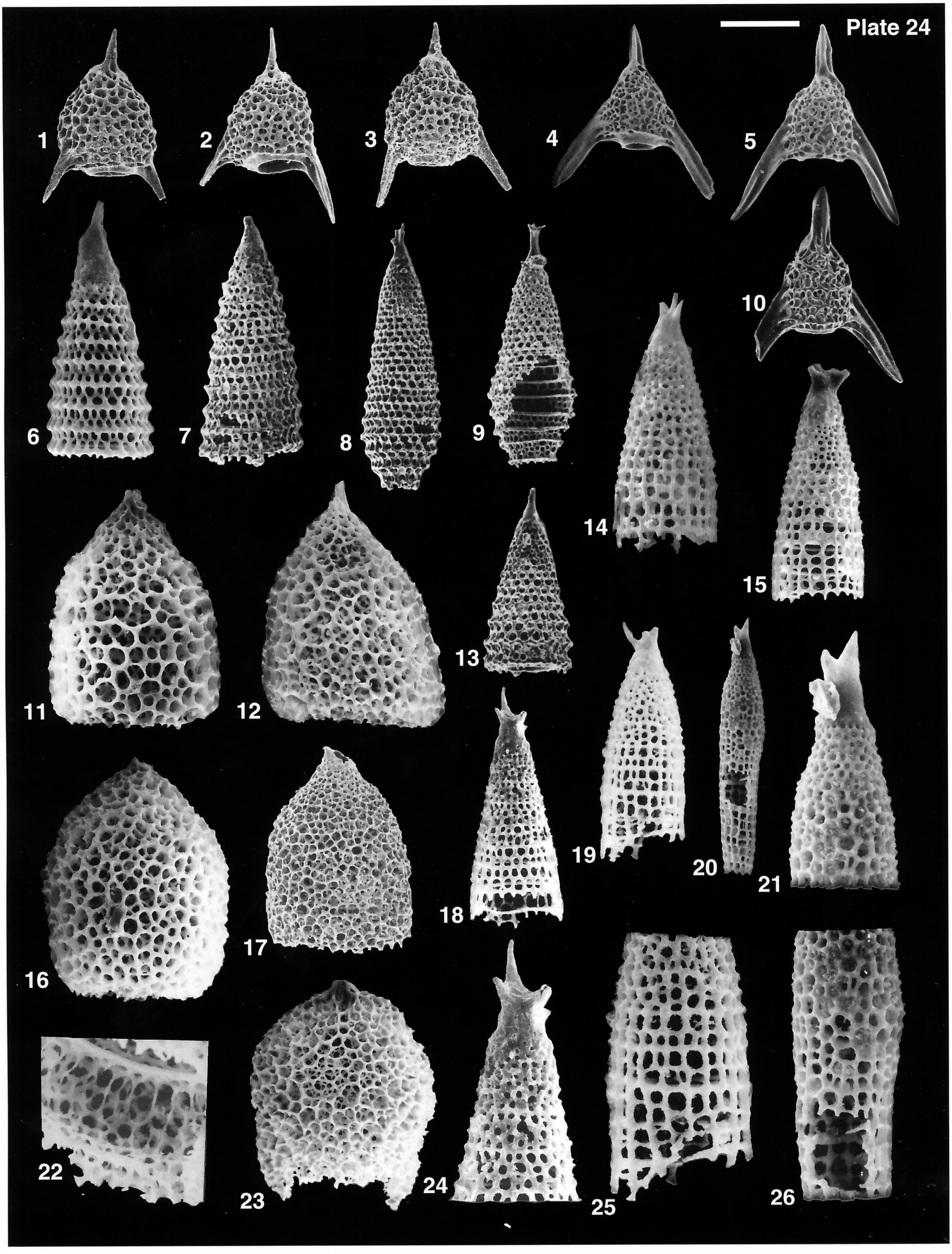
Plate 24
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PLATE 25

All figures are scanning electron micrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Length of scale bar in upper right = number of micrometres (μm) cited for each illustration.

Figures 1, 9, 15, 21
Solidea hillhousei Whalen and Carter n. sp.
Species code: SOL01
Figure 1. GSC 108655 (paratype) from QC-677, scale bar = 55 μm.
Figures 9, 15, 21. GSC 108656 (holotype) from QC-677, scale bar = 67, 31.5, and 31.5 μm.

Figures 2-4, 10, 11, 16, 22, 23
Pseudoeucyrtis fullerensis Whalen and Carter n. sp.
Species code: PSE01
Figures 2, 10, 16, 22. GSC 108657 (holotype) from QC-543, scale bar = 200, 75, 75, and 75 μm.
Figures 3, 23. GSC 108658 (paratype) from QC-543, scale bar = 200 and 75 μm.
Figures 4, 11. GSC 108659 (paratype) from QC-568, scale bar = 114 and 60 μm.

Figures 5, 12
Pseudoeucyrtis sp. B
GSC 108660 from QC-568, scale bar = 105 and 55 μm.

Figures 6-8, 13, 14, 24, 25
Laxtorum hemingense Whalen and Carter n. sp.
Species code: LAX06
Figures 6, 13, 24. GSC 108661 (holotype) from QC-549, scale bar = 86, 50, and 50 μm.
Figure 7. GSC 108662 (paratype) from QC-549, scale bar = 86 μm.
Figure 8. GSC 108663 (paratype) from QC-674, scale bar = 81 μm.
Figure 14. GSC 108664 (paratype) from QC-590A, scale bar = 86 μm.
Figure 25. GSC 108665 (paratype) from QC-590A, scale bar = 72 μm.

Figure 17
Laxtorum sp. A
GSC 108666 from QC-568, scale bar = 81 μm.

Figures 18-20
Laxtorum sp. B
Figure 18. GSC 108668 from 87-CNA-KUD-4, scale bar = 136.5 μm.
Figure 19. GSC 108667 from QC-568, scale bar = 93 μm.
Figure 20. GSC 108669 from QC-568, scale bar = 85.5 μm.

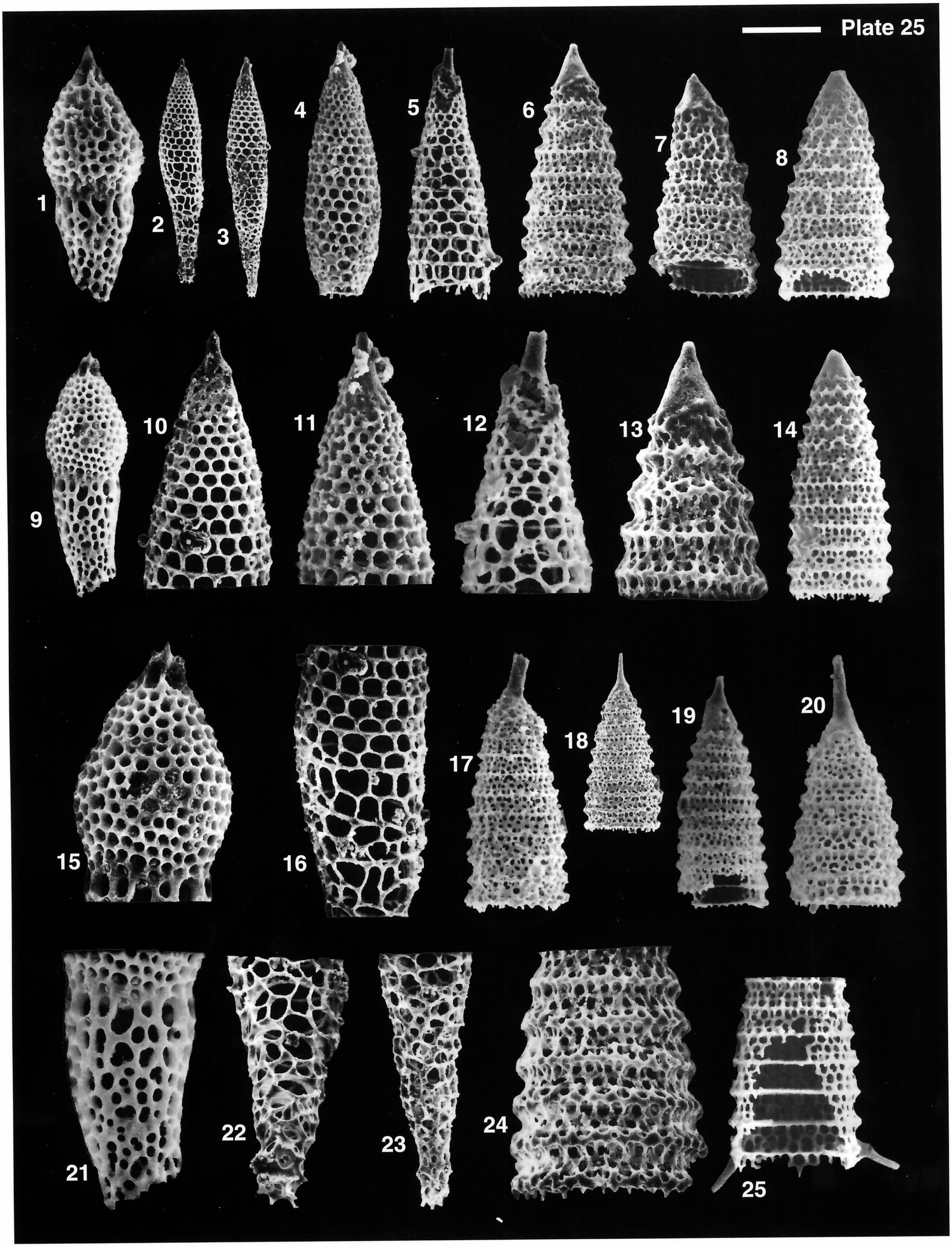
Plate 25
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PLATE 26

All figures are transmitted light photomicrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Please note that all length measurements include the horn, when a horn is present.

Figure 1
Bagotum helmetense Pessagno and Whalen
Species code: BAG02
Paratype (Pessagno Collection) from QC-590A. Length = 150 μm.

Figure 2
Broctus kuensis Pessagno and Whalen
Species code: BRO02
Paratype (USNM 307193) from QC-590A. Length = 190 μm.

Figure 3
Broctus selwynensis Pessagno and Whalen
Species code: BRO01
Paratype (USNM 307191) from QC-590A. Length = 260 μm.

Figure 4
Droltus laseekensis Pessagno and Whalen
Species code: DRO03
Paratype (USNM 307197) from QC-590A. Length = 280 μm.

Figure 5
Canoptum dixoni Pessagno and Whalen
Species code: CAN09
Paratype (USNM 307205) from QC-590A. Length = 360 μm.

Figure 6
Relanus reefensis Pessagno and Whalen
Species code: REL01
Paratype (USNM 307213) from QC-545. Length = 320 μm.

Figure 7
Wrangellium thurstonense Pessagno and Whalen
Species code: WNG01
Paratype (USNM 307215) from QC-590A. Length = 250 μm.

Figure 8
Canutus rockfishensis Pessagno and Whalen
Species code: CTS03
Paratype (USNM 307227) from QC-590A. Length = 252 μm.

Figures 9, 15
Katroma pinquitudo Whalen and Carter n. sp.
Species code: KAT03
Paratype (Whalen Collection) from QC-677. Figure 9, length = 300 μm.

Figures 10, 16
Katroma westermanni Whalen and Carter n. sp.
Species code: KAT06
Paratype (Whalen Collection) from QC-676. Length = 268 μm.

Figures 11, 17, 20
Katroma regina Whalen and Carter n. sp.
Species code: KAT02
Paratype (Whalen Collection) from QC-590A. Figure 11, length = 288 μm.

Figures 12-14, 18, 19, 21
Katroma irvingi Whalen and Carter n. sp.
Species code: KAT04
Figures 12, 21. Paratype (Whalen Collection) from QC-676. Specimen length = 308 μm.
Figures 13, 18. Paratype (Whalen Collection) from QC-676. Specimen length = 396 μm.
Figures 14, 19. Paratype (Whalen Collection) from QC-676. Specimen length = 368 μm.

Plate 26

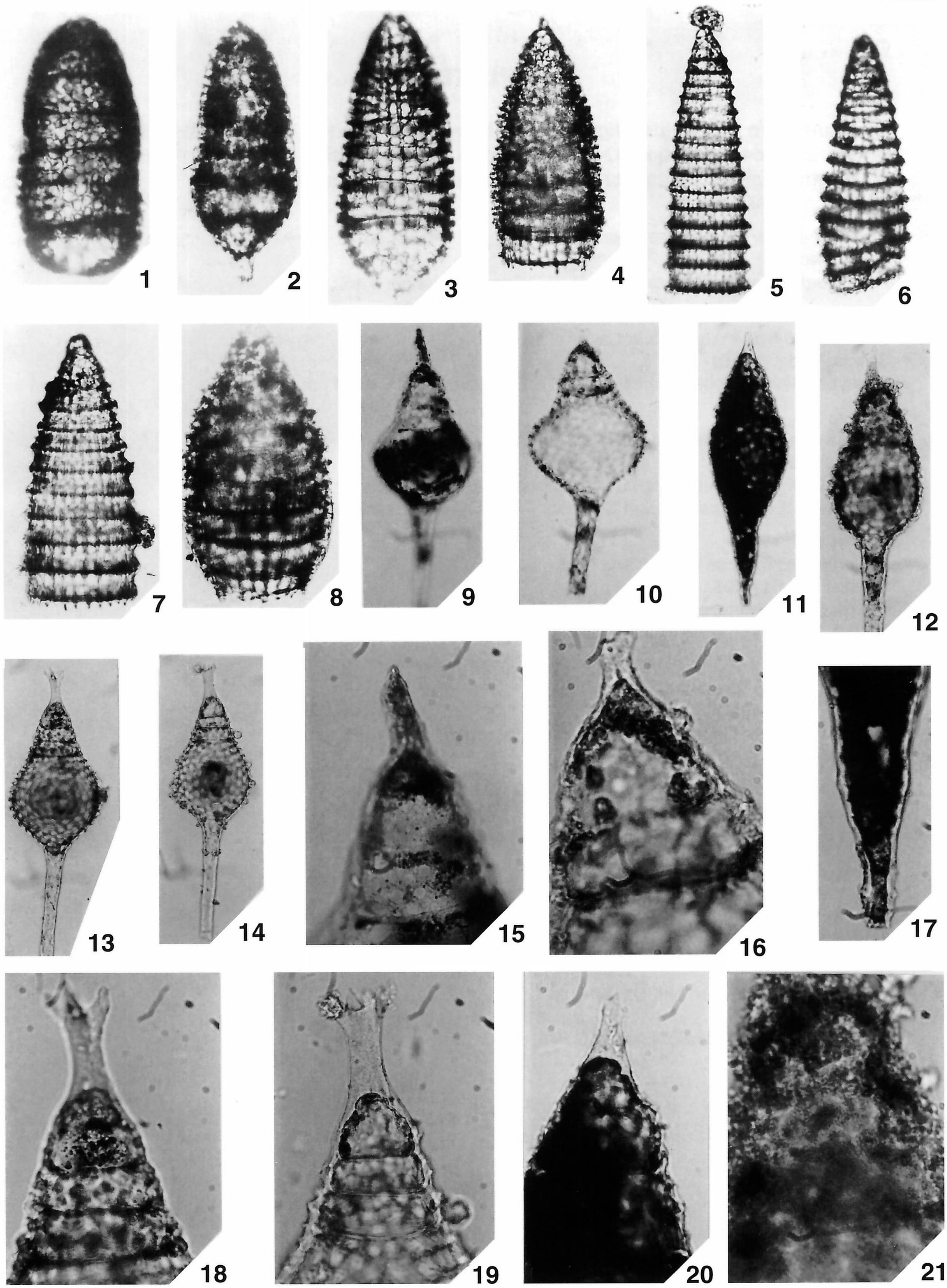


PLATE 27

All figures are transmitted light photomicrographs of early Jurassic Nassellariina from the Sandilands Formation, Queen Charlotte Islands, British Columbia. Please note that all length measurements include the horn, when a horn is present.

Figures 1, 7
Ares sutherlandi Whalen and Carter n. sp.
Species code: ARS02
Paratype (Whalen Collection) from QC-675. Specimen length = 152 μm.

Figures 2, 8
Ares moresbyensis Whalen and Carter n. sp.
Species code: ARS01
Paratype (Whalen Collection) from QC-675. Specimen length = 144 μm.

Figures 3, 4, 9, 10
Solidea hillhousei Whalen and Carter n. sp.
Species code: SOL01
Figures 3, 9. Paratype (Whalen Collection) from QC-677. Specimen length = 112 μm.
Figures 4, 10. Paratype (Whalen Collection) from QC-677. Specimen length = 132 μm.

Figures 5, 6, 16, 20
Laxtorum hemingense Whalen and Carter n. sp.
Species code: LAX06
Figures 5, 16. Paratype (Whalen Collection) from QC-590A. Specimen length = 188 μm.
Figures 6, 20. Paratype (Whalen Collection) from QC-590A. Specimen length = 212 μm.

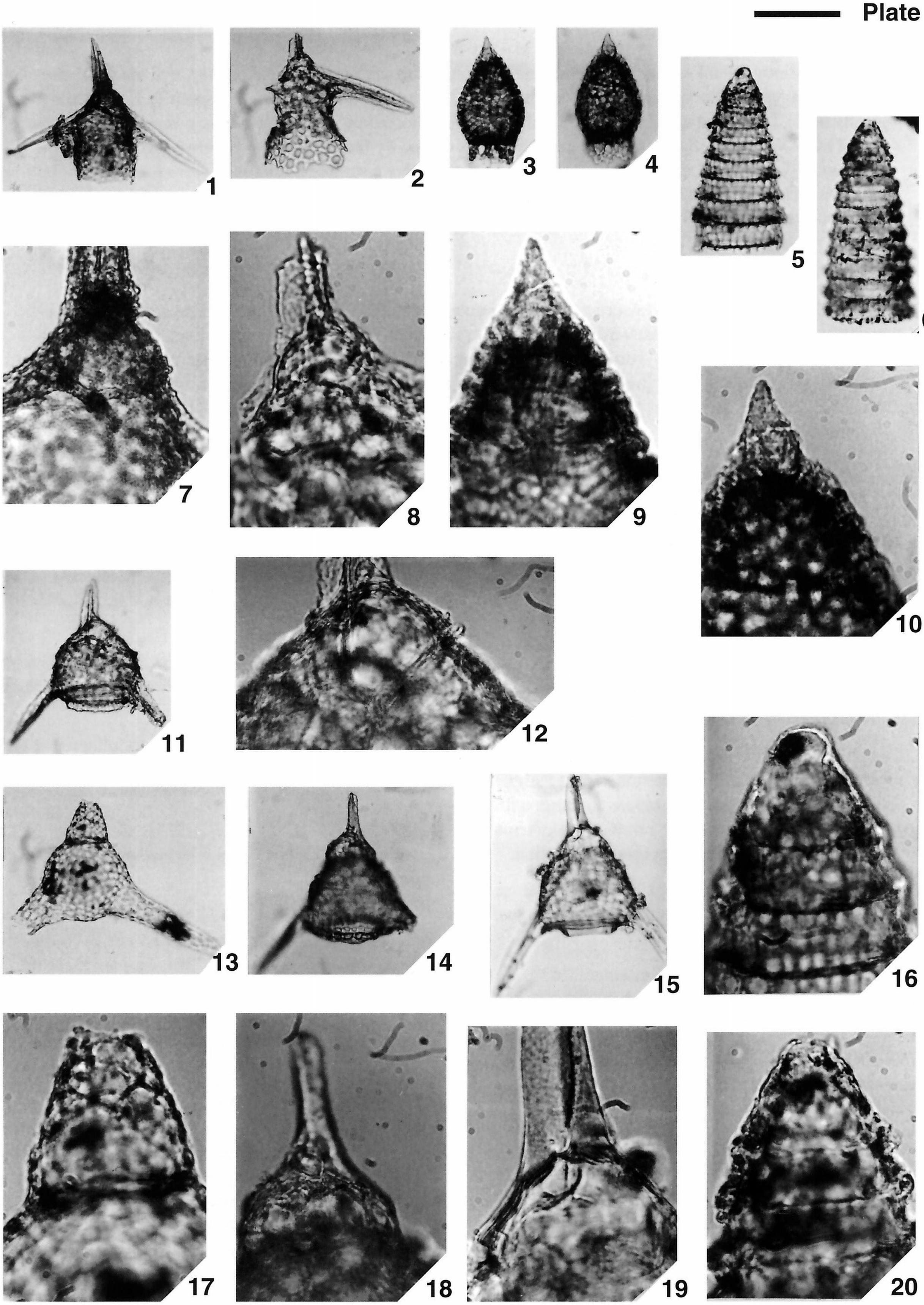
Figures 11, 12
Bipedis diadema Whalen and Carter n. sp.
Species code: BPD05
Paratype (Whalen Collection) from QC-675. Specimen length = 140 μm.

Figures 13, 17
Teesium insignitum Whalen and Carter n. sp.
Species code: TES01
Paratype (Whalen Collection) from QC-675. Specimen length = 128 μm.

Figures 14, 18
Bipedis helenae Whalen and Carter n. sp.
Species code: BPD09
Paratype (Whalen Collection) from QC-677. Specimen length = 160 μm.

Figures 15, 19
Bipedis douglasi Whalen and Carter n. sp.
Species code: BPD06
Paratype (Whalen Collection) from QC-676. Specimen length = 174 μm.

Plate 27



APPENDIX 1

Locality descriptions

Introduction

Queen Charlotte Island samples collected under the auspices of the Geological Survey of Canada are prefixed by the year collected and collector: samples CNA collected by E.S. Carter; samples OF collected jointly by M.J. Orchard and E.S. Carter; samples CAA collected by B.E.B. Cameron; and sample TD collected by H.W. Tipper. Samples DHH are from cores drilled by Intercoastal Resources in 1978 and 1979. Geological Survey of Canada locality numbers follow all above sample numbers in parentheses. Samples QC-500 series collected by E.A. Pessagno Jr. and C. Blome in 1977 and E.A. Pessagno Jr., C. Blome, and P.A. Whalen in 1979; QC-600 series collected by P.A. Whalen in 1980.

Kunga Island, southeast side

Upper Norian, Rhaetian and lower and middle Hettangian strata of the Sandilands Formation are continuously exposed, younging eastward along strike, on the southeast shore of Kunga Island, Figure 1A. Dip varies from steep to almost vertical, and the entire sequence is overturned. Upper Norian rocks are exposed only at low tide but the Rhaetian and Hettangian sequence is more resistant, outcrops higher on the shore, and the Hettangian part forms quite a high seaside knoll. Two sections (SKUD and SKUE) are discussed below.

Section 1 (SKUD)

NTS 103 B/13. Zone 9, UTM 327 240 m E; 5 848 290 m N (52°45′31.4″N; 131°33′36.6″W). Sandilands Formation, Kunga Group. An apparently conformable sequence of lower to middle Rhaetian to middle Hettangian strata. The Hettangian part of the section illustrated on Figure 5 begins immediately above sample 89-CNA-SKUD-25 (topmost Rhaetian; Carter, 1993). The upper part of section SKUD was measured and collected by E.S. Carter in 1989; ammonites were collected by G.K. Jakobs in the same year.

89-CNA-SKUD-25 (C-173287). Collected 82.4 m above the base of section; large irregular limestone lens. Sample contains abundant well preserved radiolarians together with the conodont *Neogondolella* sp. and ramiform elements (M.J. Orchard, pers. comm., 1991). Uppermost Rhaetian.

89-CNA-SKUD-339 (C-173357). Collected 84.8 m above the base of section; large irregular limestone lens. Lowest Hettangian.

89-CNA-SKUD-27 (C-173314). Collected 103.8 m above base of section; limestone nodule. Late lower-early middle Hettangian.

89-CNA-SKUD-28 (C-173315). Collected 107.45 m above base of section; lenticular limy bed, 40 cm thick and approximately 2.0 m long. Late lower-early middle Hettangian.

89-CNA-SKUD-31 (C-173318). Collected 112.55 m above base of section from nodular layer; sample is 10 cm x 3 cm limestone nodule. Middle to upper Hettangian.

89-CNA-SKUD-32 (C-173319). Collected 113.35 m above base of section; limestone nodule from nodular layer. Middle to upper Hettangian.

89-CNA-SKUD-33 (C-173320). Collected 113.65 m above base of section; limestone nodule. Middle to upper Hettangian.

89-CNA-SKUD-34A and *-34B* (*C-173321*). Collected 114.65 m above base of section; limestone nodules. Middle to upper Hettangian.

89-CNA-SKUD-36 (C-173323). Collected 119.85 m above base of section; 8 cm x 30 cm limy lens. Middle to upper Hettangian.

89-CNA-SKUD-38 (C-173325). Collected 123.85 m above base of section; 3 cm x 10 cm limy nodule. Middle to upper Hettangian.

89-CNA-SKUD-39 (C-173326). Collected 126.85 m above base of section; limy lens 15 cm x 70 cm. Section ends in volcanics 2 m above this sample. Middle to upper Hettangian.

Section 2 (SKUE)

NTS 103 B/13. Zone 9, UTM 327 220 m E; 5 848 440 m N (52°45′37″N, 131°33′37″W). Sandilands Formation, Kunga Group. Section SKUE is almost parallel to section SKUD on the opposite side of the knoll. Section begins above a short volcanic interval (perhaps a dyke) high on beach immediately south of a small cove on the southeast side of Kunga Island (see Fig. 1A and 5). Some disruption and at least one small fault occur in the lower part. Samples collected below the fault contain uppermost Rhaetian radiolarians while Hettangian ammonites and radiolarians are found above the fault. Prominent concretionary marker beds allow correlation with Hettangian beds in the upper part of section SKUD. Section SKUE measured and collected by E.S. Carter in 1989; ammonites collected by G.K. Jakobs in the same year.

89-CNA-SKUE-2 (C-173328). Collected 4.3 m above base of section; sample from 10 cm limy bed. Uppermost Rhaetian.

89-CNA-SKUE-3 (C-173329). Collected 6.8 m above base of section; micrite concretion 20 cm x 55 cm. Uppermost Rhaetian.

89-CNA-SKUE-4 (C-173330). Collected 8.8 m above base of section; 3 cm limestone bed. Uppermost Rhaetian.

89-CNA-SKUE-6 (C-173332). Collected 29.2 m above base of section; micrite concretion. Lower Hettangian.

Kunga Island, north side

The Sandilands Formation was originally named the black argillite member of the Kunga Formation by Sutherland Brown (1968), with the type locality (497 m thick) on the north side of Kunga Island. This thick, relatively continuous pile of strata is folded and disrupted in many places and at least four faults are present. Carter and Orchard measured three competent intervals between disrupted intervals in 1986 i.e. sections KUC, KUB, and KUA, and Carter completed sections KUD and KUH in 1987 and 1989 respectively. Whalen and others measured the section as one long sequence in 1977, 1979, and 1980.

Section 3 (KUD)

NTS 103B/13. Zone 9, UTM 327 260 m E; 5 849 860 m N (52°46′22.2″N; 131°33′38.5″W). Sandilands Formation, Kunga Group. Section begins above a disrupted interval just east of Section F, high on cliff above beach and 4.0 m wall (see Fig. 1A and 9). Section measured and collected by E.S.Carter in 1987 and 1989; ammonites were collected by G.K. Jakobs in 1989.

89-CNA-KUD-1 (C-173476). Collected 0.7 m below base of section as measured; two limestone nodules 8 cm x 15 cm.

89-CNA-KUD-3 (C-173478). Collected 18.6 m above base of section; limestone nodule. Upper Hettangian.

89-CNA-KUD-5 (C-173480). Collected 19.9 m above base of section; limestone nodule. Upper Hettangian.

89-CNA-KUD-6 (C-173481). Collected 19.9 m above base of section; small irregular limestone nodule. Upper Hettangian.

87-CNA-KUD-2 (C-164676). Collected 22.5 m above base of section: sample from splintery limestone pod. Upper Hettangian.

89-CNA-KUD-8 (C-173483). Collected 22.5 m above base of section; limestone nodule (probable recollection of 87-CNA-KUD-2). Upper Hettangian.

89-CNA-KUD-9 (C-173484). Collected 24.9 m above base of section; sample composed of four limestone nodules 10 cm x 20 cm. Upper Hettangian.

87-CNA-KUD-3 (C-164677). Collected 26.5 m above base of section; limestone nodule 10 cm x 30 cm. Upper Hettangian.

87-CNA-KUD-4 (C-164678). Collected 27.0 m above base of section; limestone nodule 3 cm x 20 cm. Upper Hettangian.

89-CNA-KUD-10 (C-173485). Collected 27.0 m above base of section; limestone lens 10 cm x 70 cm. Upper Hettangian.

89-CNA-KUD-12 (C-173487). Collected 27.0 m above base of section; limestone nodule 10 cm x 35 cm. Upper Hettangian.

89-CNA-KUD-11 (C-173486). Collected 27.9 m above base of section; limestone nodule. Upper Hettangian.

87-CNA-KUD-8 (C-164682). Collected 68.0 m above base of section; limestone nodule. Upper Hettangian.

87-CNA-KUD-9 (C-164683). Collected 70.0 m above base of section; limestone nodule 2 cm x 6 cm. Upper Hettangian or lower Sinemurian.

89-CNA-KUD-16 (C-173491). Collected 73.4 m above base of section; limestone nodule 3 cm x 10 cm. Upper Hettangian or lower Sinemurian.

89-CNA-KUD-17 (C-173492). Collected 74.5 m above base of section; limestone concretion 3 cm x 10 cm. Upper Hettangian or lower Sinemurian.

87-CNA-KUD-10 (C-164684). Collected 75.0 m above base of section; limestone nodule Upper Hettangian or lower Sinemurian.

89-CNA-KUD-18 (C-173493). Collected 75.0 m above base of section; limestone nodule 8 cm x 20 cm (probable recollection of 87-CNA-KUD-10). Upper Hettangian or lower Sinemurian.

87-CNA-KUD-11 (C-164685). Collected 101.0 m above base of section; limestone nodule 25 cm x 30 cm. Upper Hettangian or lower Sinemurian.

87-CNA-KUD-13 (C-164687). Collected 188.5 m above base of section; limestone nodule. Lower Sinemurian, possibly the upper part.

87-CNA-KUD-14 (C-164688). Collected 190.0 m above base of section; sample from two limestone nodules 4 cm and 15 cm in diameter. Lower Sinemurian, possibly the upper part.

87-CNA-KUD-15 (C-164689). Collected 193.5 m above base of section; limestone nodule 5 cm x 20 cm. Lower Sinemurian, possibly the upper part.

Section 4 (KUC)

NTS 103B/13. Zone 9, UTM 327 500 m E ; 5 849 840 m N (52°46′21.8″N; 131°33′25.6″W). Sandilands Formation, Kunga Group. Section C measured and collected by Orchard and Carter in 1986. Next fault block west of section KUB, measured from basal fault datum (see Fig. 1A and 10). Section recollected by E.S. Carter in 1989. Ammonites collected by M.J. Orchard and E.S. Carter in 1986 and by J. Pálfy in 1989.

89-CNA-KUC-3 (C-173457). Collected 19.6 m above datum; limestone nodule. Early upper Sinemurian.

89-CNA-KUC-4 (C-173458). Collected 22.9 m above datum; limestone nodule. Early upper Sinemurian.

89-CNA-KUB-2 (C-173462). Collected 52.0 m above datum; limestone nodule. Early upper Sinemurian.

89-CNA-KUB-4 (C-173464). Collected 64.6 m above datum; limestone nodule. Early upper Sinemurian.

89-CNA-KUB-5 (C-173465). Collected 68.3 m above datum; limestone nodule. Early upper Sinemurian.

86-OF-KUC-6 (C-150186). Collected 71.0 m above datum; from isloated limestone nodule 5 cm x 10 cm. Early upper Sinemurian.

86-OF-KUC-7 (C-150189). Collected 83.5 m above datum; small limestone nodule 5 cm x 10 cm. Early upper Sinemurian.

86-OF-KUC-8 (C-150191). Collected 89.5 m above datum; sample from composite limestone nodules 5 cm and 25 cm in diameter within 20 cm. Early upper Sinemurian.

Section 5 (KUB)

NTS 103B/13. Zone 9, UTM 327 825 m E; 5 849 790 m N (52°46′20.6″N; 131°33′8.2″W). Sandilands Formation, Kunga Group. Section A measured and collected by Orchard and Carter in 1986. Next fault block to west of section KUA, measured from basal fault datum (see Fig. 1A and 10). Section recollected by E.S. Carter in 1989. Ammonites collected by M.J. Orchard and E.S. Carter in 1986 and J. Pálfy in 1989.

86-OF-KUB-1 (C-150152). Collected 1.0 m above datum; small limestone nodule 10 cm. Early upper Sinemurian.

89-CNA-KUG-1 (C-173453). Collected 6.5 m above datum; limestone nodule. Early upper Sinemurian.

86-OF-KUB-2 (C-150154). Collected 13.0 m above datum; limestone nodule. Early upper Sinemurian.

86-OF-KUB-3 (C-150155). Collected 26.5 m above datum; limestone nodule 5 cm x 15 cm within a nodule horizon. Early upper Sinemurian.

89-CNA-KUG-1A (C-173454). Collected 27.3 m above datum; limestone nodule (possible recollection of 86-OF-KUB-3). Beyond this point no further nodules seen. Early upper Sinemurian.

Section 6 (KUA)

NTS 103B/13. Zone 9, UTM 328 050 m E; 5 849 700 m N (52°46′17.9″N; 131°32′56.1″W). Sandilands Formation, Kunga Group. Section A is the easternmost section measured and collected by Orchard and Carter in 1986 on the north side of Kunga Island. Section begins above a folded and faulted interval on a wave cut platform second beach west of eastern tip of island; section measured from fault datum (see Fig. 1A and 11). Section recollected for radiolarians by E.S. Carter in 1989. Ammonites collected by M.J. Orchard and E.S. Carter in 1986 and by J. Pálfy in 1989.

89-CNA-KUA-1A (C-173334). Collected 2.3 m above datum; large calcareous lens. Early upper Sinemurian.

86-OF-KUA-1 (C-150146). Collected 4.5 m above datum; pale, grey-weathering limestone nodule 2 cm x 15 cm in diameter and flattened parallel to bedding. Early upper Sinemurian.

86-OF-KUA-2 (C-150147). Collected 12.0 m above datum; limestone nodule. Early upper Sinemurian.

89-CNA-KUA-3 (C-173336). Collected 19.1 m above datum; limestone nodule. Early upper Sinemurian.

86-OF-KUA-3 (C-150148). Collected 20.5 m above datum; parts of two thick limy lenses (30 cm x 3.0 m). Early upper Sinemurian.

89-CNA-KUA-6 (C-173339). Collected 23.4 m above datum; limestone nodule. Early upper Sinemurian.

86-OF-KUA-5 (C-150150). Collected 31.5 m above datum; limestone nodule. Early upper Sinemurian.

86-OF-KUA-6 (C-150151). Collected 34.5 m above datum; limestone nodule. Early upper Sinemurian.

Section 7 (KUH)

NTS 103B/13. Zone 9, UTM 328 150 m E; 5 849 500 m N (52°49′11.3″N; 131°28′10.4″W). Sandilands Formation, Kunga Group. Section begins immediately above section KUA and extends to the top of the sedimentary beds at the eastern tip of the island (see Fig. 1A and 11). Section measured and collected by E.S. Carter in 1989; ammonites collected by J. Pálfy in the same year.

89-CNA-KUH-1 (C-173467). Collected 1.8 m above base of section; limestone nodule 5 cm x 30 cm. Early upper Sinemurian.

89-CNA-KUH-2 (C-173468). Collected 5.2 m above base of section; limestone nodule. Early upper Sinemurian.

89-CNA-KUH-3 (C-173469). Collected 5.8 m above base of section; limestone nodule. Early upper Sinemurian.

89-CNA-KUH-8 (C-173475). Collected 44.6 m above base of section; small limestone nodule 4 cm x 12 cm. Upper Sinemurian.

Section 8

NTS 103B/13. Zone 9, UTM 327 260 m E; 5 849 860 m N (52°46′22.2″N, 131°33′38.5″W). Sandilands Formation, Kunga Group. Type section on the north side of the island (Sutherland Brown, 1968) (see Fig. 1A and 8). Samples QC-500 series collected by E.A. Pessagno Jr. and C. Blome in 1977, and by E.A. Pessagno, Jr., P.A. Whalen, and C. Blome in 1979; QC-600 series collected by P.A. Whalen in 1980. Ammonite collections identified by H.W. Tipper (GSC, Cordilleran Division).

QC-543 (1977). Collected 34.7 m above contact with Peril Formation. Limestone nodule. Ammonites collected by Whalen (1980), QC-644A, B at 75.1 m and QC-647A, B at 80.6 m have been restudied by H.W. Tipper; they are Late Hettangian in age and belong to the Lower Canadensis Zone (H.W. Tipper, written report to E.S. Carter, 12 May, 1994). Thus this sample and QC-545 and QC-568 that follow are no younger that Late Hettangian. Comparison of the lower part of section 8 with section 2 (KUD) of Carter, indicates the ammonites and radiolarians are upper Hettangian.

QC-545 (1977). Collected 42 m above contact with Peril Formation. Limestone nodule. Upper Hettangian (see comments under QC-543).

QC-568 (1979). Collected 64.9 m above contact with Peril Formation. Dark grey micritic limestone nodule. The radiolarian assemblage present at this locality correlates closely with that at QC-545. Upper Hettangian (see comments under QC-543).

QC-571A, B (1979). Collected 88 m above contact with Peril Formation. Sample is two separate nodules of dark grey micritic limestone from the same horizon. Upper Hettangian or Lower Sinemurian.

QC-574 (1979). Collected 105 m above contact with Peril Formation. Dark grey micritic limestone nodule. Upper Hettangian or Lower Sinemurian.

QC-575 (1979). Collected approximately 119 m above contact with Peril Formation. Dark grey micritic limestone nodule. Lower Sinemurian, possibly the upper part.

QC-549 (1977). Collected 166 m above contact with Peril Formation. Dark grey micritic limestone nodule. Lower Sinemurian, possibly the upper part.

QC-550 (1977). Collected 321.6 m above contact with Peril Formation. Limestone nodule. Early upper Sinemurian.

QC-674 (1980). Collected 377 m above contact with Peril Formation. Small dark grey micritic limestone nodule (12 cm x 6 cm). Early upper Sinemurian.

QC-675 (1980). Collected 380.6 m above contact with Peril Formation. Dark grey micritic limestone nodule (15 cm x 2.5 cm). Early upper Sinemurian.

QC-590A (1979). Collected approximately 405 m above contact with Peril Formation. Micritic limestone nodule. Early upper Sinemurian.

QC-676 (1980). Collected 414 m above contact with Peril Formation. Two small dark grey micritic limestone nodules (8 cm x 3 cm; 11 cm x 3 cm). Early upper Sinemurian.

QC-677 (1980). Collected 415.2 m above contact with Peril Formation. Small, dark grey micritic limestone nodule 13 cm x 8 cm. Upper Sinemurian.

Kennecott Point, northwest Graham Island

Upper Norian to lower Sinemurian strata of the Sandilands Formation are exposed on a widespread bench at Kennecott Point just south of Peril Bay. The Sandilands Formation conformably overlies the upper part of the Peril Formation whose resistant, highly outcropping beds contain a great abundance of monotid bivalves. Two sections (KPD and KPB) are discussed below.

Section 9 (KPD)

NTS 103F/14. Zone 8, UTM: 621 250 m E; 5 975 340 m N (53°54′51.2″N; 133°09′14.5″W). Sandilands Formation, Kunga Group. A continuous sequence of Rhaetian to lower Hettangian beds is exposed on another area of the bench (Fig. 1E and 2) southeast of section KPA along the beach. Section begins at lower *Choristoceras* beds. Section measured and collected by E.S. Carter and H.W. Tipper in 1988 and 1990; ammonites collected by H.W. Tipper in same field seasons.

90-CNA-KPD-3 (C-156877). Collected 4.8 m above datum. Sample contains radiolarians belonging to the upper Rhaetian *Globolaxtorum tozeri* Zone (Carter, 1993). Ammonites collected at datum (A1) and 4.8 m (A2) are indicative of the Crickmayi Zone (see Appendix 2).

90-CNA-KPD-4 (C-156878). Collected 20.0 m above datum. Sample contains a very low diversity radiolarian fauna composed of simple, primitive forms (lacks *Archaeocenosphaera laseekensis*) and totally lacks all highly evolved, architecturally complex forms characteristic of the Rhaetian. Lowermost Hettangian.

90-CNA-KPD-5 (C-156879). Collected 22.8 m above datum. Sample contains a low diversity fauna composed of simple primitive forms plus *Archaeocenosphaera laseekensis*. Lowermost Hettangian.

90-TD-11A (C-177383). Collected 24.3 m above datum and 0.5 m below suspected unconformity. Lowermost Hettangian.

88-CNA-KPD-4A (C-156839). Collected from limestone nodule 26.0 m above datum and 1.2 m above suspected unconformity. An ammonite identified as *Psiloceras* aff. *primocostatum* HILLEBRANDT was found 0.5 m below this sample. *P. primocostatum* is the zonal ammonite of Hillebrandt's second Hettangian zone in South America. Lowermost Hettangian.

88-CNA-KPD-5 (C-156843). Collected 30.7 m above datum from limestone lens 4 cm x 80 cm. Between 88-CNA-KPD-4A and 88-CNA-KPD-5 are several lower Hettangian psiloceratid ammonites.

Section 10 (KPB)

NTS 103F/14. Zone 8, UTM: 621 325 m E; 5 975 160 m N. (53°54′45.3″N; 133°09′10.6″W). Sandilands Formation, Kunga Group. A continuous succession of lower Hettangian to lower Sinemurian beds are exposed along the beach (Fig. 1E and 2). Section measured and collected by E.S. Carter and H.W. Tipper in 1987 and 1988, and by E.S. Carter in 1989. Ammonites collected by H.W. Tipper, G.K. Jakobs, and J. Pálfy 1987-1990.

87-CNA-KPB-1 (C-140496). Collected 8.0 m above base of section from limestone concretion 2.0 m diameter. ?Lower to mid-Hettangian.

89-CNA-KPB-3 (C-159312). Collected 8.15 m above base of section from low-lying, large limestone concretion (possible recollection of 87-CNA-KPB-2). ?Lower to middle Hettangian.

89-CNA-KPB-5B (C-159315). Collected 11.3 m above base of section from an irregular pod of micrite. ?Lower to middle Hettangian.

87-CNA-KPB-4 (C-140498). Collected from nodule bed 11.5 m above base of section. Composite sample of dark grey limestone nodules 2 cm x 8 cm to 5 cm x 15 cm in diameter. ?Lower to middle Hettangian.

87-CNA-KPB-5A (C-164653). Collected from nodular layer 11.7 m above base of section. Composite sample of dark grey limestone nodules approximately 3 cm x 10 cm in diameter. ?Lower to middle Hettangian.

88-CNA-KPB-6A (C-156763). Collected 11.75 m above base of section from a 3-4 cm limestone bed (probable recollection of 87-CNA-KPB-5A). ?Lower to middle Hettangian.

88-CNA-KPB-6B (C-156764). Collected 11.75 m above base of section. Limestone nodule 2 cm x 10 cm (see 88-CNA-KPB-6A above). ?Lower to middle Hettangian.

88-CNA-KPB-7 (C-156765). Collected 12.25 m above base of section. Sample from three 5 cm diameter carbonaceous nodules. ?Lower to middle Hettangian.

87-CNA-KPB-9 (C-164658). Collected 39.0 m above base of section from a 20-25 cm thick concretionary limestone bed. Upper Hettangian.

87-CNA-KPB-10 (C-164659). Collected 45.2 m above base of section from a coarse concretionary limestone lens. Probably uppermost Hettangian.

89-CNA-KPB-13A (C-159323). Collected 46.0 m above base of section from parts of two flattened limestone nodules 10 cm x 40 cm. Probably uppermost Hettangian.

87-CNA-KPB-11 (C-164660). Collected from a thin limy bed 48.0 m above base of section. Probably uppermost Hettangian.

87-CNA-KPB-12 (C-164661). Collected 51.2 m above base of section from a mottled grey-green limestone nodule (20 cm x 40 cm). Probably uppermost Hettangian.

89-CNA-KPB-14 (C-159325). Collected 51.4 m above base of section; parts of two large limestone nodules approximately 50 cm in diameter. Uppermost Hettangian or lowermost Sinemurian.

89-CNA-KPB-15 (C-159327). Collected 52.1 m above base of section from limestone nodule 10 cm x 40 cm. Uppermost Hettangian or lowermost Sinemurian.

Graham Island, Yakoun River area

Section 11

NTS 103F/8. Zone 8, UTM 681 500 m E; 5 921 800 m N (53°24′57.3″N; 132°16′8.3″W). Sandilands Formation, Kunga Group. Samples collected by B.E.B. Cameron in transit along west side of Yakoun River, south of junction with Ghost Creek, central Graham Island (see Fig. 1D). Ammonites collected in association with limestone samples are upper Sinemurian and belong to the *Harbledownense* Assemblage of Pálfy (1991) (H.W. Tipper, pers. comm., 1994).

86-CAA-T-2/1 (C-127800). Collected 15 m above base; spot sample, carbonate. Upper Sinemurian.

86-CAA-T-2/2 (C-140408). Collected 30 m above base; spot sample, carbonate. Upper Sinemurian.

86-CAA-T-2/3 (C-140441). Collected 76 m above base; spot sample, carbonate. Upper Sinemurian.

Section 12

NTS 103F/8. Zone 8, UTM 681 400 m E; 5 921 725 m N (53°24′55″N, 132°16′13.9″W). Sandilands Formation, Kunga Group. East of Yakoun River, south of junction with Phantom Creek, central Graham Island, (see Fig. 1D). Intercostal Resources core I-178. Stratigraphic Section No. 2 of Cameron and Tipper (1985). Samples processed from limestones.

DHH-178; 305′-324.5′ (C-080635). Diamond-drill core. Upper Sinemurian.

DHH-178; 34′-52′ (C-080634). Diamond-drill core. Upper Sinemurian.

Sandilands Island, Skidegate Inlet

Section 13

NTS 103F/1. Zone 8, UTM 694 600 m E; 5 895 200 m N (53°10′20.8″N, 132°05′18.4″W). Sandilands Formation, Kunga Group. Southeast shore of Sandilands Island, type locality of Cameron and Tipper (1985) (see Fig. 1C). Section not measured by Carter but samples collected stratigraphically upward from base of section. All samples are from medium grey limestone lenses. Ammonites collected by Cameron and Tipper are upper Sinemurian and belong to *Harbledownense* Assemblage of Pálfy (1991) (H.W. Tipper, pers. comm., 1994).

84-CNA-SP-19; lms. 1 (C-080617). Spot sample collected near base of outcrop. Upper Sinemurian.

84-CNA-SP-19; lms. 8 (C-080624). Spot sample collected approximately midway through outcrop. Upper Sinemurian.

84-CNA-SP-19; lms. 12 (C-080628). Spot sample collected in upper part of outcrop. Upper Sinemurian.

Maude Island, Skidegate Inlet

Section 14

NTS 103F/1. Zone 8, UTM 696 290 m E; 5 897 830 m N (53°11′43.6″N; 132°03′41″W). Sandilands Formation, Kunga Group. Collected on south shore of Maude Island in disrupted Sandilands strata approximately 50 m below base of Ghost Creek Formation (Lower Pliensbachian) (see Fig. 1C). Occurs with ammonites of *Harbledownense* Assemblage (upper Sinemurian) (H.W. Tipper, pers. comm., 1994).

87-CNA-SP-18/3 (C-164717). Spot sample from ammonite-bearing carbonate. Upper Sinemurian.

Tasu Sound, Moresby Island

Section 15

NTS 103C/16. Zone 8, UTM 695 510 m E; 5 851 490 m N (52°46′46.9″N; 132°06′4.5″W). Sandilands Formation, Kunga Group. West side of Lomgon Bay, Tasu Sound (see Fig. 1B).

88-OF-LB-1 (C-150568). Spot sample from ammonoid-bearing carbonate. Upper Sinemurian.

Section 16

NTS 103B/1. Zone 9, UTM 300 650 m E; 5 851 770 m N (52°46′50.9″N; 131°57′20.8″W). Sandilands Formation, Kunga Group. West side of Wilson Bay, Tasu Sound; cliff exposure on logging road (see Fig. 1B). Typical Sandilands Formation strata with prominent green shale beds.

88-OF-WB-3 (C-158508). Spherical nodule 8 cm diameter within green shale beds. Lower Sinemurian.

APPENDIX 2

Ammonoid identifications

Ammonoids prefaced TD were collected by H.W. Tipper in 1987-1990; KGN and KGS by G. Jakobs in 1989; 25, 60, 61, and 70 by J. Pálfy in 1989 and 1990; QC by P.A. Whalen in 1980; CNA by E.S. Carter in 1984; and CAA by B.E.B. Cameron in 1986. Hettangian ammonites and a few Sinemurian ammonites identified by H.W. Tipper, some in collaboration with J. Guex; other Sinemurian ammonites from Kennecott Point and Kunga Island identified by J. Pálfy (zonal assignments from Pálfy et al., 1994). Triassic ammonites identified by E.T. Tozer.

Field no.	level (m)	GSC no.	Ammonites	Zone/Assemblage/beds	Age
Kunga Island, south side					
Section SKUD (UA section 1)					
89-KGS-1	96.8	C-159351	*Psiloceras*?	unknown	early Hettangian
89-KGS-3	100.6	C-159352	ammonite indet.	unknown	early Hettangian
89-KGS-3	100.6	C-159352	ammonite indet.	unknown	early Hettangian
89-KGS-3	100.6	C-159352	ammonite indet.	unknown	early Hettangian
89-KGS-3	100.6	C-159352	ammonite indet.	unknown	early Hettangian
89-KGS-3	100.6	C-159352	ammonite indet.	unknown	early Hettangian
89-KGS-2	100.9	C-159353	ammonite indet.	unknown	early Hettangian
89-KGS-4	106.0	C-159354	*Psiloceras* sp. *polyphyllum?*	unknown	early Hettangian
89-KGS-5	107.6	C-159355	*Kammerkarites*?	Euphyllites	late early Hettangian
89-KGS-6	107.75	C-159356	*Kammerkarites* sp. *frigga*?	Euphyllites	early to middle Hettangian
89-KGS-6	107.75	C-159356	phylloceratid	unknown	early to middle Hettangian
89-KGS-6	107.75	C-159356	smooth evolute ammonite	unknown	early to middle Hettangian
89-KGS-7	108.05	C-159357	ammonite indet.	unknown	middle Hettangian
89-KGS-7	108.05	C-159357	*Discamphiceras* sp. *silberlingi*?	unknown	middle Hettangian
89-KGS-8/13	108.85	C-159359	*Alsatites*?	unknown	middle Hettangian
89-KGS8/13	108.85	C-159359	ammonite indet.	unknown	middle Hettangian
89-KGS-10	110.95	C-159360	*Franziceras*? sp.	unknown	middle Hettangian
89-KGS-10	110.95	C-159360	*Schlotheimia* sp.	unknown	middle Hettangian
89-KGS-11	117.45	C-159361	*Schlotheimia*? sp.	unknown	middle Hettangian
Section SKUE (UA section 2)					
89-KGS-24	16.4	C-159363	*Psiloceras* aff. *pacificum*? or *planorbis*?	Pacificum	early Hettangian
89-KGS-23	16.6	C-159363	*Psiloceras* sp.	unknown	early Hettangian
89-KGS-15	21.4	C-159364	*Psiloceras* sp. or *P. polymorphum*	unknown	early Hettangian
89-KGS-19	24.3	C-159367	*Psiloceras*?	unknown	early Hettangian
89-KGS-16	25.0	C-159365	*Psiloceras*? sp. *polymorphum*	unknown	early Hettangian
89-KGS-20	29.7	C-159368	*Psiloceras* sp. *polyphyllum*?	unknown	late early Hettangian
89-KGS-21	30.7	C-159369	*Psiloceras*?	unknown	late early Hettangian
89-KGS-22	31.5	C-159370	*kammerkarites*?	unknown	late earlyHettangian
Kunga Island, north side					
Section KUD (UA section 3)					
89-KGN-9	8.5	C-159380	*Badouxia* cf. "*oregonensis*"	pre-Canadensis	late Hettangian
89-KGN-8	9.6	C-159379	*Schlotheimia* aff. *S. angulata*		middle? to late Hettangian
89-KGN-10	11.5	C-159378	*Badouxia* n. sp.		late Hettangian
890KGN-7	11.5	C-159377	*Schlotheimia* sp.		middle to late Hettangian
89-KGN-6	12.8	C-159376	*Schlotheimia*? sp.		middle to late Hettangian

Field no.	level (m)	GSC no.	Ammonites	Zone/Assemblage/beds	Age
89-KGN-5	13.3	C-159375	*Schlotheimia*? sp.		middle to late Hettangian
89-KGN-4	13.6	C-159374	*Schlotheimia* sp.		probably late Hettangian
89-KGN-3	20.4	C-159373	*Vermiceras* n. sp.		late Hettangian
89-KGN-2	21.1	C-159372	*Badouxia*? sp.	pre-Canadensis	late Hettangian
704A	57.4	C-177251	*Badouxia canadensis*	Canadensis	late Hettangian or early Sinemurian
704A	57.4	C-177251	*Badouxia* cf. *canadensis*	Canadensis	late Hettangian or early Sinemurian
704A	57.4	C-177251	*Badouxia* sp.	Canadensis	late Hettangian or early Sinemurian
704A	57.4	C-177251	*Vermiceras* sp.	Canadensis	late Hettangian or early Sinemurian
704B	65.2	C-177252	*Badouxia canadensis*	Canadensis	late Hettangian or early Sinemurian
704B	65.2	C-177252	*Badouxia* cf. *canadensis*	Canadensis	late Hettangian or early Sinemurian
704B	65.2	C-177252	*Vermiceras* sp.	Canadensis	late Hettangian or early Sinemurian
704C	67.5	C-177253	*Badouxia canadensis*	Canadensis	late Hettangian or early Sinemurian
704C	67.5	C-177253	*Badouxia* cf. *canadensis*	Canadensis	late Hettangian or early Sinemurian
704C	67.5	C-177253	*Badouxia* sp.	Canadensis	late Hettangian or early Sinemurian
704C	67.5	C-177253	*Angulaticeras*? sp.	Canadensis	late Hettangian or early Sinemurian
704C	67.5	C-177253	*Vermiceras* sp.	Canadensis	late Hettangian or early Sinemurian
704D	81.8	C-177254	*Badouxia* cf. *canadensis*	Canadensis	early Sinemurian
704D	81.8	C-177254	*Badouxia* cf. *columbiae*	Canadensis	early Sinemurian
704D	81.8	C-177254	*Eolytoceras tasekoi*	Canadensis	early Sinemurian
704E	97.7	C-177255	*Badouxia canadensis*	Canadensis	early Sinemurian
704E	97.7	C-177255	*Badouxia* sp.	Canadensis	early Sinemurian
704F	110.9	C-177256	*Angulaticeras*? sp.	Canadensis	early Sinemurian
704F	110.9	C-177256	*Sulciferites*? sp.	Canadensis	early Sinemurian
704H	127.3	C-177258	*Juraphyllites* cf. *transylvanicus*	?uppermost Canadensis/*Coroniceras*	early Sinemurian
704H	127.3	C-177258	*Juraphyllites* sp.	?uppermost Canadensis/*Coroniceras*	early Sinemurian
708A	132.5	C-177259	*Angulaticeras*? sp.	?*Coroniceras*	early Sinemurian
708A	132.5	C-177259	*Juraphyllites* cf. *transylvanicus*	?*Coroniceras*	early Sinemurian
708A	132.5	C-177259	*Juraphyllites* sp	?*Coroniceras*	early Sinemurian
708B	161.5	C-177260	*Juraphyllites* sp.	?*Cononiceras*	early Sinemurian
708C	197.7	C-177261	*Arnioceras arnouldi*	*Arnouldi*	early Sinemurian

Section KUC (UA section 4)

708D	4.3	C-177262	*Arnioceras* sp.	*Arnouldi*	early Sinemurian
708D	4.3	C-177262	*Juraphyllites*? sp.	*Arnouldi*	early Sinemurian
708E	7.7	C-177263	*Arnioceras* sp	*Arnouldi*	late early Sinemurian
708F	10.7	C-177264	*Arnioceras* ex gr. *ceratitoides*	*Varians*	early late Sinemurian
708F	10.7	C-177264	*Asteroceras* aff. *margarita*	*Varians*	early late Sinemurian
708F	10.7	C-177264	*Arnioceras* cf. *speciosum*	*Varians*	early late Sinemurian
708F	10.7	C-177264	*Asteroceras* sp.	*Varians*	early late Sinemurian
708G	12.2	C-177265	*Arnioceras arnouldi*	*Varians*	early late Sinemurian
708I	34.5	C-177267	*Arnioceras* sp.	*Varians*	early late Sinemurian
708J	43.9	C-177269	*Arnioceras* cf. *oppeli*	*Varians*	early late Sinemurian
708J	43.9	C-177269	*Arnioceras* sp.	*Varians*	early late Sinemurian
708L	65.0	C-177271	*Asteroceras* sp.	*Varians*	early late Sinemurian
708K	66.5	C-177270	*Asteroceras* sp.	*Varians*	early late Sinemurian
708M	66.8	C-177272	*Asteroceras* sp.	*Varians*	early late Sinemurian

Section KUB (UA section 5)

708P	12.3	C-177275	*Arnioceras* sp.	*Varians*	early late Sinemurian
708P	12.3	C-177275	*Asteroceras* aff. *margarita*	*Varians*	early late Sinemurian
708Q	27.5	C-177276	*Asteroceras* sp.	*Varians*	early late Sinemurian
708R	29.0	C-177277	*Asteroceras* aff. *margarita*	*Varians*	early late Sinemurian

Field no.	level (m)	GSC no.	Ammonites	Zone/Assemblage/beds	Age
Section KUA (UA section 6)					
709A	18.8	C-177280	*Arnioceras*? sp.	*Varians*	early late Sinemurian
709A	18.8	C-177280	*Asteroceras* sp.	*Varians*	early late Sinemurian
709B	20.7	C-177281	*Epophioceras* aff. *carinatum*	*Varians*	early late Sinemurian
709B	20.7	C-177281	*Epophioceras* sp.	*Varians*	early late Sinemurian
709B	20.7	C-177281	*Arnioceras* sp.	*Varians*	early late Sinemurian
709B	20.7	C-177281	*Asteroceras* sp.	*Varians*	early late Sinemurian
709C	21.4	C-177282	*Asteroceras* sp.	*Varians*	early late Sinemurian
709D	24.4	C-177283	*Arnioceras* ex gr. *ceratitoides*	*Varians*	early late Sinemurian
709D	24.4	C-177283	*Arnioceras* sp.	*Varians*	early late Sinemurian
709E	27.9	C-177284	*Arnioceras* sp.	*Varians*	early late Sinemurian
709E	27.9	C-177284	*Asteroceras* aff. *margarita*	*Varians*	early late Sinemurian
709E	27.9	C-177284	*Asteroceras* cf. *varians*	*Varians*	early late Sinemurian
Section KUH (UA section 7)					
709N	10.5	C-177293	*Asteroceras* cf. *saltriense*	*Varians*	early late Sinemurian
709O	15.0	C-177294	*Asteroceras*? sp.	*Varians*	early late Sinemurian
709P	17.2	C-177295	*Asteroceras* aff. *margarita*	*Varians*	early late Sinemurian
709Q	36.0	C-177296	*Plesechioceras*? cf. *aklavikense*	*Harbledownense*	late Sinemurian
709Q	36.0	C-177296	*Paltechioceras*? sp. indet.	*Harbledownense*	late Sinemurian
709S	39.4	C-177298	*Tetraspidoceras* n. sp.	*Harbledownense*	late Sinemurian
709Z	44.5	C-177303	*Paltechioceras* sp. indet.	*Harbledownense*	late Sinemurian
UA section 8					
QC644A	75.1	C-087208	*Badouxia canadensis*	lower Canadensis	late Hettangian
QC644B	75.1	C-087209	*Sulciferites* cf. *trapezoidalis*		late Hettangian
QC647A	80.6	C-087210	*Badouxia canadensis*	lower Canadensis	late Hettangian
QC467B	80.6	C-087211	*Badouxia canadensis*	lower Canadensis	late Hettangian
QC586	316.9	C-081954	*Arnioceras*? sp.		Sinemurian
Kennecott Point, northwest Graham Island **Section KPD (UA section 9)**					
TD-A1	datum		*Choristoceras nobile*	Crickmayi	late Rhaetian
TD-A2	10.3		*Chorstoceras rhaeticum*	Crickmayi	late Rhaetian
TD-A3	25.1	C-177351	*Psiloceras* aff. *primocostatum*	Planorbis	very early Hettangian
TD-A4	26.0	C-177353	*Psiloceras* sp.		very early Hettangian
TD-A5	27.2	C-156966	*Paradasyceras* aff. *veromoense*		very early Hettangian
TD-A6	28.85	C-156967	*Paradasyceras* aff. *veromoense*		very early Hettangian
TD-A6	28.85	C-156340	*Psiloceras* sp.		very early Hettangian
TD-A7	31.5	C-156968	*Psiloceras* sp.		very early Hettangian
TD-A7	31.5	C-156970	*Psiloceras* cf. *polymorphum*		very early Hettangian
TD-A8	38.7	C-156971	*Psiloceras* aff. *plicatulum*?		very early Hettangian
TD-A9	43.1	C-177352	*Euphyllites*? or *Discamphiceras*?		very early Hettangian
Section KPB (UA section 10)					
TD-K4	9.5	C-156998	*Discamphiceras* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K4	9.5	C-156901	*Kammerkarites* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K5	10.6	C-156904	*Discamphiceras* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K5	10.6	C-156904	*Kammerkarites* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K5	10.6	C-156904	*Pleuroacanthites* spp.	*Euphyllites*	?early to mid-Hettangian

Field no.	level (m)	GSC no.	Ammonites	Zone/Assemblage/beds	Age
TD-K5	10.6	C-156904	*Fergusonites striatus*	*Euphyllites*	?early to mid-Hettangian
TD-K5	10.6	C-156904	*Euphyllites occidentalis*	*Euphyllites*	?early to mid-Hettangian
TD-K6	11.4	C-156302	*Discamphiceras* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K6	11.4	C-156302	*Kammerkarites* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K6	11.4	C-156302	*Pleuroacanthites* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K6	11.4	C-156302	*Fergusonites striatus*	*Euphyllites*	?early to mid-Hettangian
TD-K6	11.4	C-156302	*Euphyllites occidentalis*	*Euphyllites*	?early to mid-Hettangian
TD-K7	12.0	C-156304	*Discamphiceras* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K7	12.0	C-156304	*Kammerkarites* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K7	12.0	C-156304	*Pleuroacanthites* spp.	*Euphyllites*	?early to mid-Hettangian
TD-K7	12.0	C-156304	*Fergusonites striatus*	*Euphyllites*	?early to mid-Hettangian
TD-K7	12.0	C-156304	*Euphyllites occidentalis*	*Euphyllites*	?early to mid-Hettangian
TD-K8	12.4	C-156988	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K8	12.4	C-156909	*Kammerkarites* spp.	*Franziceras*	mid- to late Hettangian
TD-K8	12.4	C-156988	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K8	12.4	C-156909	*Fergusonites striatus*	*Franziceras*	mid- to late Hettangian
TD-K8	12.4	C-156997	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K8	12.4	C-156997	*Saxoceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Kammerkarites* spp.	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Ferursonites striatus*	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Saxoceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Franziceras* aff. *coronoides*	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Paradasyceras* sp.	*Franziceras*	mid- to late Hettangian
TD-K9	13.4	C-156332	*Caloceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Franziceras* aff. *coronoides*	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Paradasyceras* sp.	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Caloceras* aff. *multicostatum*	*Franziceras*	mid- to late Hettangian
TD-K10	16.75	C-156303	*Franziceras* sp. 2	*Franziceras*	mid- to late Hettangian
TD-K11	18.0	C-156311	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K11	18.0	C-156311	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K11	18.0	C-156311	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K11	18.0	C-156311	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K11	18.0	C-156311	*Franziceras* aff. *coronoides*	*Franziceras*	mid- to late Hettangian
TD-K11	18.0	C-156311	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K11	18.0	C-156311	*Paradasyceras* sp.	*Franziceras*	mid- to late Hettangian
TD-K11	18.0	C-156311	*Caloceras* aff. *multicostatum*	*Franziceras*	mid- to late Hettangian
TD-K12	18.35	C-156310	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K12	18.35	C-156310	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K12	18.35	C-156310	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K12	18.35	C-156310	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K12	18.35	C-156310	*Franziceras* aff. *coronoides*	*Franziceras*	mid- to late Hettangian
TD-K12	18.35	C-156310	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K12	18.35	C-156310	*Paradasyceras* sp.	*Franziceras*	mid- to late Hettangian

Field no.	level (m)	GSC no.	Ammonites	Zone/Assemblage/beds	Age
TD-K13	18.75	C-156309	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K13	18.75	C-156309	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K13	18.75	C-156309	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K13	18.75	C-156309	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K13	18.75	C-156309	*Franziceras* aff. *coronoides*	*Franziceras*	mid- to late Hettangian
TD-K13	18.75	C-156309	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K13	18.75	C-156309	*Paradasyceras* sp.	*Franziceras*	mid- to late Hettangian
TD-K14	19.0	C-156306	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K14	19.0	C-156306	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K14	19.0	C-156306	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K14	19.0	C-156306	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K14	19.0	C-156306	*Franziceras* aff. *coronoides*	*Franziceras*	mid- to late Hettangian
TD-K14	19.0	C-156306	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K14	19.0	C-156306	*Paradasyceras* sp.	*Franziceras*	mid- to late Hettangian
TD-K15	19.25	C-156305	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K15	19.25	C-156305	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K15	19.25	C-156305	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K15	19.25	C-156305	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K15	19.25	C-156305	*Franziceras* aff. *coronoides*	*Franziceras*	mid- to late Hettangian
TD-K15	19.25	C-156305	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K15	19.25	C-156305	*Paradasyceras* sp.	*Franziceras*	mid- to late Hettangian
TD-K15	19.25	C-156305	*Alsatites* aff. *nigromontanus*	*Franziceras*	mid- to late Hettangian
TD-K16	23.75	C-156314	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K16	23.75	C-156314	*Pleuroacanthites* spp.	*Franziceras*	mid- to late Hettangian
TD-K16	23.75	C-156314	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K16	23.75	C-156314	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K16	23.75	C-156314	*Franziceras* aff. *coronoides*	*Franziceras*	mid- to late Hettangian
TD-K16	23.75	C-156314	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K16	23.75	C-156314	*Alsatites* aff. *nigromontanus*	*Franziceras*	mid- to late Hettangian
TD-K17	24.1	C-156312	*Discamphiceras* spp.	*Franziceras*	mid- to late Hettangian
TD-K17	24.1	C-156312	*Schlotheimia* spp.	*Franziceras*	mid- to late Hettangian
TD-K17	24.1	C-156312	*Alsatites* aff. *proaries*	*Franziceras*	mid- to late Hettangian
TD-K17	24.1	C-156312	*Franziceras* sp. 1	*Franziceras*	mid- to late Hettangian
TD-K17	24.1	C-156312	*Alsatites* aff. *nigromontanus*	*Franziceras*	mid- to late Hettangian
TD-K18	25.4	C-156313	*Discamphiceras* spp.	*Doetzkirchneri*	late Hettangian
TD-K18	25.4	C-156313	*Schlotheimia* spp.	*Doetzkirchneri*	late Hettangian
TD-K18	25.4	C-156313	*Alsatites* aff. *nigromontanus*	*Doetzkirchneri*	late Hettangian
TD-K18	25.4	C-156313	*Augulaticeras* spp.	*Doetzkirchneri*	late Hettangian
TD-K18	25.4	C-156313	*Eolytoceras tasekoi*	*Doetzkirchneri*	late Hettangian
TD-K18	25.4	C-156313	*Paracaloceras* sp.	*Doetzkirchneri*	late Hettangian
TD-K18	25.4	C-156313	*Sunrisites* sp.	*Doetzkirchneri*	late Hettangian
TD-K19	26.8	C-156321	*Alsatites* aff. *nigromontanus*	*Doetzkirchneri*	late Hettangian
TD-K19	26.8	C-156321	*Augulaticeras* spp.	*Doetzkirchneri*	late Hettangian
TD-K19	26.8	C-156321	*Eolytoceras tasekoi*	*Doetzkirchneri*	late Hettangian
TD-K19	26.8	C-156321	*Paracaloceras* sp.	*Doetzkirchneri*	late Hettangian
TD-K19	26.8	C-156321	*Sunrisites* sp.	*Doetzkirchneri*	late Hettangian
TD-K19	26.8	C-156321	*Ectocentrites petersi*	*Doetzkirchneri*	late Hettangian
TD-K19	26.8	C-156321	*Pseudaetomoceras doetzkirchneri*	*Doetzkirchneri*	late Hettangian
TD-K20	30.5	C-156325	*Augulaticeras* spp.	*Doetzkirchneri*	late Hettangian
TD-K20	30.5	C-156325	*Eolytoceras tasekoi*	*Doetzkirchneri*	late Hettangian
TD-K20	30.5	C-156325	*Paracaloceras* sp.	*Doetzkirchneri*	late Hettangian
TD-K20	30.5	C-156325	*Sunrisites* sp.	*Doetzkirchneri*	late Hettangian
TD-K20	30.5	C-156325	*Ectocentrites petersi*	*Doetzkirchneri*	late Hettangian

Field no.	level (m)	GSC no.	Ammonites	Zone/Assemblage/beds	Age
TD-K20	30.5	C-156325	*Pseudaetomoceras doetzkirchneri*	*Doetzkirchneri*	late Hettangian
TD-K21	33.0	C-156327	*Augulaticeras* spp.	*Doetzkirchneri*	late Hettangian
TD-K21	33.0	C-156327	*Eolytoceras tasekoi*	*Doetzkirchneri*	late Hettangian
TD-K21	33.0	C-156327	*Paracaloceras* sp.	*Doetzkirchneri*	late Hettangian
TD-K21	33.0	C-156327	*Sunrisites* sp.	*Doetzkirchneri*	late Hettangian
TD-K21	33.0	C-156327	*Ectocentrites petersi*	*Doetzkirchneri*	late Hettangian
TD-K22	35.0	C-156328	*Augulaticeras* spp.	*Doetzkirchneri*	late Hettangian
TD-K22	35.0	C-156328	*Eolytoceras tasekoi*	*Doetzkirchneri*	late Hettangian
TD-K22	35.0	C-156328	*Paracaloceras* sp.	*Doetzkirchneri*	late Hettangian
TD-K22	35.0	C-156328	*Sunrisites* sp.	*Doetzkirchneri*	late Hettangian
TD-K22	35.0	C-156328	*Ectocentrites petersi*	*Doetzkirchneri*	late Hettangian
TD-K22	35.0	C-156328	*Badouxia* sp.	*Doetzkirchneri*	late Hettangian
TD-K23	37.0	C-156329	*Eolytoceras tasekoi*	*Doetzkirchneri*	late Hettangian
TD-K23	37.0	C-156329	*Paracaloceras* sp.	*Doetzkirchneri*	late Hettangian
TD-K23	37.0	C-156329	*Ectocentrites petersi*	*Doetzkirchneri*	late Hettangian
TD-K23	37.0	C-156329	*Badouxia* sp.	*Doetzkirchneri*	late Hettangian
TD-K24	38.8	C-156330	*Augulaticeras* spp.	*Doetzkirchneri*	late Hettangian
TD-K24	38.8	C-156330	*Eolytoceras tasekoi*	*Doetzkirchneri*	late Hettangian
TD-K24	38.8	C-156330	*Paracaloceras* sp.	*Doetzkirchneri*	late Hettangian
TD-K24	38.8	C-156330	*Ectocentrites petersi*	*Doetzkirchneri*	late Hettangian
TD-K24	38.8	C-156330	*Badouxia* n. sp.	*Doetzkirchneri*	late Hettangian
604A	40.2	C-159251	*Badouxia* n. sp.	lower Canadensis	latest Hettangian
604A	40.2	C-159251	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
604A	40.2	C-159251	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
604A	40.2	C-159251	*Sulciferites* sp.	lower Canadensis	latest Hettangian
604A	40.2	C-159251	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610J	40.6	C-159290	*Badouxia* n. sp	lower Canadensis	latest Hettangian
610J	40.6	C-159290	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
610J	40.6	C-159290	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
610J	40.6	C-159290	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610J	40.6	C-159290	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
610J	40.6	C-159290	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
610H	41.5	C-159289	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
610H	41.5	C-159289	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
610H	41.5	C-159289	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610H	41.5	C-159289	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
610H	41.5	C-159289	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
610H	41.5	C-159289	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
610G	45.0	C-159288	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
610G	45.0	C-159288	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
610G	45.0	C-159288	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610G	45.0	C-159288	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
610G	45.0	C-159288	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
610G	45.0	C-159288	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
610F	45.8	C-159287	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
610F	45.8	C-159287	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
610F	45.8	C-159287	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610F	45.8	C-159287	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
610F	45.8	C-159287	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
610F	45.8	C-159287	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
604B	46.25	C-159252	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
604B	46.25	C-159252	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
604B	46.25	C-159252	*Badouxia canadensis*	lower Canadensis	latest Hettangian

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604B	46.25	C-159252	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
604B	46.25	C-159252	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
604B	46.25	C-159252	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
25A	46.7	C-175211	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
25A	46.7	C-175211	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
25A	46.7	C-175211	*Badouxia canadensis*	lower Canadensis	latest Hettangian
25A	46.7	C-175211	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
25A	46.7	C-175211	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
25A	46.7	C-175211	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
25A	46.7	C-175211	*Ectocentrites*? sp.	lower Canadensis	latest Hettangian
610D	47.2	C-159285	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
610D	47.2	C-159285	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
610D	47.2	C-159285	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610D	47.2	C-159285	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
610D	47.2	C-159285	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
610D	47.2	C-159285	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
610D	47.2	C-159285	*Ectocentrites*? sp.	lower Canadensis	latest Hettangian
610C	47.7	C-159284	*Vermiceras* cf. *supraspiratum*	lower Canadensis	latest Hettangian
610C	47.7	C-159284	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
610C	47.7	C-159284	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610C	47.7	C-159284	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
610C	47.7	C-159284	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
610C	47.7	C-159284	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
610C	47.7	C-159284	*Ectocentrites*? sp.	lower Canadensis	latest Hettangian
610C	47.7	C-159284	*Metophioceras* spp.	lower Canadensis	latest Hettangian
610B	48.0	C-159283	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
610B	48.0	C-159283	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610B	48.0	C-159283	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
610B	48.0	C-159283	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
610B	48.0	C-159283	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
610B	48.0	C-159283	*Ectocentrites*? sp.	lower Canadensis	latest Hettangian
610B	48.0	C-159283	*Metophioceras* spp.	lower Canadensis	latest Hettangian
610A	48.6	C-159282	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
610A	48.6	C-159282	*Badouxia canadensis*	lower Canadensis	latest Hettangian
610A	48.6	C-159282	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
610A	48.6	C-159282	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
610A	48.6	C-159282	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
610A	48.6	C-159282	*Ectocentrites*? sp.	lower Canadensis	latest Hettangian
610A	48.6	C-159282	*Metophioceras* spp.	lower Canadensis	latest Hettangian
610A	48.6	C-159282	*Sulciferites* cf. *trapezoidalis*	lower Canadensis	latest Hettangian
609L	48.8	C-159281	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
609L	48.8	C-159281	*Badouxia canadensis*	lower Canadensis	latest Hettangian
609L	48.8	C-159281	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
609L	48.8	C-159281	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
609L	48.8	C-159281	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
609L	48.8	C-159281	*Ectocentrites*? sp.	lower Canadensis	latest Hettangian
609L	48.8	C-159281	*Metophioceras* spp.	lower Canadensis	latest Hettangian
609L	48.8	C-159281	*Sulciferites* cf. *trapezoidalis*	lower Canadensis	latest Hettangian
609K	49.6	C-159280	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
609K	49.6	C-159280	*Badouxia canadensis*	lower Canadensis	latest Hettangian
609K	49.6	C-159280	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
609K	49.6	C-159280	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
609K	49.6	C-159280	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian

Field no.	level (m)	GSC no.	Ammonites	Zone/Assemblage/beds	Age
609K	49.6	C-159280	*Ectocentrites*? sp.	lower Canadensis	latest Hettangian
609K	49.6	C-159280	*Metophioceras* spp.	lower Canadensis	latest Hettangian
609K	49.6	C-159280	*Sulciferites* cf. *trapezoidalis*	lower Canadensis	latest Hettangian
609J	50.8	C-159279	*Vermiceras* ex gr. *coregonense*	lower Canadensis	latest Hettangian
609J	50.8	C-159279	*Badouxia canadensis*	lower Canadensis	latest Hettangian
609J	50.8	C-159279	*Eolytoceras* n. sp.	lower Canadensis	latest Hettangian
609J	50.8	C-159279	*Angulaticeras* cf. *ventricosum*	lower Canadensis	latest Hettangian
609J	50.8	C-159279	*Eolytoceras* cf. *tasekoi*	lower Canadensis	latest Hettangian
609J	50.8	C-159279	*Ectocentrites*? sp.	lower Canadensis	latest Hettangian
609J	50.8	C-159279	*Metophioceras* spp.	lower Canadensis	latest Hettangian
609J	50.8	C-159279	*Sulciferites* cf. *trapezoidalis*	lower Canadensis	latest Hettangian
609I	51.6	C-159278	*Vermiceras* ex gr. *coregonense*	upper Canadensis	earliest Sinemurian
609I	51.6	C-159278	*Badouxia canadensis*	upper Canadensis	earliest Sinemurian
609I	51.6	C-159278	*Eolytoceras* n. sp.	upper Canadensis	earliest Sinemurian
609I	51.6	C-159278	*Angulaticeras* cf. *ventricosum*	upper Canadensis	earliest Sinemurian
609I	51.6	C-159278	*Eolytoceras* cf. *tasekoi*	upper Canadensis	earliest Sinemurian
609I	51.6	C-159278	*Metophioceras* spp.	upper Canadensis	earliest Sinemurian
609I	51.6	C-159278	*Sulciferites* cf. *trapezoidalis*	upper Canadensis	earliest Sinemurian
609I	51.6	C-159278	*Badouxia columbiae*	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Vermiceras* ex gr. *coregonense*	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Badouxia canadensis*	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Eolytoceras* n. sp.	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Angulaticeras* cf. *ventricosum*	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Eolytoceras* cf. *tasekoi*	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Ectocentrites*? sp.	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Metophioceras* spp.	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Sulciferites* cf. *trapezoidalis*	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Badouxia columbiae*	upper Canadensis	earliest Sinemurian
610K	52.2	C-159292	*Vermiceras* sp. indet.	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Vermiceras* ex gr. *coregonense*	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Badouxia canadensis*	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Eolytoceras* n. sp.	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Angulaticeras* cf. *ventricosum*	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Eolytoceras* cf. *tasekoi*	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Ectocentrites*? sp.	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Metophioceras* spp.	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Sulciferites* cf. *trapezoidalis*	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Badouxia columbiae*	upper Canadensis	earliest Sinemurian
609H	53.0	C-159277	*Lytoceras* sp.	upper Canadensis	earliest Sinemurian
614D	54.2	C-156415	*Badouxia canadensis*	upper Canadensis	earliest Sinemurian
614D	54.2	C-156415	*Badouxia columbiae*	upper Canadensis	earliest Sinemurian
614C	55.0	C-156414	*Badouxia* aff. *occidentalis*	upper Canadensis	earliest Sinemurian
614C	55.0	C-156414	*Badouxia columbiae*	upper Canadensis	earliest Sinemurian
614C	55.0	C-156414	*Vermiceras* ex gr. *coregonense*	upper Canadensis	earliest Sinemurian
614C	55.0	C-156414	*Metophioceras*? sp. indet.	upper Canadensis	earliest Sinemurian
614B	56.0	C-156413	*Vermiceras* sp. indet.	upper Canadensis	earliest Sinemurian
614B	56.0	C-156413	*Angulaticeras* cf. *ventricosum*	upper Canadensis	earliest Sinemurian
614B	56.0	C-156413	*Badouxia columbiae*	upper Canadensis	earliest Sinemurian
614B	56.0	C-156413	*Sulciferites* cf. *trapezoidalis*	upper Canadensis	earliest Sinemurian
614A	56.6	C-156413	*Eolytoceras* sp. indet.	upper Canadensis	earliest Sinemurian
614A	56.6	C-156413	Schloteimiidae gen. et sp. indet.	upper Canadensis	earliest Sinemurian
609B	58.3	C-159271	*Badouxia canadensis*	upper Canadensis	earliest Sinemurian
609B	58.3	C-159271	*Angulaticeras* cf. *ventricosum*	upper Canadensis	earliest Sinemurian

Field no.	level (m)	GSC no.	Ammonites	Zone/Assemblage/beds	Age
609B	58.3	C-159271	*Eolytoceras* cf. *tasekoi*	upper Canadensis	earliest Sinemurian
609B	58.3	C-159271	*Ectocentrites*? sp.	upper Canadensis	earliest Sinemurian
609B	58.3	C-159271	*Metophioceras* spp.	upper Canadensis	earliest Sinemurian
609B	58.3	C-159271	*Badouxia columbiae*	upper Canadensis	earliest Sinemurian
608D	59.6	C-159269	*Badouxia canadensis*	upper Canadensis	earliest Sinemurian
608D	59.6	C-159269	*Eolytoceras* cf. *tasekoi*	upper Canadensis	earliest Sinemurian
608D	59.6	C-159269	*Ectocentrites*? sp.	upper Canadensis	earliest Sinemurian
608D	59.6	C-159269	*Metophioceras* spp.	upper Canadensis	earliest Sinemurian
608D	59.6	C-159269	*Badouxia columbiae*	upper Canadensis	earliest Sinemurian
608C	65.0	C-159268	*Badouxia canadensis*	upper Canadensis	earliest Sinemurian
608C	65.0	C-159268	*Ectocentrites*? sp.	upper Canadensis	earliest Sinemurian
608C	65.0	C-159268	*Metophioceras* spp.	upper Canadensis	earliest Sinemurian
608C	65.0	C-159268	*Vermiceras* sp.	upper Canadensis	earliest Sinemurian
608B	65.8	C-159267	*Badouxia canadensis*	upper Canadensis	earliest Sinemurian
608B	65.8	C-159267	*Ectocentrites*? sp.	upper Canadensis	earliest Sinemurian
608B	65.8	C-159267	*Metophioceras* spp.	upper Canadensis	earliest Sinemurian
608B	65.8	C-159267	*Vermiceras* sp.	upper Canadensis	earliest Sinemurian
608B	65.8	C-159267	*Phylloceras* sp.	upper Canadensis	earliest Sinemurian
608B	65.8	C-159267	*Juraphyllites* sp.	upper Canadensis	earliest Sinemurian
608B	65.8	C-159267	*Metophioceras* aff. *rotarium*	upper Canadensis	earliest Sinemurian

Yakoun River, Graham Island
UA section 11

CAA-T-2/F1			echioceratid	*Harbledownense*	late Sinemurian
CAA-T-2/F2			echioceratid	*Harbledownense*	late Sinemurian

Sandilands Island, Skidegate Inlet
UA sections 13

84 CNA SP 19			*Paltechioceras*? sp.	*Harbledownense*	late Sinemurian

APPENDIX 3

Unitary Association database

SECTION 1_KUNGA_ISLAND_SOUTH

< 10 {89 CNA SKU D39}

ARC04, AMU02, CHA01, DAN01, UDA01, UDA05, PAN08, PAN09, PAN10, PAR06, PAR08, PAR09, EMP01, SAT01, SAT04, THU01, THU05, TOZ01, SPI01, SPI02, BPD03, CAN08, DRO02, PSE01, PTK01, REL01

< 9 {89 CNA SKU D38}

ARC04, CHA01, UDA01, PAN08, PAN10, PAR06, SPI04, THU05, TOZ01, SPI01, SPI02, BPD03, DRO02, PSE01

< 8 {89 CNA SKU D36}

SAT01, TOZ01, BPD03, REL01

< 7 {89 CNA SKU D34A; 89 CNA SKU 34B}

ARC04, AMU01, CHA01, DAN01, UDA01, UDA05, PAN08, PAN09, PAN10, PAR06, PAR08, EMP01, EMP02, SAT01, SAT02, SAT03, SAT04, THU01, THU03, THU05, TOZ01, SPI01, SPI02, BPD03, CAN08, DRO02, PSE01, JAC02, PTK01, PSE02, REL01, NITO2

< 6 {89 CNA SKU D33}

ARC04, AMU01, CHA01, DAN01, UDA01, PAN08, SPI04, SAT01, SAT02, THU01, THU05, TOZ01, SPI01, SPI02, BPD03, PSE01

< 5 {89 CNA SKU D32}

ARC04, AMU01, CHA01, DAN01, UDA01, PAN08, PAR08, EMP01, THU01, TOZ01, SPI01, SPI02, BPD03, DRO02, REL01

< 4 {89 CNA SKU D31}

ARC04, AMU01, CHA01, UDA01, UDA05, PAN08, SPI04, THU01, THU03, THU05, TOZ01, SPI01, SPI02, BPD03, PSE01

< 3 {89 CNA SKU D28}

ARC04, AMU01, PAN08, PAR06, SPI02, CAN06, DRO02, REL01, EUPHY

< 2 {89 CNA SKU D27}

ARC04, DAN01, UDA01, UDA05, PAN08, SAT02, THU01, THU05, TOZ01, SPI01, BPD03, DRO02, PSE01, NITO2, EUPHY

< 1 {89 CNA SKU D339}

ARC04, PAN08, TOZ01, BPD03, DRO02

SECTION 2_KUNGA_ISLAND_SOUTH

< 1 {89 CNA SKU E6}

ARC04, AMU01, CHA01, UDA01, UDA05, PAN08, PAR06, EMP02, SAT01, SAT02, SAT04, THU01, THU03, THU05, TOZ01, SPI01, SPI02, BPD03, DRO02, PSE01, NITO2, EUPHY

SECTION 3_KUNGA_ISLAND_NORTH

< 18 {87 CNA KU D15}

CHA06, CRU06, CRU07, HAG01, UDA01, UDA03, UDA04, UDA05, SOP07, ORB02, SAT03, THU04, THU05, SPI03, ATA02, DRO03, KAT04, LAX06, PHS01, PTK01, PSE02, TRX01

< 17 {87 CNA KU D14}

AMU02, CHA01, CRU06, CRU07, HAG01, UDA03, UDA04, SOP07, PAN17, PAR10, SAT03, SAT04, THU03, THU04, THU05, SPI03, ATA02, BAG01, BPD07, BPD08, DRO03, KAT04, PHS01

< 16 {87 CNA KU D13}

CRU06, CRU07, HAG01, UDA03, UDA04, SOP07, SPI03

< 15 {87 CNA KU D11}

ARC04, AMU02

< 14 {87 CNA KU D10, 89 CNA KU D18}

ARC04, AMU02, CHA01, CRU07, DAN01, UDA03, UDA04, UDA05, ORB02, PAN10, PAN12, PAR06, PAR08, PAR09, SAT04, THU01, THU04, THU05, TOZ01, SPI03, ATA01, BPD03, BPD07, CAN08, CAN10, DRO02, JAC02, NIT01, PTK01, PSE02, PTK03, REL01, TRX01, CANAD

< 12 {89 CNA KU D17}

ARC04, CHA01, UDA04, PAN10, PAN12, PAR06, PAR08, PAR09, SPI04, SAT04, THU05, BPD07, NIT01, PTK03

< 11 {89 CNA KU D16}

AMU02, CHA01, DAN01, UDA03, UDA04, PAN10, PAN12, PAR06, PAR08, PAR09, EMP01, SAT03, SAT04, THU03, THU04, THU05, DRO02, PSE01, NIT01, PTK01, PSE02, PTK03, TRX01

< 10 {87 CNA KU D9}

ARC04, AMU02, CHA01, UDA01, UDA03, UDA04, UDA05, PAN10, PAN12, PET01, PAR06, PAR08, PAR09, EMP01, SAT01, SAT02, SAT03, SAT04, THU05, SPI03, ATA01, DRO02, PSE01, JAC02, NIT01, PTK01, PSE02, PTK03, REL01, TRX01

< 9 {87 CNA KU D8}

UDA01, UDA05, PAN10, PAN12, THU05, PTK01, PSE02, CANAD

< 8 {89 CNA KU D11}

DAN01, UDA01, UDA05, PAN08, PAN12, PET01, PAR08, SPI04, EMP01, SAT01, SAT02, SAT03, SAT04, THU04, THU05, TOZ01, SPI01, SPI02, ATA01, BPD03, DRO02, PSE01, PTK01, REL01

< 7 {87 CNA KU D4; 89 CNA KU D10; 89 CNA KU D12}

ARC04, AMU01, CHA01, DAN01, UDA01, UDA04, UDA05, PAN08, PAN09, PAN10, PET01, PAR06, PAR08, SPI04, EMP01, SAT01, SAT02, SAT03, SAT04, THU03, THU04, TOZ01, SPI01, SPI02, ATA01, BPD03, CAN08, DRO02, PSE01, HCK03, PTK01, PSE02, REL01, NITO2

< 6 {87 CNA KU D3}

ARC04, AMU01, UDA01, UDA04, UDA05, PAR06, PAR08, EMP02, SAT01, SAT04, THU05, SPI01, SPI02, PSE01

< 5 {89 CNA KU D9}

ARC04, DAN01, UDA01, UDA05, PAN09, PAN10, PAN12, PAR08, EMP01, THU04, THU05, SPI01, DRO02, PTK01

< 4 {87 CNA KU D2; 89 CNA KU D8}

ARC04, AMU01, CHA01, DAN01, UDA01, UDA05, PAN08, PAN09, PAN10, PET01, PAR06, PAR08, SPI04, EMP01, SAT01, SAT02, SAT03, SAT04, THU03, THU05, TOZ01, SPI01, SPI02, BPD03, DRO02, PSE01, HCK03, PTK01, PSE02, REL01, NITO2

< 3 {89 CNA KU D5; 89 CNA KU D6}

ARC04, AMU01, CHA01, DAN01, UDA01, UDA05, PAN08, PAN09, PAN10, PET01, PAR06, PAR08, EMP01, SAT01, SAT02, SAT03, SAT04, THU01, THU03, THU04, THU05, TOZ01, SPI01, SPI02, ATA01, BPD07, CAN06, CAN08, DRO02, PSE01, PTK01, PSE02, REL01, NITO2

< 2 {89 CNA KU D3}

ARC04, AMU01, CHA01, DAN01, UDA01, UDA05, PAN08, PAN09, PAR06, PAR08, SAT01, SAT02, THU01, THU03, THU05, TOZ01, SPI01, SPI02, BPD03, PTK01, REL01

< 1 {89 CNA KU D1}

ARC04, AMU01, PAN08, PAR06, SAT01, THU05, TOZ01, CAN08

SECTION 4_KUNGA_ISLAND_NORTH

< 8 {86 OF KU C8}

AMU02, CHA02, CHA03, CHA04, CHA05, CRU07, CRU09, CRU10, HAG01, HAG02, HAG04, UDA04, UDA05, SOP07, ORB02, PAN11, PAN13, PAN14, PAN16, PAN17, PAR10, PAR12, SAT05, SPI03, SPI05, ARS01, BAG01, BAG02, BPD05, BPD11, BRO02, CAN08, CTS03, CUN01, DRO02, DRO03, DRO04, DRO06, ECT01, FAR01, FRM01, KAT02, KAT04, KAT06, LAX06, NAP01, PHS01, TRX01, WNG01

< 7 {86 OF KU C7}

AMU02, CHA02, CHA03, CRU07, HAG02, HAG04, UDA04, UDA05, SOP06, ORB02, PAN11, PAN13, PAN14, PAN17, PAR10, PAR12, SAT04, SAT05, SAT08, SPI03, SPI05, BAG01, BPD09, BPD12, BRO02, CTS03, DRO02, DRO03, DRO04, DRO05, DRO06, FRM01, KAT02, KAT04, KAT06, LAX06, NAP01, PHS01, FAR01, SOL01, TRX01

< 6 {86 OF KU C6}

AMU02, CHA02, CHA03, CRU07, CRU10, HAG01, HAG02, HAG04, UDA03, UDA05, SOP07, ORB02, PAN11, PAN14, PAN16, PAR10, PAR12, SAT04, SAT05, SAT07, SAT08, SPI03, BPD12, BRO02, CTS03, CUN01, DRO03, DRO05, DRO06, ECT01, FRM01, KAT02, KAT04, KAT06, PHS01, TES01

< 5 {89 CNA KU B5}

CHA02, CHA03, CRU07, HAG04, PAN09, PAN13, PAN14, PAR09, SPI05, BPD09, CTS03, CTS05, DRO02, KAT04, PHS01, TRX01

< 4 {89 CNA KU B4}

CHA02, CHA03, ORB02, PAN17, PAR10, SAT05, CTS03, KAT04, TRX01

< 3 {89 CNA KU B2}

CHA02, CHA03, SOP07, PAN11, PAN13, PAR09, KAT04, PHS01

< 2 {89 CNA KU C4}

HAG04, SPI03, PHS01

< 1 {89 CNA KU C3}

HAG04, ATA02, CTS03, PHS01

SECTION 5_KUNGA_ISLAND_NORTH

< 5 {89 CNA KU G1A}

AMU02, CHA02, CHA03, CHA04, CRU07, CRU09, HAG02, HAG03, SOP06, ORB02, ORB03, PAR09, PAR10, PAR12, SAT05, SPI03, SPI05, BPD11, CAN08, CTS03, DRO03, DRO04, DRO06, FRM01, KAT04

< 4 {86 OF KU B3}

AMU02, CHA02, CHA03, CHA04, CRU06, CRU07, CRU09, HAG02, HAG03, HAG04, UDA04, UDA05, SOP06, SOP07, ORB02, PAN11, PAN13, PAN14, PAN17, PAR10, PAR12, SAT05, SAT08, SPI03, SPI05, ATA02, BAG01, BPD05, BPD12, CAN08, CTS04, DRO03, DRO04, DRO05, DRO06, FAR01, FRM01, KAT02, KAT04, KAT06, NAP01, PHS01, TRX01

< 3 {86 OF KU B2}

AMU02, CHA02, CHA03, CHA04, CRU07, CRU09, CRU10, HAG01, HAG02, HAG03, HAG04, UDA04, UDA05, ORB02, PAN11, PAN14, PAN16, PAR09, PAR10, PAR12, SAT05, SAT07, SAT08, SPI03, SPI05, ARS01, ARS02, ATA02, BAG01, BAG02, BPD06, BPD11, BPD12, CAN08, CTS03, CUN01, DRO02, DRO03, DRO04, DRO05, DRO06, FRM01, KAT02, KAT04, KAT06, LAX06, NAP01, PHS01, SUM01, BPD05

< 2 {89 CNA KU G1}

CHA02, CHA03, CHA04, CRU10, HAG04, UDA05, ORB02, PAR12, SPI03, SPI05, BPD09, CTS03, KAT04, PHS01, WNG01

< 1 {86 OF KU B1}

HAG02, SPI03, BPD09, CTS03, DRO02, KAT04

SECTION 6_KUNGA_ISLAND_NORTH

< 8 {86 OF KU A6}

AMU02, CHA02, CHA04, CHA05, CRU06, CRU07, CRU09, CRU10, HAG02, HAG03, HAG04, ORB01, PAN11, PAN13, PAN14, PAN17, PAR10, SAT05, SAT07, THU05, SPI03, SPI05, BAG02, BPD05, BPD06, BPD09, BPD11, BPD12, CTS03, CTS04, CUN01, DRO02, DRO05, DRO06, KAT04, PHS01, TRX01, WNG01

< 7 {86 OF KU A5}

SAT07, SAT08

< 6 {89 CNA KU A6}

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< 5 {86 OF KU A3}

AMU02, CHA02, CHA05, CRU10, HAG02, HAG03, HAG04, UDA04, UDA05, SOP06, ORB02, ORB03, PAN11, PAN16, PAN17, PAR10, SAT05, SAT08, SPI03, SPI05, BPD05, BPD11, BPD12, CAN08, CTS03, CTS04, DRO03, DRO06, FAR01, KAT04, NAP01, PHS01, SUM01, TRX01, WNG01

< 4 {89 CNA KU A3}

AMU02, CHA02, CHA03, SOP06, PAN13, PAN16, PAN17, PAR09, SPI03, BPD05, BPD12, CTS03, DRO03, DRO04, KAT02, KAT04, KAT06

< 3 {86 OF KU A2}

AMU02, CHA02, CHA03, CHA04, CRU10, HAG02, HAG03, HAG04, UDA04, UDA05, ORB02, PAN11, PAN13, PAN14, PAN16, PAR09, PAR10, PAR12, SAT05, SPI03, ARS01, ARS02, BPD11, CTS03, DRO03, DRO04, DRO06, ECT01, KAT02, KAT04, NAP01, PHS01, SUM01, SOL01, TRX01

< 2 {86 OF KU A1}

CHA03, HAG02, UDA03, UDA04, UDA05, SOP06, SOP07, ORB02, PAN11, PAN13, PAN14, PAN16, PAN17, SPI03, ATA02, DRO02, DRO04, DRO06, FAR01, KAT04

< 1 {89 CNA KU A1A}

CHA02, CHA03, HAG02, HAG04, ORB02, PAR10, SPI03, BPD09, BPD12, DRO02, DRO06, KAT02, KAT04, PHS01

SECTION 7_KUNGA_ISLAND_NORTH

< 4 {89 CNA KU H8}

CHA02, CHA03, CHA04, CHA05, CRU06, CRU07, CRU09, HAG01, HAG02, ORB01, ORB02, ORB03, PAN11, PAN14, PAN16, PAN17, PAR10, PAR11, SAT05, SPI03, BPD09, BPD11, BPD12, CTS04, DRO02, DRO03, KAT02, KAT04, LAX06, PHS01

< 3 {89 CNA KU H3}

CHA02, CHA03, CRU06, CRU07, CRU09, HAG02, ORB02, ORB03, PAR10, SAT05, SAT07, SPI03, BPD09, BPD11, BPD12, CAN11, CTS03, CTS04, DRO02, DRO06, KAT04, SOL01

< 2 {89 CNA KU H2}

CHA02, CHA03, CHA04, CHA05, CRU07, CRU09, HAG02, HAG03, HAG04, ORB01, ORB02, PAN13, PAN14, PAN16, PAN17, SAT08, SPI03, BPD05, BPD09, BPD12, CTS03, CTS04, DRO05, DRO06, KAT04

< 1 {89 CNA KU H1}

CHA02, CHA03, CHA04, CHA05, CRU07, CRU09, CRU10, HAG02, HAG03, HAG04, ORB01, ORB02, PAN11, PAN13, PAN17, PAR09, PAR12, SPI03, SPI05, BPD05, BPD09, CAN08, CTS03, CTS04, CTS05, DRO03, DRO05, DRO06, KAT04, TRX01

SECTION 8_KUNGA_ISAND_NORTH

< 13 {QC 677}

CHA02, CHA03, CHA04, CHA05, CRU07, CRU10, HAG02, ORB02, PAN11, PAN13, PAN14, PAN17, PAR09, PAR10, SAT05, THU05, SPI03, BAG02, BPD05, BPD06, BPD09, BRO02, CAN11, CTS03, CTS05, DRO04, DRO05, DRO06, FRM01, JAC01, KAT02, KAT03, KAT04, KAT06, NAP01, SOL01, TRX01, WNG01

< 12 {QC 676}

CHA02, CHA03, CHA04, CRU07, CRU10, HAG03, HAG04, UDA05, SOP07, ORB02, PAN11, PAN13, PAN17, PAR10, SAT07, SAT08, THU05, SPI03, BAG02, BPD05, BPD06, BPD09, BPD12, CAN08, CAN11, CTS03, CTS05, DRO02, DRO03, DRO04, DRO05, DRO06, FRM01, KAT02, KAT03, KAT04, KAT05, KAT06, NAP01, PHS01, SOL01, TRX01, WNG01

< 11 {QC 590A; QC 590B}

CHA02, CHA03, CHA04, CRU07, CRU10, HAG01, HAG02, HAG03, HAG04, SOP07, ORB02, PAN11, PAN13, PAN14, PAN16, PAN17, PAR09, PAR10, PAR12, SAT05, SAT08, SPI03, ARS01, BAG02, BPD05, BPD09, BPD12, BRO01, BRO02, CAN09, CAN11, CTS03, DRO02, DRO03, FRM01, KAT02, KAT03, KAT04, KAT06, LAX06, NAP01, SOL01, TRX01, WNG01

< 10 {QC 675}

CHA02, CHA03, CRU07, CRU10, HAG04, SOP06, ORB01, ORB02, PAN11, PAN13, PAN14, PAN17, PAR09, PAR10, EMP01, SPI03, ARS01, ARS02, BAG02, BPD05, BPD11, BPD12, BRO01, CAN08, CAN11, CTS03, CUN01, DRO02, DRO03, DRO05, ECT01, FRM01, JAC02, KAT02, KAT04, NAP01, PTK03, SUM01, SOL01, TES01, TRX01, WNG01

< 9 {QC 674}

AMU02, CHA02, CHA03, CHA04, CRU06, CRU07, CRU10, HAG03, HAG04, ORB01, ORB02, PAN11, PAN17, PAR09, PAR10, SAT05, SAT08, SPI03, ARS01, ARS02, ATA02,BAG02, BPD09, BPD11, BPD12, CAN08, CTS03, DRO02, DRO03, DRO05, DRO06, ECT01, FRM01, KAT02, KAT03, KAT04, LAX06, PHS01, PTK03, TRX01, WNG01

< 8 {QC 550}

ORB01, PAN11, PAN17, ARS01, BAG01, BAG02, CAN09, CTS03, CUN01, DRO02, DRO06, ECT01, FRM01, KAT02, KAT04, NAP01, PHS01, SOL01

< 7 {QC 549}

CRU07, HAG01, UDA03, UDA04, SOP07, ORB02, PAN11, PAN17, THU04, SPI03, TOZ01, ATA02, BAG01, BPD03, BPD08, DRO02, DRO03, DRO06, FRM01, LAX06, PHS01, TRX01

< 6 {QC 575}

CHA04, DAN01, THU05, SPI01, ARS02, BPD07, CAN08, DRO02, ECT01, JAC02, PSE02, PTK03, SUM01, SUM02, TRX01

< 5 {QC 574}

AMU01, AMU02, CHA04, CHA06, UDA01, UDA03, UDA04, UDA05, ORB02, PAN08, PAN10, PAN12, PET01, PAR06, PAR09, SAT01, THU03, THU05, SPI01, TOZ01, ATA01, BPD07, BPD08, CAN11, NIT01, PSE02, PTK03, SUM02, TRX01

< 4 {QC 571A; QC 571B}

ARC04, DAN01, UDA01, UDA03, PAN10, PET01, THU05, ATA01, BPD07, PSE01, NIT01, PTK01, PSE02, PTK03, SUM01, CANAD

< 3 {QC 568}

ARC04, CHA01, DAN01, UDA01, UDA03, UDA04, UDA05, PAN08, PAN09, PAN10, PAN11, PET01, PAR06, PAR08, EMP01, EMP02, SAT01, SAT02, THU01, THU03, THU04, THU05, SPI01, TOZ01, ATA01, BPD07, CAN10, ECT01, PSE01, HCK03, LAX06, PTK01, REL01, SUM02, TRX01, NITO2, CANAD

< 2 {QC 545}

ARC04, AMU01, CHA01, DAN01, UDA01, UDA03, UDA04, UDA05, PAN08, PAN09, PAN10, PAN11, PET01, PAR06, PAR08, SPI04, EMP01, SAT01, SAT02, SAT03, THU03, THU05, SPI01, SPI02, TOZ01, ATA01, BPD07, CAN10, DRO02, PSE01, HCK03, PTK01, PSE02, PTK03, REL01

< 1 {QC 543}

ARC04, CHA01, UDA01, UDA05, PAN08, PAN09, PET01, PAR06, PAR08, SPI04, EMP01, SAT01, SAT02, SAT03, SAT04, SPI01, SPI02, TOZ01, BPD07, CAN06, DRO02, PSE01, PTK01, REL01, NITO2

SECTION 9_KENNECOTT_POINT

< 4 {88 CNA KPD 5}

ARC04, PAN08, PAR06, TOZ01, BPD03, REL01, PSILO

< 3 {88 CNA KPD 4A}

ARC04, AMU01

< 2 {90 TD 11A}

ARC04, AMU01, UDA01, PAR06, TOZ01, CAN06, DRO02, PSILO

< 1 {90 CNA KPD 5}

ARC04, UDA01, TOZ01, CAN06

SECTION 10_KENNECOTT_POINT

< 15 {89 CNA KPB 15}

ARC04, CHA01, CHA02, CHA06, CRU07, DAN01, UDA03, UDA04, UDA05, SAT04, THU04, THU05, TOZ01, SPI03, CAN08, NIT01, PTK03, TRX01, CANAD

< 14 {89 CNA KPB 14}

ARC04, CHA02, UDA03, UDA04, PAN10, PAN12, SPI03, ATA01, SUM01

< 13 {87 CNA KPB 12}

AMU02, CHA01, CHA02, CHA06, CRU07, UDA03, UDA04, UDA05, PAN09, PAN10, PAN12, PAR08, SAT04, THU04, THU05, TOZ01, SPI03, BPD07, BPD08, CAN08, DRO02, LAX06, NIT01, PSE02, PTK03

< 12 {87 CNA KPB 11}

ARC04, AMU02, CHA01, CRU07, UDA03, UDA04, UDA05, PAN08, PAN09, PAN10, PAN12, PAR06, PAR08, PAR09, THU05, TOZ01, ATA01, BPD07, BPD08, CAN08, DRO02, DRO03, NIT01, PTK03, REL01

< 11 {89 CNA KPB 13A}

ARC04, AMU01, AMU02, UDA03, UDA04, PAN10, PAN12, THU05, SPI03, CAN08, PTK03, TRX01 PAN09

< 10 {87 CNA KPB 10}

ARC04, CHA01, CRU07, HAG01, UDA03, UDA04, UDA05, PAN08, PAN10, PAN12, THU05, SPI01, BPD08, BPD09, CAN08, CAN10, NIT01, PSE02, PTK03, TRX01

< 9 {87 CNA KPB 9}

ARC04, UDA03, PAR08, PAR09, THU05, CANAD

< 8 {88 CNA KPB 7}

ARC04, PAN08, SPI04, SAT01, SAT02, THU01, THU05, TOZ01, ATA01, BPD03, BPD07, CAN08, PSE01, PTK01, REL01, EUPHY

< 6 {88 CNA KPB 6A, 88 CNA KPB 6B}

ARC04, AMU01, CHA01, UDA01, PAN08, PAR06, PAR09, SAT02, THU05, TOZ01, ATA01, BPD03, CAN06, CAN08, PSE01, PSE02, REL01, EUPHY

< 5 {87 CNA KPB 5}

CHA01, UDA01, PAN08, PAR06, PAR08, THU01, THU05, TOZ01, ATA01

< 4 {87 CNA KPB 4}

ARC04, AMU01, CHA01, UDA01, PAN08, PAR06, PAR08, SPI04, EMP01, SAT01, SAT02, THU01, THU05, TOZ01, SPI01, ATA01, CAN06, CAN08, PSE01, REL01

< 3 {89 CNA KPB 5B}

PAN08, THU01, TOZ01, PTK01

< 2 {89 CNA KPB 3}

ARC04, CHA01, UDA01, PAN08, PAR06, SAT02, THU01, TOZ01, ATA01, CAN06, PSE01, PTK01, REL01

< 1 {87 CNA KPB 1}

UDA01, PAN08, SAT01, THU01, THU05, SPI01, CAN06, CAN08, DRO02, REL01, EUPHY

SECTION 11_YAKOUN_RIVER

< 3 {CAA 86-T-2/1}

JAC01, KAT04

< 2 {CAA 86-T-2/2}

ORB01, SPI03, BRO01, CAN08, CTS04

< 1 {CAA 86-T-2/3}

AMU02, CHA02, CHA03, CHA04, CRU07, CRU09, CRU10, HAG03, HAG04, UDA05, ORB01, ORB02, ORB03, PAN11, PAN13, PAN14, PAN16, PAR10, PAR11, PAR12, SAT05, SAT07, THU05, SPI03, SPI05, BAG02, BPD05, BPD11, BPD12, BRO01, BRO02, CAN08, CAN11, CTS03, CTS04, CTS05, DRO02, DRO03, DRO04, DRO05, FAR01, FRM01, KAT03, KAT04, KAT05, KAT06, NAP01, TRX01, WNG01

SECTION 12_GRAHAM ISLAND

< 2 {DHH 178 34-52'}

AMU02, HAG01, PAR10, CTS04, DRO03

< 1 {DHH 178 305-324.5'}

PAR11, SPI03, CTS04, DRO03, KAT04, PHS01

SECTION 13_SANDILANDS_ISLAND

< 3 {84 CNA SP 19/12}

CRU07, HAG01, HAG04, UDA04, UDA05, SOP07, ORB01, ORB02, SPI03, BPD09, DRO02, DRO03, DRO05, DRO06, LAX06, TRX01

< 2 {84 CNA SP 19/8}

CRU06, UDA04, UDA05, ORB01, BPD09

< 1 {84 CNA SP 19/1}

UDA04, SOP07, SPI03, DRO03, LAX06, PHS01, TRX01

SECTION 14_MAUDE_ISLAND

< 1 {87 CNA SP 18/3}

HAG03, ORB02, SAT05, SAT07, SPI03, BPD12, KAT04

SECTION 15_LOMGON_BAY

< 1 {88 OF LB 1}

CRU07, ORB01, ORB02, ORB03, PAR10, PAR11, SPI03, BAG02, CTS03, CTS04, DRO03, DRO06

SECTION 16_WILSON_BAY

< 1 {88 OF WB 3}

ARC04, CHA01, CHA02, DAN01, UDA04, UDA05, PAN10, PAN12, PAR08, ATA01, BPD08, CAN10, DRO02, DRO03, NIT01, PHS01