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*E.S. Carter and M.J. Orchard*

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# Intercalibrated conodont-radiolarian biostratigraphy and potential datums for the Carnian–Norian boundary within the Upper Triassic Peril Formation, Queen Charlotte Islands, British Columbia

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*Carter, E.S. and Orchard, M.J., 2000: Intercalibrated conodont-radiolarian biostratigraphy and potential datums for the Carnian–Norian boundary within the Upper Triassic Peril Formation, Queen Charlotte Islands, British Columbia; Geological Survey of Canada, Current Research 2000-A7, 11 p. (online; <http://www.nrcan.gc.ca/gsc/bookstore>)*

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**Abstract:** The succession of nasellarian radiolarians around the Carnian–Norian (Upper Triassic) boundary in Queen Charlotte Islands indicate their potential as tools for global correlation. Faunal similarities with central Oregon and Japan are noted, as are diagnostic European taxa. The boundary interval reflects a time of gradual radiolarian change, new taxa appearing synchronously with both Communisti and Primitius conodont zone faunas. The base of the Communisti Zone and the Macrolobatus ammonoid Zone are broadly coincident and hence this datum can be recognized with all three fossil groups. The base of the Primitius Zone falls within the Macrolobatus Zone and does not correspond to a clear ammonoid datum, whereas the base of the succeeding Kerri ammonoid Zone does not correspond to a clear microfossil signal. *Norigondolella navicula*, a conodont formerly used to subdivide the Primitius Zone, is facies controlled and cannot be used as a reliable indicator of the boundary.

**Résumé :** La succession de radiolaires nassellaires qui peut être reconnue près de la limite Carnien-Norien (Trias supérieur) dans les îles de la Reine-Charlotte offre des possibilités en tant qu'outil de corrélation à l'échelle planétaire. L'étude de ces radiolaires a permis d'établir des similitudes fauniques avec l'Orégon central et le Japon ainsi que d'identifier des taxons caractéristiques européens. L'intervalle associé à la limite témoigne d'une période de changement progressif dans la composition des faunes de radiolaires, de nouveaux taxons de radiolaires apparaissant en même temps que se manifestent les faunes des zones de conodontes à Communisti et à Primitus. La base de la Zone à Communisti coïncide grossièrement avec celle de la Zone d'ammonoïdés à Macrolobatus, de sorte que ce niveau de référence peut être identifié à l'aide des trois groupes de fossiles. La base de la Zone à Primitus se situe au sein de la Zone à Macrolobatus et ne correspond pas à un niveau de référence bien défini dans la composition des faunes d'ammonoïdés, alors que la base de la Zone d'ammonoïdés à Kerri subséquente n'est pas révélée de façon claire dans la composition des faunes de microfossiles. *Norigondolella navicula*, un conodonte auparavant utilisé pour subdiviser la Zone à Primitus, est une espèce dont la présence est déterminée par le faciès et ne peut donc être utilisé comme indicateur fiable de la limite.

## INTRODUCTION

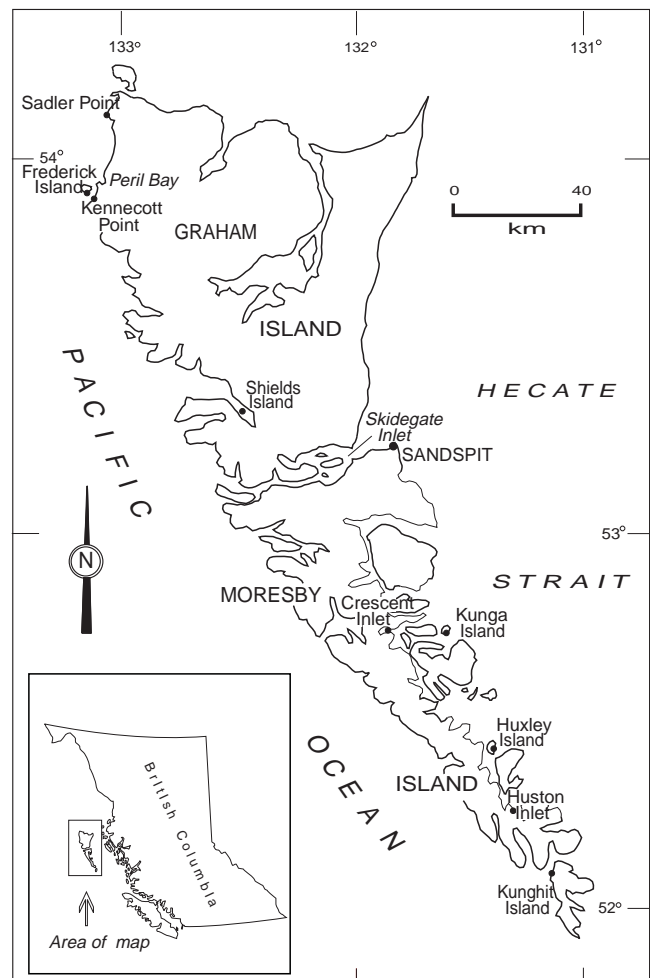
One remarkable feature of the Upper Triassic sections outcropping on Queen Charlotte Islands is the outstanding successions of conodont and radiolarian microfossils contained within the Peril Formation of the Kunga Group (Carter et al., 1989; Desrochers and Orchard, 1991; Orchard, 1991a; Carter, 1991, 1993). This report focuses on the successions about the Carnian–Norian boundary at several key localities. This boundary, the precise position of which remains undefined, may coincide with an interval of significant change in global fauna and flora, particularly in terrestrial habitats (e.g. Simms and Ruffell, 1990; Benton, 1991; Hallam and Wignall, 1997). In some areas of western Canada, the boundary also approximates a time of significant change in sedimentary regime, as for example in marginal cratonic sequences of northeast British Columbia where shallow-water carbonate rocks of the Baldonnel Formation are succeeded by deeper water facies of the Pardonet Formation. In Queen Charlotte Islands, the boundary lies entirely within the ‘oceanic’ slope deposits of the Peril Formation, part of the allochthonous Wrangell Terrane. The purpose of this study is to demonstrate faunal change that may potentially be used in global correlation and definition of the Carnian–Norian boundary, and thus contribute towards the resolution of historical events that date from that time.

The Geological Survey of Canada began biostratigraphic investigations of the Late Triassic part of the Kunga Group in Queen Charlotte Islands in 1987. The Late Triassic biostratigraphic succession (Upper Carnian to Rhaetian) is extraordinarily complete containing significant occurrences of conodonts, radiolarians, and fewer ammonoids and bivalves (Orchard et al., 1995). The radiolarian succession is essentially continuous from the Upper Carnian ammonoid zone of *Tropites welleri* through the end of the Rhaetian, although Middle Norian collections are relatively sparse. The radiolarian collections have been documented in a preliminary fashion (Orchard et al., 1990; Carter, 1991) but only the diverse Rhaetian succession has hitherto been documented in detail (Carter, 1990, 1993; Carter and Guex, 1999; Dumitrica and Carter, in press). The remainder of this important fauna remains largely undescribed.

The present report summarizes the radiolarian change within the Carnian–Norian boundary interval identified primarily by conodonts (Orchard, 1991a) but supplemented by some molluscan (mainly ammonoid) data. Much of the conodont zonation employed here was established in northeastern British Columbia, where ammonoids are more common and where a highly resolved and intercalibrated conodont-ammonoid zonation has been achieved (Orchard, 1991b; Orchard and Tozer, 1997). The present extrapolation of the zonation serves to document at least the partial range of some well known but previously poorly dated radiolarian taxa, and also suggests that the conodont zonation about the Carnian–Norian boundary requires some modification.

## STRATIGRAPHY

Triassic strata of the Kunga Group (Sutherland Brown, 1968) are widespread in Queen Charlotte Islands, mostly on Moresby and other islands south of Skidegate Inlet (Fig. 1). The most important and best preserved Triassic sections, however, are to be found on northwest Graham Island, around Peril Bay and Sadler Point. These two localities lend their names to two of the four Triassic formations recognized in Queen Charlotte Islands, namely the Sadler Limestone and the overlying Peril Formation (Desrochers and Orchard, 1991). The basal part of the Triassic succession consists of the volcanic rocks of the Karmutsen Formation, whereas the uppermost part is assigned to the Sandilands Formation, which ranges into the Lower Jurassic. Desrochers and Orchard (1991) have described the distribution, age, and depositional setting of the Triassic strata, each formation of which represents a distinct phase of Triassic deposition. Biostratigraphic studies have shown that virtually the entire



**Figure 1.** Map of Queen Charlotte Islands showing important conodont-radiolarian localities relevant to this study.

Upper Carnian, Norian, and Rhaetian stages are represented in the Kunga Group, which has a remarkably uniform development over the length and breadth of the islands.

The Peril Formation consists mainly of thinly bedded and siliceous, dark-grey to black limestone. Although compaction phenomena and a pervasive silicification often obscures primary depositional textures of the limestone units, three major limestone lithofacies are recognized, 1) radiolarian-rich, often nodular calcilitite; 2) laminated calc-arenite; and 3) bivalve (halobiids, monotids) coquina. In addition, intraformational conglomerate and echinoderm calc-arenite occur as minor lithofacies. The three major lithofacies dominate, respectively, the lower, middle, and upper parts of the Peril Formation, which is consequently differentiated into three informal members (Desrochers and Orchard, 1991). These members are recognized throughout the length of Queen Charlotte Islands but nowhere is there a single section in which the whole formation can be seen. Estimates of unit thickness have been compiled through a summation of several sections that are paleontologically dated as Upper Carnian through Upper Norian (see Orchard, 1991a). A total thickness of about 350 m is summed for the Peril Formation, with the lower, middle, and upper members being, respectively, about 90 m, 210 m, and 40+ m thick.

The most common lithofacies in the lower member of the Peril Formation, which embraces the Carnian–Norian boundary, consists of the radiolarian-rich calcilitite units, which often occur in fossiliferous nodules. Occasionally, small trace fossils of deposit-feeders such as *Planolites* and *Chondrites* occur in these strata, which are regarded as having accumulated slowly in deep water under low-energy, usually dysaerobic conditions. The lime mud is interpreted to have been derived from adjacent shallow-water carbonate platforms. Although no contemporaneous source is known from Queen Charlotte Islands, one did exist elsewhere in Wrangellia, as, for example, on north-central Vancouver Island (Jeletzky, 1976). A relatively rapid sea-level rise in the Upper Carnian resulted in the drowning of the older carbonate platform (Sadler Limestone), and the subsequent deposition of deeper water Peril Formation sediments in slope and basin settings.

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## LOCALITIES AND BIOCHRONOLOGICAL FRAMEWORK

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Microfaunas including radiolarians and conodonts were collected from fine-grained micrite concretions in measured sections of the Peril Formation. The most complete sequences are present at Sadler Point and Frederick Island on northern Graham Island (Fig. 1). At these localities, only poorly preserved ammonoids and/or occurrences of the bivalve *Perihalobia alaskana* are known. The latter has been regarded as an indicator of the Lower Norian *Stikinoceras kerri* Zone (Tozer, 1967, p. 36). Additional radiolarian collections from Shields Island, Kunga Island, Crescent Inlet, Huxley Island, Huston Inlet, and Kunghit Island (Fig. 1) provide supplementary information on the Carnian–Norian boundary microfaunas. Ammonoids of the uppermost

Carnian *Klamathites macrolobatus* Zone are known at both Huxley Island (GSC loc. C-157119, C-157123) and Kunghit Island (GSC loc. C-157382), which thus provides direct tie-in with the ammonoid zonal standard (Orchard, 1991a, Fig. 5).

The conodont succession about the Carnian–Norian boundary in western Canada has been outlined in a series of papers (Orchard, 1983, 1991a, b; Orchard and Tozer, 1997) that have also described the key conodont indices. The taxonomy and nomenclature of the species about this boundary are still in a state of flux but criteria presented previously (Orchard, 1991a, b) serve to adequately define successive zones that embrace potential levels for definition of the Carnian–Norian boundary, namely the *Nodosus*, *Communisti*, and *Primitius* zones. Subdivision of the *Primitius* Zone into Lower and Upper parts is based on the appearance of *Norigondolella navicula* (Huckriede). The base of the Upper *Primitius* Zone has been used as a working base for the Norian because its diagnostic conodonts are known in association with many occurrences of the *Kerri* Zone (e.g. in northeast British Columbia, GSC loc. C-87905, Brown Hill; GSC loc. 98515, 98562, Pardonet Hill), the ammonoid zone assigned to the basal Norian (Tozer, 1967, 1994). However, *Norigondolella* is sometimes absent from *Primitius* Zone faunas of *Kerri* Zone age (e.g. in northeast British Columbia, GSC loc. C-87906, Brown Hill; GSC loc. C-101773, Pardonet Hill), and in the Queen Charlotte Islands (Sadler Point, GSC loc. C-176928=SP-U6, Fig. 2) the genus is known to appear immediately prior to *Metapolygnathus primitius*. This situation invalidates the separation of a Lower *Primitius* Zone, and suggests that the appearance of *Norigondolella* is controlled rather by facies and is not a reliable event of chronostratigraphic significance. In the deeper water facies of the Wrangellian Peril Formation, *Norigondolella* appears earlier than in the epicratonic seas of western Pangea, now represented by the Triassic successions of northeast British Columbia.

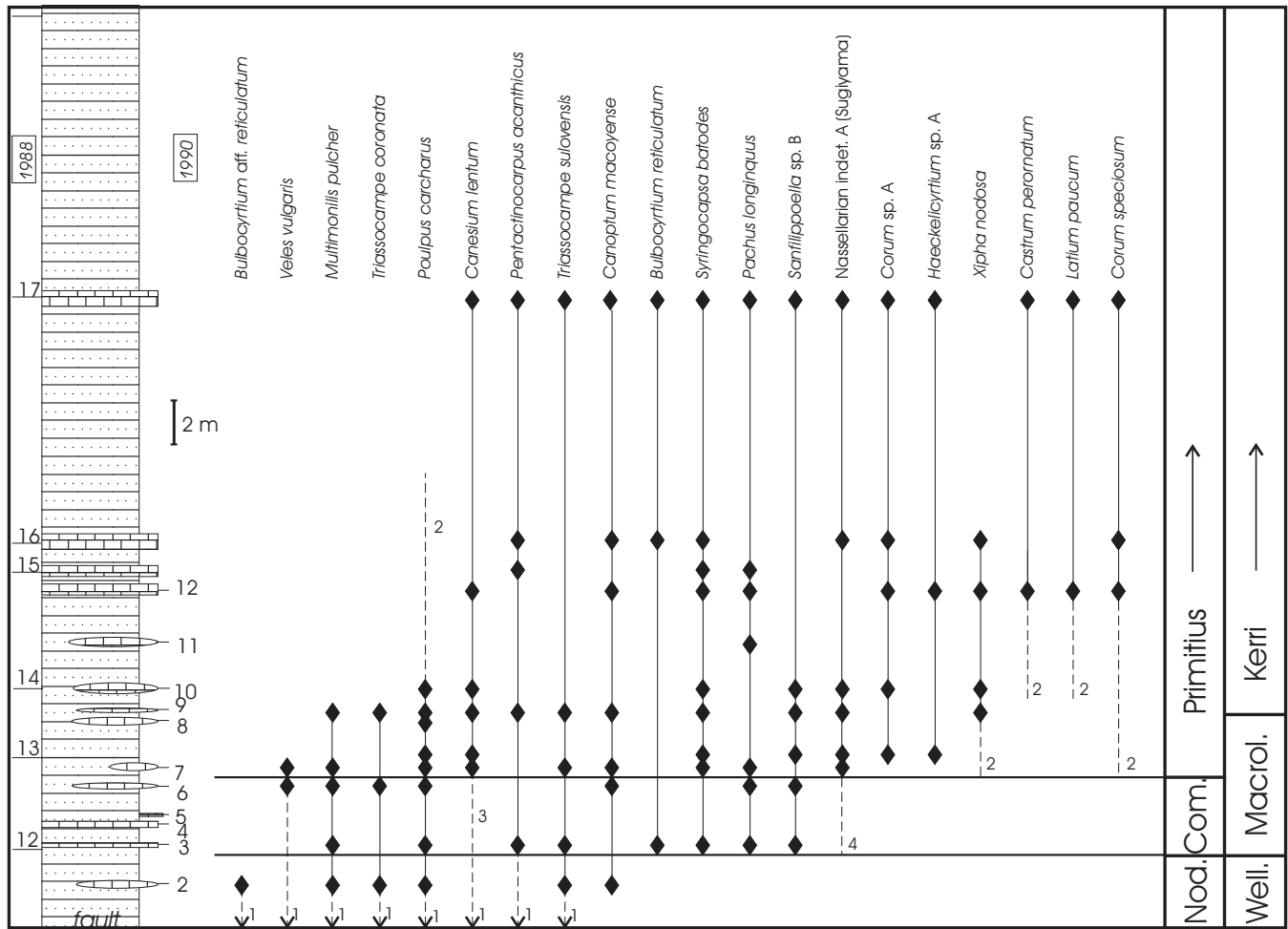
Radiolarians from Queen Charlotte Islands are associated with conodonts of the *Communisti* and *Primitius* zones of Orchard (1991a), those from the latter zone being the more common. A single collection from the underlying *Nodosus* Zone is also partly documented here to provide a lower datum. Radiolarians are common in strata equivalent to the *Nodosus* and *Primitius* zones with many collections available for detailed study. Coverage is much more limited in the *Communisti* Zone, an interval of rapid evolution in the conodont faunas. The radiolarian assemblages are also dated by comparison with existing zonations of Blome (1984) and Sugiyama (1997), although both schemes are imprecise in terms of independent dating.

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## RADIOLARIAN FAUNA

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Radiolarian faunas from the Carnian–Norian boundary interval are well preserved, diverse, and contain many well known forms along with a variety of new species. Numerical counts were not made owing to the statistical unreliability of the selectively picked samples studied, but spumellarians overwhelmingly dominate the fauna, comprising upwards of 80%



**Figure 2.** Range chart for selected Late Triassic radiolarians in strata of the *Nodosus* (Nod.), *Communisti* (Com.) and *Primitius* conodont zones on Sadler Point. Notations: 1 = range lowered to *Nodosus* Zone as suggested by data from Burnaby Island; 2 = range extended higher and lower in the *Primitius* Zone as suggested by data from Frederick Island; 3 = range lowered to *Communisti* Zone as suggested by data from Shields Island; 4 = range lowered to *Communisti* Zone as suggested by data from Kunghit Island; Well. = *Welleri*; Macrol. = *Macrolobatus*.

of individuals with genera such as *Capnodoce* De Wever, *Capnuhosphaera* De Wever, and *Sarla* Pessagno being the most common. The vast numbers and diversity of spumellarians, some possibly endemic, suggests they were well adapted to the region.

This study focuses on the less abundant nassellarian fauna which displays greater variety of shape and form and may prove more useful for global correlation. Over 90 species are recognized in the 33 samples studied; the distribution and abundance of 54 of the most common (including one spumellarian) from Sadler Point and Frederick Island is shown on Tables 1 and 2.

The most abundant nassellarian genera in the Queen Charlotte assemblages are *Canesium* Blome, *Canoptum* Pessagno, *Corum* Blome, *Multimonilis* Yeh, *Poulpus* De Wever, *Syringocapsa* Neviani, *Triassocampe* Dumitrica, Kozur and Mostler, and *Trilatus* Yeh. Numerous species

described from Oregon (see Blome, 1984; Yeh, 1989) are present in varying abundance including *Bulbocyrtium tubum* Yeh, *Canesium lentum* Blome, *Canoptum farawayense* Blome, *Canoptum macoyense* Blome, *Castrum perornatum* Blome, *Corum speciosum* Blome, *Latium paucum* Blome, *Multimonilis pulcher* Yeh, *Pachus longinquus* Blome, *Pseudosaturnumforma minuta* Blome, and *Triassocampe immaturum* Blome. The dominance of these species in both Oregon and Queen Charlotte Islands is not surprising given the general proximity of these two areas on the western edge of Pangea in Late Triassic time. It is also noteworthy that some of these species have been found in Japan (Sugiyama, 1997) and in the accreted terranes of southern British Columbia (Cordey, 1998).

The rare occurrence of some demonstrably global indicators described from southern Europe, Japan, and the Russian Far East is judged to be more important for correlation. These include *Bulbocyrtium reticulatum*, *Hozmadia spinosa*,

**Table 1.** Distribution and relative abundance of radiolarians from samples collected at Sadler Point in 1988 and 1990.

	9	8	9	9	8	9	9	8/	9	9	8/	9	8	8	8
<b>N</b> = Nodosus Zone	0	8	0	0	8	0	0	8/	0	0	8/	0	8	8	8
<b>C</b> = Communisti Zone	S	S	S	S	S	S	S	S/	S	S	S/	S	S	S	S
<b>P</b> = Primitius Zone	P	P	P	P	P	P	P	P/	P	P	P/	P	P	P	P
R = rare, 1-2 specimens	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
C = common, 3-6 specimens	2	12	6	7	13	8	9	14	10	11	15	12	16	17	18
A = abundant, >6 specimens															
<b>Conodont Zones</b>	<b>N</b>	<b>C</b>	<b>C</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>
<i>Annulopoulpus</i> sp. A		C		R	C		R	C	C	R	R	R		C	
<i>Anisicyrtis</i> aff. <i>formanae</i> Kozur & Mostler														R	C
<i>Bulbocyrtium reticulatum</i> Kozur & Mostler		C													
<i>Bulbocyrtium</i> aff. <i>reticulatum</i> Kozur & Mostler		C													
<i>Bulbocyrtium</i> aff. <i>insolitum</i> (Blome)		R		R	R			R					R	C	R
<i>Bulbocyrtium tubum</i> (Yeh)														C	R
<i>Canesium lentum</i> Blome				R	R		R	C	R			A		R	R
<i>Canesium</i> sp. C	R	C		C	C		C		C			A	R	C	C
<i>Canesium</i> sp. D				C	C			R				R	C	C	C
<i>Canoptum farawayense</i> Blome	R			A	C						C	C	C	C	C
<i>Canoptum macoyense</i> Blome	R		C	A			C					C	C	C	C
<i>Castrum perornatum</i> Blome												C	R	C	C
<i>Corum perfectum</i> Blome				R	R									C	
<i>Corum regium</i> Blome								?							R
<i>Corum speciosum</i> Blome													R	C	
<i>Corum</i> sp. A					R			C				R	C	C	
<i>Deflandrecyrtium</i> aff. <i>parvispinosum</i> Kozur & Mostler		C		R											
<i>Deflandrecyrtium</i> sp. B		R		R				R							
<i>Goestlingella</i> sp. A														C	C
<i>Haeckelicyrtium</i> sp. A (Sugiyama)					R							R		C	C
<i>Haeckelicyrtium</i> sp. A	C							R						C	C
<i>Hozmadia spinosa</i> Kozur & Mostler														C	C
<i>Hozmadia</i> sp. A	C			R			R							C	C
<i>Latium paucum</i> Blome												C	R		
<i>Multimonilis pulcher</i> Yeh	A	A	R	C		C									
<i>Nassellarian</i> indet. A (Sugiyama)				A	C		C		C				C	C	R
<i>Pachus longinquus</i> Blome		R					R		A	C	C	A		C	R
<i>Pentactinocarpus acanthicus</i> Dumitrica, Kozur & Mostler		R					R						R	A	
<i>Poulpus carcharus</i> Sugiyama	C	A	R	C	C	C	C	R	R						
<i>Poulpus pansus</i> DeWever														C	R
<i>Poulpus phasmatodes</i> DeWever				R		R								C	R
<i>Poulpus piabyx</i> DeWever				R			R							C	R
<i>Poulpus</i> sp. B	C	C		A	C	C	A	R	R			C		R	C
<i>Pseudosaturniiforma minuta</i> Blome														C	R
<i>Pseudotriassocampe hungarica</i> Kozur & Mostler														C	R
<i>Ruesticyrtium</i> sp. A		R	R	R				R	C						R
<i>Sanfilippoella</i> sp. B		R			R			R	C						R
<i>Sanfilippoella?</i> sp. D		C			R			R				R	C		C
<i>Silicarmiger</i> sp. A	R				R			R							
<i>Spinotriassocampe</i> sp. A				R	R							R	C		
<i>Syringocapsa batodes</i> DeWever		R		R	R			R	C			C	C	C	A
<i>Triassocampe coronata</i> Bragin	C		C					C					C		R
<i>Triassocampe immaturum</i> Blome				R	R							C	C		
<i>Triassocampe sulovensis</i> Kozur & Mostler	C	C		R	R			R							R
<i>Trilatus longicornutus</i> Yeh				R	R										
<i>Trilatus robustus</i> (Nakaseko & Nishimura)					R								R	R	C
<i>Trilatus</i> aff. <i>robustus</i> (Nakaseko & Nishimura)					R			C	R	R	C	C		R	C
<i>Trilatus</i> sp. B	R	C			C	R		C	C	C	C	C		C	C
<i>Veghia</i> sp. A			R	R	C	R		C	R	R				C	C
<i>Veles vulgaris</i> Sugiyama			R	R											
<i>Xipha nodosa</i> Sugiyama								R		R			C	R	
<i>Xiphotheca karpensionensis</i> DeWever															C
<i>Xiphotheca longa</i> Kozur & Mostler															R

**Table 2.** Distribution and relative abundance of radiolarians from samples collected at Frederick Island in 1988; samples A9-A13 in succession; samples 1 and 2 separated by a fault.

<b>P = Primitius Zone</b>	8	8	8	8	8
R = rare, 1-2 specimens	8	8	8	8	8
C = common, 3-6 specimens	F	F	F	F	F
A = abundant, >6 specimens	I	I	I	I	I
	A	A	A		
	9	11	13	1	2
<b>Conodont Zones</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>
<i>Annulopoulpus</i> sp. A	R			C	C
<i>Bulbocyrtium reticulatum</i> Kozur & Mostler				C	
<i>Bulbocyrtium disertum</i> (Blome)	R				
<i>Bulbocyrtium</i> aff. <i>insolitum</i> (Blome)	R				R
<i>Bulbocyrtium tubum</i> (Yeh)					R
<i>Canesium lentum</i> Blome				R	R
<i>Canesium</i> sp. C	C			C	C
<i>Canesium</i> sp. D				C	
<i>Canoptum farawayense</i> Blome	C			C	R
<i>Canoptum macoyense</i> Blome	C			C	R
<i>Castrum perornatum</i> Blome			R	R	
<i>Corum perfectum</i> Blome				C	
<i>Corum regium</i> Blome				R	
<i>Corum speciosum</i> Blome	C		R	A	
<i>Corum</i> sp. A	R			A	
<i>Deflandrecyrtium</i> aff. <i>parvispinosum</i> Kozur & Mostler	R				
<i>Deflandrecyrtium</i> sp. B		R			
<i>Hozmadia</i> sp. A				R	
<i>Latium paucum</i> Blome				R	
<i>Pachus longinquus</i> Blome	C		C	C	
<i>Pentactinocarpus acanthicus</i> Dumitrica, Kozur & Mostler	R			C	
<i>Poulpus carcharus</i> Sugiyama	C		R		
<i>Poulpus pansus</i> DeWever				R	
<i>Poulpus phasmatodes</i> DeWever			R		
<i>Poulpus</i> sp. B	R		R	R	R
<i>Pseudosaturiniforma minuta</i> Blome				R	R
<i>Ruesticyrtium</i> sp. A				R	
<i>Sanfilippoella</i> sp. B				C	
<i>Sanfilippoella?</i> sp. D			R	C	R
<i>Spinotriassocampe</i> sp. A				R	
<i>Syringocapsa batodes</i> DeWever		R		C	C
<i>Trilatus robustus</i> (Nakaseko & Nishimura)			R		
<i>Trilatus</i> aff. <i>robustus</i> (Nakaseko & Nishimura)	C	R		C	
<i>Trilatus</i> sp. B	C		R	C	
<i>Veghia</i> sp. A				C	
<i>Xipha nodosa</i> Sugiyama	C				
<i>Xiphotheca karpensionensis</i> DeWever				R	R

*Pentactinocarpus acanthicus*, *Pseudosaturiniforma carnica*, *Pseudotriassocampe hungarica*, *Triassocampe sulovensis*, and *Xiphotheca longa*, described by Kozur and Mostler (1979, 1981, 1994) and Dumitrica et al. (1980) from areas in Austria, Hungary, and Italy; *Poulpus pansus*, *P. phasmatodes*, *P. piabyx*, *Syringocapsa batodes*, and *Xiphotheca karpensionensis*, described by De Wever (in De Wever et al., 1979) from Greece; *Triassocampe coronata* from the Russian Far East (Bragin, 1991); and, from Japan, *Haeckelicyrtium* sp. A, *Poulpus carcharus*, *Veles vulgaris*, *Xipha nodosa*, and Nassellarian indet. A, described by Sugiyama (1997), and *Trilatus robustus*, described by Nakaseko and Nishimura (1979). Distribution data for these species are presented on Tables 1 and 2. The balance of the Queen Charlotte Islands

fauna is new and consists mostly of species of *Annulopoulpus* Kozur and Mostler, *Bulbocyrtium* Kozur and Mostler, *Canesium* Blome, *Corum* Blome, *Haeckelicyrtium* Kozur and Mostler, *Poulpus* De Wever, *Sanfilippoella* Kozur and Mostler, *Trilatus* Yeh, *Veghia* Kozur and Mostler, and several indeterminate nassellarians.

Distributional data from all localities sampled indicates that over two-thirds of nassellarian species studied range through the Communisti and Primitius conodont zones, suggesting that the Carnian–Norian boundary interval was a time of gradual, rather than dramatic radiolarian change. This change is apparent more in the increasing abundance of certain genera and species than in abrupt extinctions and the appearance of successor taxa. For example, some genera



arising in strata equivalent to the Communisti Zone, e.g. *Pachus* Blome and *Syringocapsa* Neviani, are rare and represented by a single species whereas in the younger Primitius Zone they are more abundant and diverse. This phenomenon is true also for *Corum* Blome, which occurs sporadically in the lower part of Primitius Zone strata but a little higher becomes very abundant and diverse.

The succession of conodont and radiolarian faunas is best demonstrated in the stratigraphic sequence at Sadler Point, which is the most complete anywhere in Queen Charlotte Islands. The range of 20 of the most abundant nassellarian species with respect to the conodont zones is shown in Figure 2, which also incorporates overall ranges suggested by supplementary data from Burnaby Island, Shields Island, and Kunghit Island. Against the background of fairly gradual radiolarian evolution across the boundary, four new appearances are recorded in the Communisti Zone and seven in the lower part of the Primitius Zone. The last appearance of *Bulbocerythium* aff. *reticulatum* (which ranges down to the Nodosus Zone), occurs in the Communisti Zone, whereas *Multimonilis pulcher*, *Veles vulgaris*, *Triassocampe coronata*, and *Poulpus carcharus* go extinct in the Primitius Zone. *Xipha nodosa* Sugiyama appears to be restricted to Primitius Zone in Queen Charlotte Islands; its range in Japan is similarly short, although somewhat older (see Sugiyama, 1997).

## SUMMARY AND CONCLUSIONS

Preliminary observations on the radiolarian succession in Queen Charlotte Islands indicate that the potential for global correlation around the Carnian–Norian boundary using Late Triassic nassellarians is quite good. Both older and younger nassellarians need to be studied to realize the full potential of the group, and the larger spumellarian fauna could clearly add substantial data. As presently understood, the Queen Charlotte Islands radiolarian fauna compares most closely with faunas described by Blome (1984) and Yeh (1989, 1990) from central Oregon but strong similarities are also recognized with faunas from Japan (Sugiyama, 1997).

Broadly, over two-thirds of total radiolarian species studied range through the Communisti and Primitius conodont zones indicating the Carnian–Norian boundary interval was a time of gradual, rather than dramatic radiolarian change. Nevertheless, new taxa are recognized at the base of both the Communisti and Primitius zones, either of which could serve as a datum for boundary definition.

The Communisti Zone corresponds to a position coincident with, or approximating the base of, the Macrolobatus ammonoid Zone based on occurrences on Queen Charlotte Islands (GSC loc. C-157382, Kunghit Island) and northeast British Columbia (GSC loc. 68202, Mt. McLearn) (Orchard, 1991a, Fig. 5; Orchard and Tozer, 1997, p. 684). Use of the base of the Communisti Zone as the datum for the Carnian–Norian boundary has the advantage of providing contemporaneous ammonoid, conodont, and radiolarian indices for its recognition.

Data from both the Queen Charlotte Islands (GSC loc. C-157119, C-157123, Huxley Island) and northeastern British Columbia (GSC loc. 64616, 64628, Pardonet Hill; GSC loc. 94738, Mt. Laurier) demonstrate that the base of the Primitius Zone also falls within the Macrolobatus Zone (Orchard, 1991a, Fig. 8; Orchard and Tozer, 1997, p. 685). Hence although the use of the Primitius Zone as the datum for the Carnian–Norian boundary has clear microfossil characteristics, it has the effect of including some Macrolobatus Zone ammonoid faunas within the Norian. Resolution of that ammonoid zone is not possible on ammonoid fauna alone, there being very little data on ammonoid succession within it (E.T. Tozer, pers. comm., 1999). This lack of a well defined ammonoid signature corresponding to the base of the Communisti Zone therefore constitutes a problem for boundary definition.

Use of the base of the succeeding Kerri ammonoid Zone as the boundary datum, as has been customary in North America, apparently does not correspond to a clear or reliable conodont or radiolarian signal. Samples from the Kerri Zone invariably yield a Primitius Zone conodont fauna, but it may or may not include *Norigondolella navicula*, a taxon used formerly to differentiate Lower and Upper parts of the Primitius Zone (Orchard, 1983, 1991a, b). Apparent facies control of this species precludes its use as an index to the Carnian–Norian boundary. At Sadler Point in Queen Charlotte Islands, the Primitius Zone cannot be subdivided.

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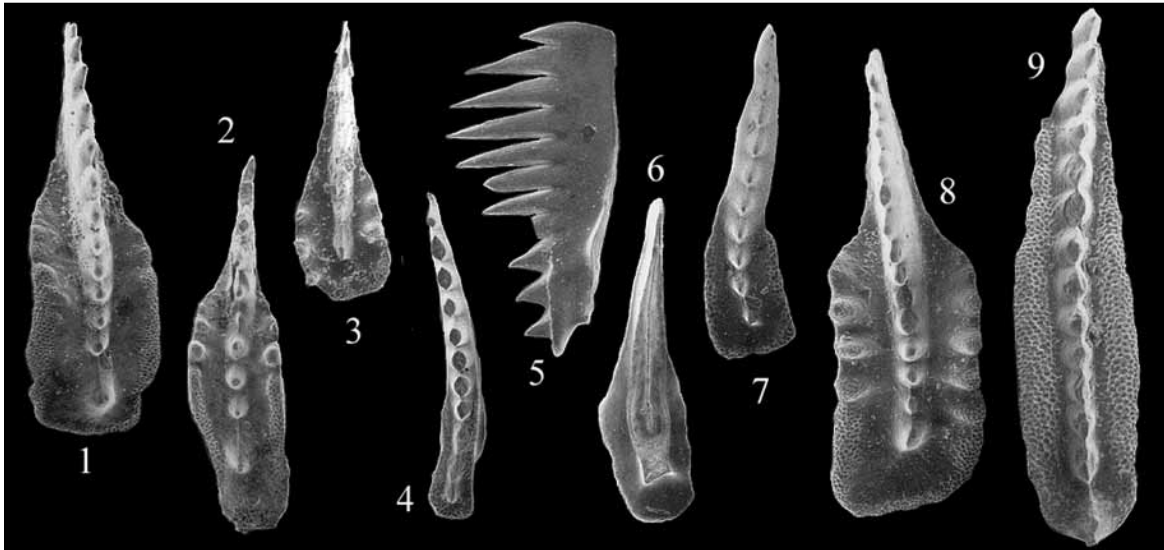
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## Plate 1



## PLATE 1

Scanning electron micrographs of conodonts from the Upper Triassic Peril Formation, Queen Charlotte Islands, British Columbia. Specimens are mostly upper views (fig. 5=lateral; and 6=lower) of specimens from Frederick Island (fig. 9=Sadler Point), at x80 magnification. See Orchard (1991a) for age of each sample in terms of conodont zone.

Figure 1. *Metapolygnathus nodosus* (Hayashi). GSC 101815, from GSC loc. C-156538 (sample 88-FI-A9).

Figure 2. *Metapolygnathus nodosus* (Hayashi). GSC 101816, from GSC loc. C-156536 (sample 88-FI-A7).

Figure 3. *Metapolygnathus pseudoechinatus*. GSC 101817, from GSC loc. C-156541 (sample 88-FI-A12).

Figure 4. *Metapolygnathus communisti* (Hayashi). GSC 101818, from GSC loc. C-156538 (sample 88-FI-A9).

Figure 5. *Metapolygnathus communisti* (Hayashi). GSC 101819, from GSC loc. C-156538 (sample 88-FI-A9).

Figure 6. *Metapolygnathus communisti* (Hayashi). GSC 101820, from GSC loc. C-156538 (sample 88-FI-A9).

Figure 7. *Metapolygnathus communisti* (Hayashi). GSC 101821, from GSC loc. C-156538 (sample 88-FI-A9).

Figure 8. *Metapolygnathus primitius* (Mosher). GSC 101822, from GSC loc. C-156538 (sample 88-FI-A9).

Figure 9. *Norigondolella navicula* (Huckriede). GSC 101823, from GSC loc. C-156579 (sample 88-SP-16).

## PLATE 2

Scanning electron micrographs of radiolarians from the Upper Triassic Peril Formation, Queen Charlotte Islands, British Columbia. All specimens are nassellarians except figure 4 (a spumellarian). See Orchard (1991a) for age of each sample in terms of conodont zone.

Figure 1. *Syringocapsa batodes* De Wever. GSC 108708, x168, from GSC loc. C-156575, Sadler Point (sample 88-SP-12).

Figure 2. *Bulbocyrtium* aff. *reticulatum* Kozur and Mostler. GSC 108709, x133, from GSC loc. C-157294, Burnaby Island (sample 87-BI-4C).

Figure 3. *Bulbocyrtium reticulatum* Kozur and Mostler. GSC 108710, x200, from GSC loc. C-156529, Frederick Island (sample 88-FI-1).

Figure 4. *Pentactinocarpus acanthicus* Dumitrica, Kozur and Mostler. GSC 108711, x115, from GSC loc. C-156529, Frederick Island (sample 88-FI-1).

Figure 5. *Sanfilippoella* sp. B. GSC 108712, x200, from GSC loc. C-176577, Sadler Point (sample 88-SP-14).

Figure 6. *Canesium lentum* Blome. GSC 108713, x200, from GSC loc. C-176577, Sadler Point (sample 88-SP-14).

Figure 7. *Poulpus carcharus* Sugiyama. GSC 108714, x133. GSC loc. C-176934, Sadler Point (sample 90-SP-U9).

Figure 8. Nassellarian indet. A (Sugiyama, 1997). GSC 108715, x200. GSC loc. C-176931, Sadler Point (sample 90-SP-U7).

Figure 9. *Castrum perornatum* Blome. GSC 108716, x200, from GSC loc. C-156529, Frederick Island (sample 88-FI-1).

Figure 10. *Canoptum macoyense* Blome. GSC 108717, x200. GSC loc. C-156575, Sadler Point (sample 88-SP-12).

Figure 11. *Corum* sp. A. GSC 108718, x200, from GSC loc. C-156529, Frederick Island (sample 88-FI-1).

Figure 12. *Haeckelicyrtium* sp. A (Sugiyama, 1997). GSC 108719, x206, from GSC loc. C-157149, Crescent Inlet (sample 87-CRE-4).

Figure 13. *Multimonilis pulcher* Yeh. GSC 108720, x173, from GSC loc. C-176923, Sadler Point (sample 90-SP-U2).

Figure 14. *Triassocampe sulovensis* Kozur and Mostler. GSC 108721, x232, from GSC loc. C-156575, Sadler Point (sample 88-SP-12).

Figure 15. *Triassocampe coronata* Bragin. GSC 108722, x200. GSC loc. C-176934, Sadler Point (sample 90-SP-U9).

Figure 16. *Pachus longinquus* Blome. GSC 108723, x200, from GSC loc. C-156529, Frederick Island (sample 88-FI-1).

Figure 17. *Corum speciosum* Blome. GSC 108724, x200, from GSC loc. C-156529, Frederick Island (sample 88-FI-1).

Plate 2

