Natural Resources Canada   Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 9071

Palynological analyses of samples from the Comox Sub-basin, Suquash Sub-basin, and Cretaceous strata of northern Vancouver Island, British Columbia

J.M. Galloway, S.M.S. McLachlan, A. Sproule,
S.E. Dashtgard, and M. Bringué

2023

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 9071

Palynological analyses of samples from the Comox Sub-basin, Suquash Sub-basin, and Cretaceous strata of northern Vancouver Island, British Columbia

J.M. Galloway [1], S.M.S. McLachlan[2], A. Sproule[3], S.E. Dashtgard[3], and M. Bringué[1]

[1]Geological Survey of Canada, 3303-33rd Street N.W., Calgary, Alberta
[2]Earth and Environmental Sciences, University of Minnesota, 116 Church St SE Minneapolis, Minnesota, USA 55455
[3]Earth Sciences, Simon Fraser University, 8888 University Drive, Burnaby, British Columbia

2023

Permanent link: https://doi.org/10.4095/332316

Recommended citation
Galloway, J.M., McLachlan, S.M.S., Sproule, A., Dashtgard, S.E., and Bringué, M., 2023. Palynological analyses of samples from the Comox Sub-basin, Suquash Sub-basin, and Cretaceous strata of northern Vancouver Island, British Columbia; Geological Survey of Canada, Open File 9071, 87 p. https://doi.org/10.4095/332316

ISSN 2816-7155
ISBN 978-0-660-68915-9
Catalogue No. M183-2/9071E-PDF

Table of Contents

FOREWORD

This work develops a more comprehensive palynological framework than currently exists for the purpose of improved stratigraphic correlation of Upper Cretaceous strata of northern Vancouver Island. Improved chronostratigraphic control will aid in informing the timing of accretion of exotic terranes to the western Canadian margin as well as to provide new insight into the unique paleovegetation, paleoecology, and depositional environments of northern Vancouver Island during the Late Cretaceous.

PROJECT SUMMARY

Pollen, spore, and dinoflagellate cyst-based biostratigraphic analyses are presented on twenty-three samples of Cretaceous age collected from the Comox and Suquash sub-basins of northern Vancouver Island. The samples reveal depauperate dinoflagellate cyst assemblages but diverse and well-preserved pollen and spore assemblages that indicate a Late Cretaceous age for most of the samples. The pollen and spores preserved in the material are representative of the latest Cretaceous Continental Margin floristic province that is characterized by numerous endemic taxa due to geographic isolation from the western interior of North America and a temperate maritime climate.

INTRODUCTION

Canada’s west coast contains several sedimentary basins in British Columbia (BC), including the Georgia Basin, Queen Charlotte Basin, Tofino Basin, and the Hecate Depression. The boundaries between basins are estimated based on chronostratigraphic correlation of strata and/or geographic separation. Upper Cretaceous sedimentary strata of northern Vancouver Island (Fig. 1) define the outlying Suquash Sub-basin (Muller and Jeletzky, 1970; Bickford and Kenyon, 1988; Kent et. al, 2020) that is correlative to the Georgia Basin. Triassic to Lower Cretaceous strata that appear to underlie the Suquash Sub-Basin, or are laterally adjacent to it, are correlated to the Queen Charlotte Basin based on molluscan fossils. These correlations indicate either an overlap between the basins or incorrect inferences in existing stratigraphic correlations for these time intervals. Strata of many convergent-margin basins, including forearc basins such as the Georgia Basin, remain characterized mainly by lithostratigraphic and/or biostratigraphic frameworks that were not developed with the intent to determine time equivalency of strata or to reconstruct basin evolution. Thus, the lithostratigraphy alone of the Georgia Basin has led to on-going uncertainty of basin architecture and its depositional history, impeding correlation both within the basin and to strata in other basins. The Georgia Basin is known globally because it preserves strata of the Nanaimo Group that are key to the ‘Baja BC’ hypothesis that states that the Georgia Basin was situated off northern Mexico/southern California during deposition of the Nanaimo Group, and was subsequently translated north (e.g., Irving, 1985). Understanding the tectono-evolution of Canada’s landmass has many scientific and economic derivations, including assessment of natural resources and interpreting the response of past ecosystems to climatic and tectonic perturbations that can be used to inform how ecosystems are likely to respond to future change.

Herein, we present palynological results and interpret ages for samples collected from Cretaceous strata exposed across northern Vancouver Island and for Nanaimo Group strata exposed along the Oyster River in the northern Georgia Basin (Figs. 1–4). The purpose of this work is to improve correlation of strata on northern Vancouver Island to those of successions within both the Georgia and Queen Charlotte basins and to broadly infer paleoenvironments. We develop the most comprehensive palynological framework to date for strata of northern Vancouver Island. The improved palynology-based chronostratigraphic control will aid in informing the timing of accretion of exotic terranes to the western Canadian margin and serve to provide new insight into the unique paleovegetation, paleoecology, and depositional environments of northern Vancouver Island during the Late Cretaceous.

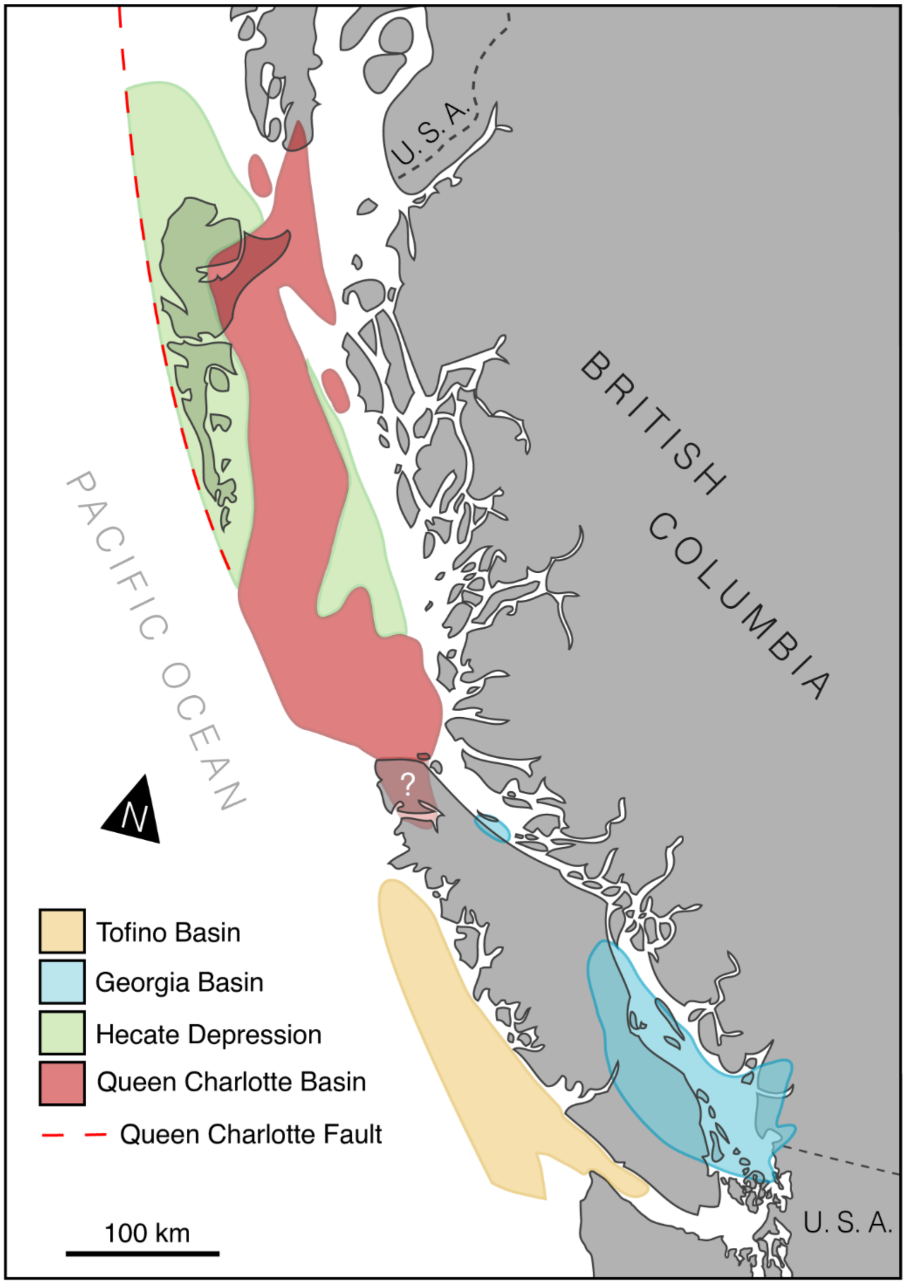

Figure 1. Map of Canada's west coast showing the approximate extents of the Tofino Basin (yellow), Georgia Basin (blue), Hecate Depression (green), and Queen Charlotte Basin (red) (after Wheeler et al., 1996 and Huang et al., 2019). The Suquash Sub-basin occurs in the Georgia Basin remnant on the northeastern coast of Vancouver Island.

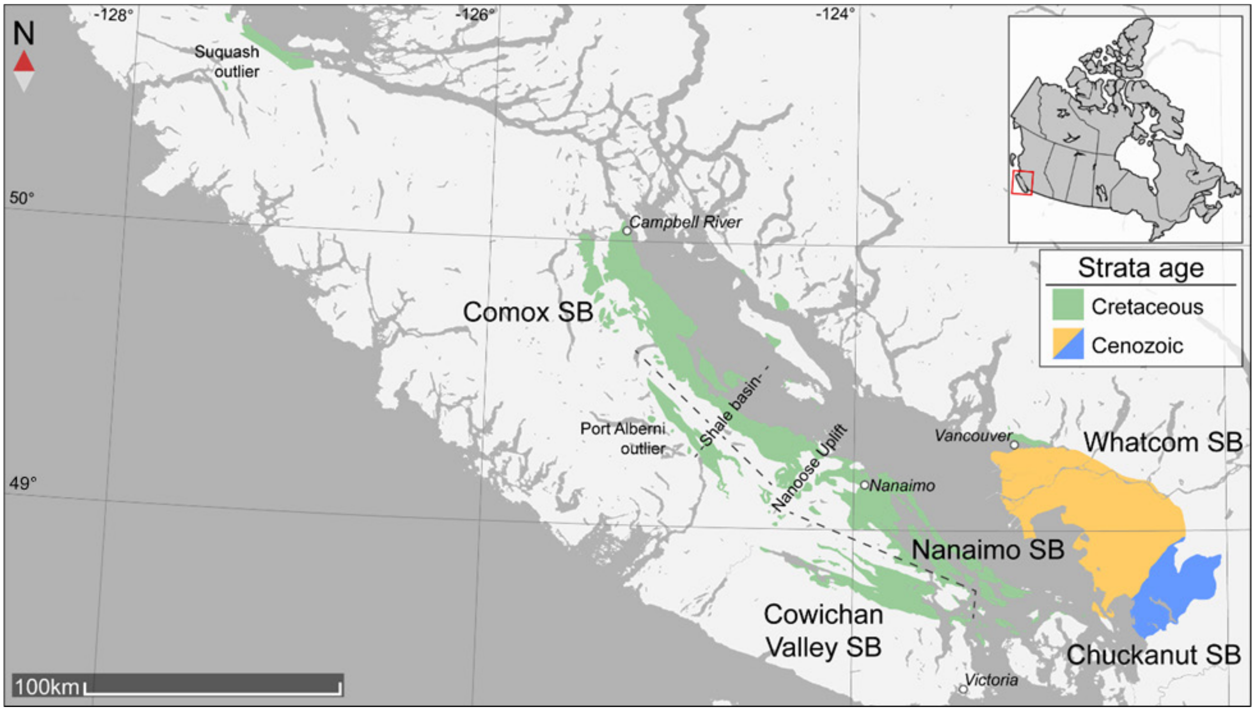

Figure 2. Major outcrop areas of the Georgia Basin and associated sub-basins (SBs) of Vancouver Island and the adjacent mainland of British Columbia from Huang et. al. (2022). Red square in inset map of Canada shows enlarged area. Cretaceous sub-basins filled with Nanaimo Group strata are shown in green, and sub-basins filled with Cenozoic-aged strata are shown in orange (Whatcom SB) and blue (Chuckanut SB). Dashed lines indicate boundaries between the different sub-basins and outcrop areas. The Suquash Sub-basin or outlier is located on the northeastern coast of Vancouver Island.

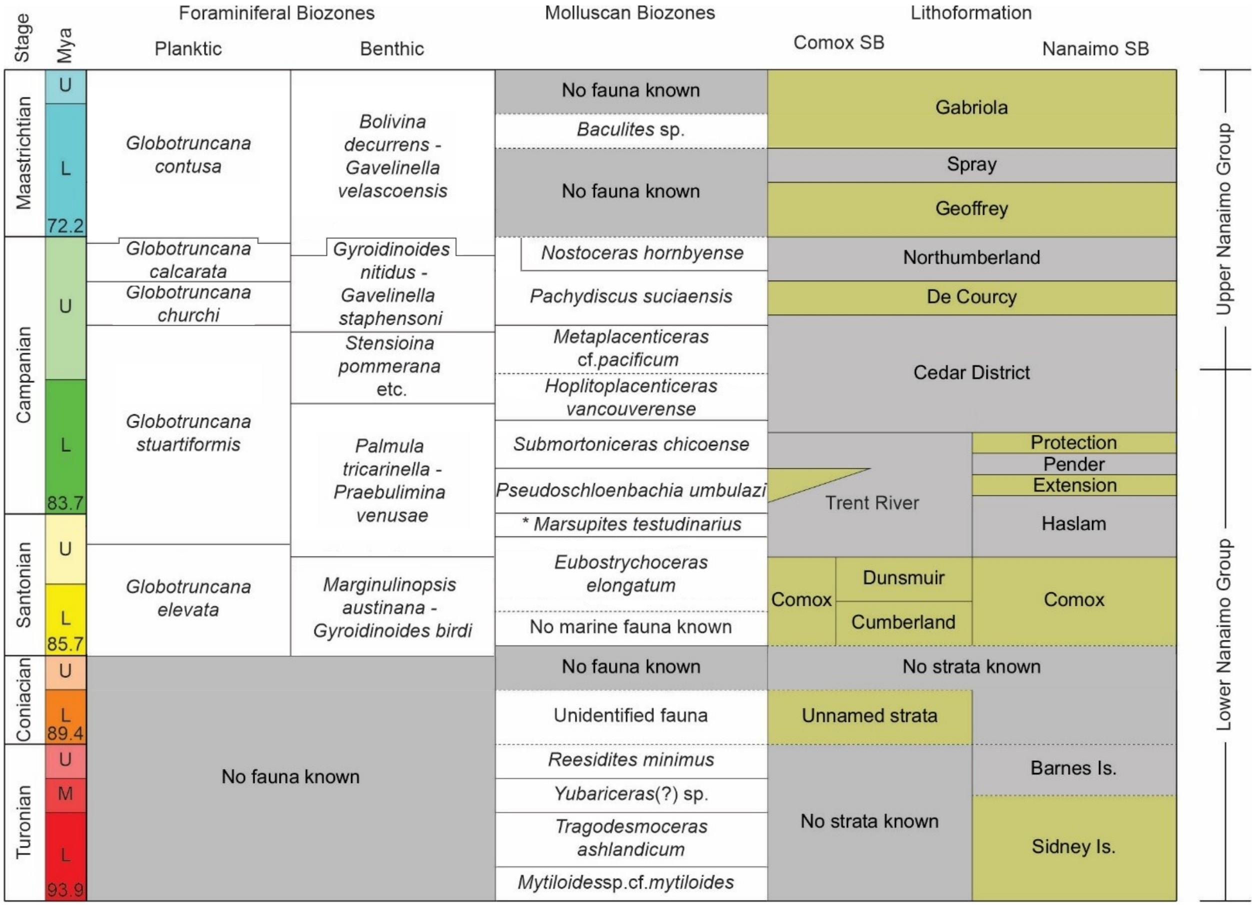

Figure 3. Nanaimo Group lithostratigraphy (Mustard, 1994; Haggart et al., 2005) and published biostratigraphic schemes, including: foraminiferal (Sliter, 1973; McGugan, 1979) and molluscan biozones (Jeletzky, 1970; Ward, 1978; Haggart et al., 2005, 2009, 2011; Ward et al., 2012; Haggart and Graham, 2018; McLachlan and Haggart, 2018). In the lithoformation column, yellow indicates predominantly coarse-grained strata (sandstone and/or conglomerate) and gray indicates predominantly fine-grained strata (mudstone/shale). Abbreviations: U – upper; M – middle; L – lower; SB – sub-basin. ****Marsupites testudinarius* **is a crinoid (Echinodermata). Figure modified from Huang et al. (2022). The Geological Time Scale v. 2020 is used (Gale et al., 2020).**

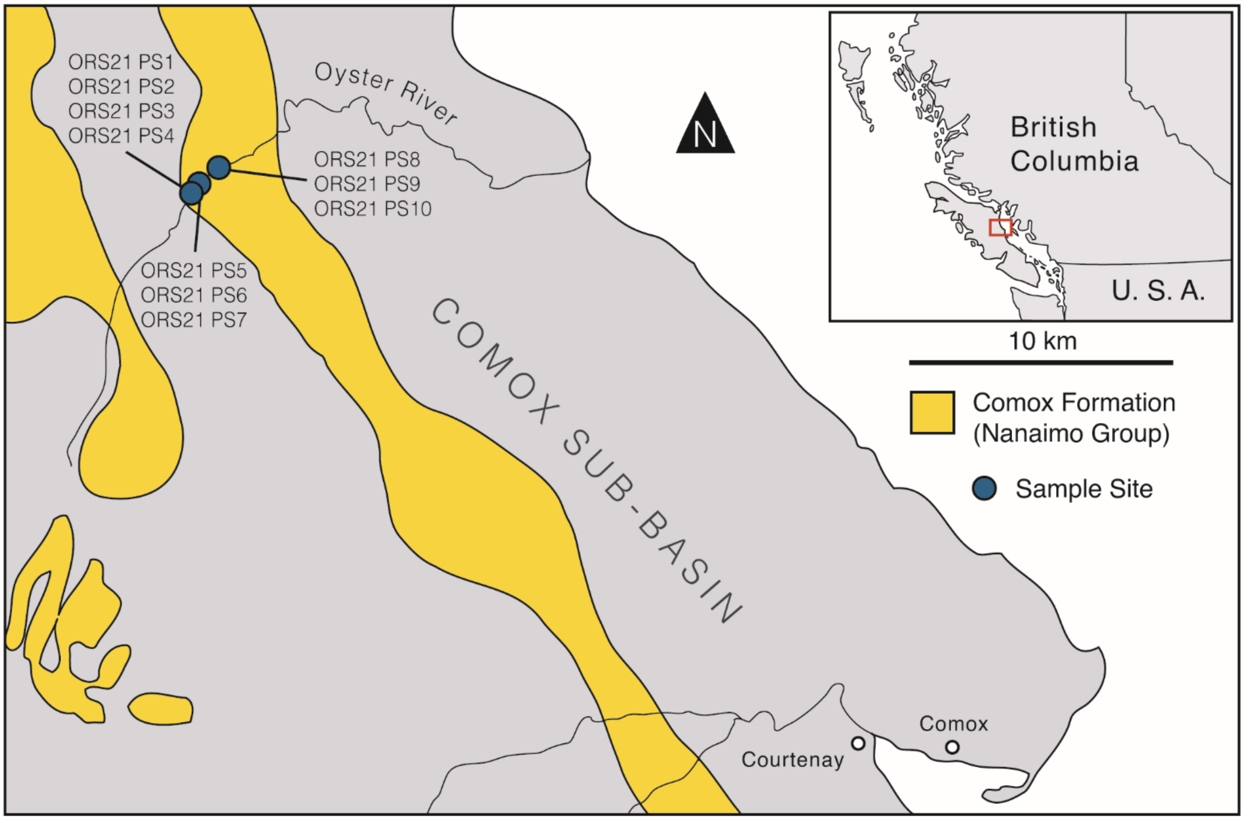

Figure 4. Map of eastern Vancouver Island showing the location of samples collected from the Comox Formation (yellow) of the Nanaimo Group along the Oyster River within the Comox Sub-basin. Geology after Mustard (1994).

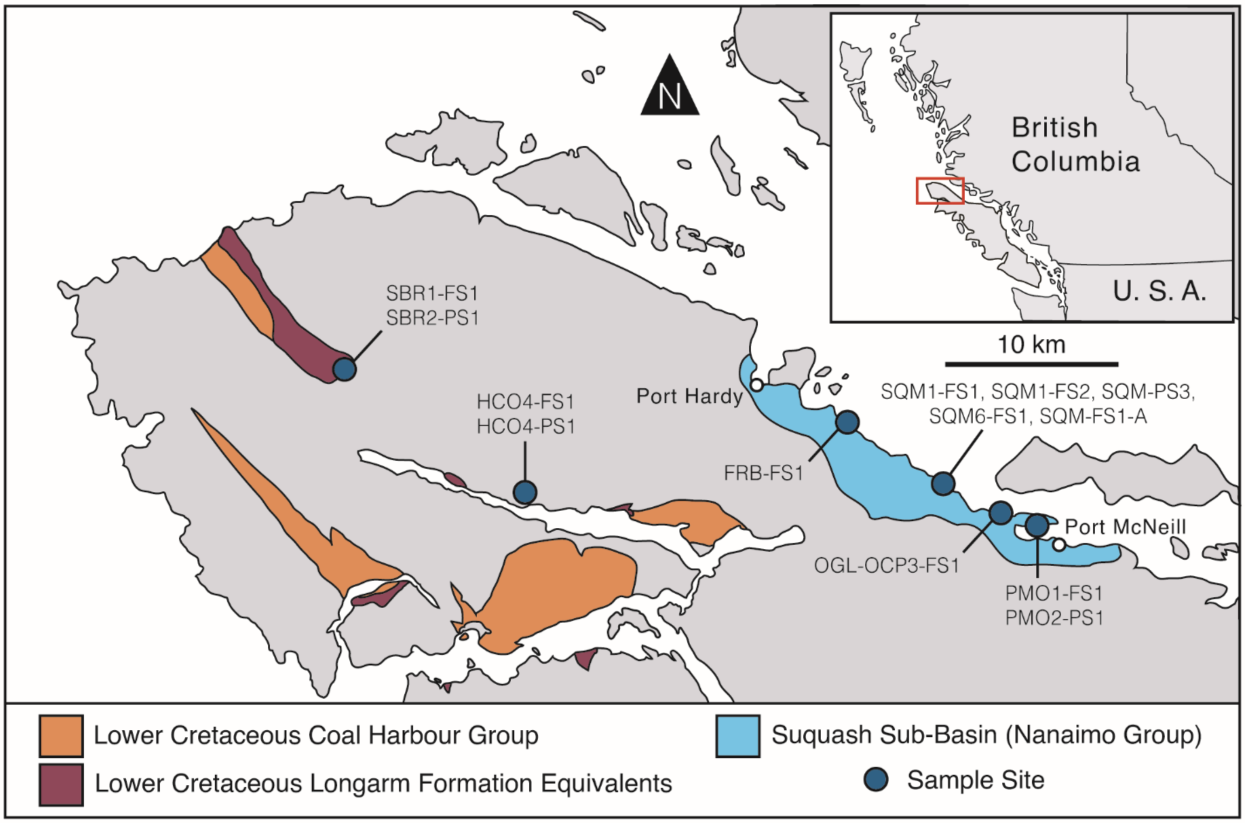

Figure 5. Map of northern Vancouver Island showing the location of samples collected from Lower Cretaceous rocks of Longarm Formation equivalents (maroon) as well as the Coal Habour Group (orange) and Suquash Sub-basin (blue) of Nanaimo Group equivalents. Geology after Muller (1974) and Jeletzky (1976). Sample FRB-FS1 corresponds approximately to GSC loc. 82962 and 82963 in proximity to the mouth of the Keogh River.

The Late Cretaceous Normapolles floristic province occupied southern and eastern North America and Europe up to the West Siberian Plain between 56 °N and 36 °N, while the *Aquilapollenites* floristic province, which had elements in common with the Normapolles floristic province, occupied the northern and western parts of North America, from at least northern New Mexico northward to the Arctic islands and Alaska (Batten, 1984; cf. Braman and Koppelhus, 2005). A less widespread phytogeoprovince, the Continental Margin floristic province, occupied coastal BC and California during the Campanian to Maastrichtian (Frederiksen, 1987). This province is preserved in Upper Cretaceous strata that overlie rocks of the Wrangellia terrane and the Coast Plutonic Complex in southwestern BC, on the Salinian terrane of the La Panza Range, and on the Stanley Mountain terrane of the southeastern San Rafael Mountains (Frederiksen, 1987). The Continental Margin floristic province differs from the Normapolles and *Aquilapollenites* floristic provinces in its largely endemic pollen taxa, a notable abundance of *Tschudypollis* (formerly *Proteacidites*) pollen, and low abundance or absence of *Aquilapollenites*, *Callistopollenites*, and Normapolles pollen, as well as possibly wind-pollinated triporate and monosulcate angiosperm pollen (Fredericksen, 1987). This phytogeoprovince was isolated from others to the east due to oceanic and mountain barriers, but its endemism also probably reflects a more tropical climate of a maritime setting than was experienced in more inland regions of North America (Fredericksen, 1987). The endemism of the Continental Margin floristic province presents a challenge for palynological-based biostratigraphy in the absence of independent age control. Therefore, from a palynostratigraphic perspective, northern

Vancouver Island can be considered a frontier area that requires more research into land plant evolution, paleoecology, and chronostratigraphy. The paper that first describes the Continental Margin floristic province is that of Fredericksen (1987), which is cited in Google Scholar (accessed Nov. 16th, 2022) only 21 times, representing the paucity of published records (as a proxy for knowledge) pertaining to this floristic province.

GEOLOGICAL SETTING

The Nanaimo Group is preserved in the Georgia Basin, the erosional remnant of a single northwest-trending structural and topographic depression that presently underlies the Georgia Strait, Gulf Islands, and eastern Vancouver Island (Fig. 1). The current preserved extent of the Georgia Basin (now broken into several regions by fault-bounded basement uplifts) is about 250 x 100 km, but the original depositional extent was probably much greater (Mustard and Monger, 1991; Hamblin, 2012). At times the basin was probably open to the ocean to the west (Ward and Stanley, 1982; Johnstone, et al., 2006), and at other times was separated by an emergent highland (Mustard, 1994; Kent et al., 2020; Girotto et al., in review). To the east, the basin was bound by the Coast Plutonic complex (Monger et. al, 1982; Monger and Price, 2002), which comprises a series of Jurassic to Eocene continental arc plutons (Cecil et al., 2018). It may also have received sediment from plutons situated along the margin of North America (Mahoney et al., 1999; 2021; Matthews et al., 2017; Coutts et al., 2020).

On Vancouver Island, strata of the Nanaimo Group unconformably overlie Wrangellia terrane, an arc terrane and one of the most outboard of the major Cordilleran terranes. Wrangellia is a complex of Devonian to Jurassic metamorphosed and deformed sedimentary and igneous rocks (e.g., Yorath et al., 1999; Greene et al., 2010) that was either emplaced on the western margin of North America during a phase of transpressional deformation that occurred prior to deposition of the Nanaimo Group (Cant and Stockmal, 1989; Mustard, 1994), or comprises an island arc that collided and welded to the continental margin of North America (Alberts et al., 2021).

The Upper Cretaceous lower Nanaimo Group was deposited in the Georgia Basin (Fig. 1) that developed in a forearc setting and records the initiation and early depositional evolution and architecture of the basin. The Nanaimo Group comprises a 5-km-thick sedimentary succession of terrestrial to deep marine deposits that outcrop across southeastern Vancouver Island and range in age from Turonian to Maastrichtian (Mustard, 1994 and references therein; Haggart et al., 2005). The main Nanaimo Group outcrops are separated into two sub-basins—the Comox and Nanaimo—by a northeast trending topographic high known as the Nanoose Uplift or Nanoose Arch, which see their own lithostratigraphic nomenclatures under the dual basin model (e.g., England and Bustin, 1998; Huang et al., 2019, 2022; Girotto et al., in review). Deposition of the Nanaimo Group and subsidence of the Georgia Basin occurred due to accelerated subduction of the Farallon and Kula plates beneath North America (Hamblin, 2012) during the Turonian to Maastrichtian (England and Bustin, 1998; Haggart et al., 2005). Other sub-basins that contain Nanaimo Group strata are the Port Alberni outlier, and the Cowichan Valley and Suquash sub-basins. Significant topography on the basal non-conformity of the Nanaimo Group has resulted in assignment of lithostratigraphic groups in the sub-basins that are not time-correlative.

Dawson (1890) first proposed the name ‘Nanaimo Group’ for economically-important coal-bearing strata. Early geological mapping by Clapp (1914) in the Nanaimo area, and by Clapp and Cooke (1917) in the Duncan area, established lithological formations and terminology, many of which are still in use today. Muller and Jeletzky (1970) created a unified regional geological map of the eastern coastal margin of Vancouver Island and recognized that the Nanaimo Group represents deposition in a single large basin, despite the current distribution of the strata in several isolated areas. They also suggested that the Nanaimo Group represents four major fining-upward (transgressive) cycles of deposition that became less dominated by shoreline and shallow marine deposition, and more dominated by deeper marine deposition through time (Muller and Jeletzky, 1970). Despite these considerable efforts, type and reference sections have yet to be formalized for Cretaceous strata, but effectively, eleven formations of the Nanaimo Group are separated into the lower and upper Nanaimo Group (Mustard, 1994; Hamblin, 2012), with ages defined primarily by molluscan and microfaunal biostratigraphy (e.g., Jeletzky, 1970; Ward, 1978; Haggart et al., 2005; Haggart and Graham, 2018).

The lower Nanaimo Group comprises, in ascending order, the Comox/Benson, lower Trent River/Haslam, and upper Trent River/Extension, Pender, and Protection formations that are predominantly terrestrial to shallow marine deposits. Comox/Benson Formation coarse clastics are highly diachronous and reflect the continued and slow drowning of the basal non-conformity of the Georgia Basin. The lower Trent River Formation and Haslam Formation equivalent marks the first major drowning of the basin (Bickford and Keynon, 1988; Kent et al., 2020; Girotto et al, in review), and deposition of turbidites, and the Extension-Pender-Protection formations record coarse-clastic deposition in, and around, the Nanoose Uplift (Fig. 2; Bickford and Keynon, 1988; Girotto et al., in review). Nanaimo deposition may have been influenced by syn-depositional tectonism, and these strata were deformed by post-depositional, strike-slip, and thrust compression during the Cenozoic (Mustard, 1994; Girotto et al., in review).

The early evolution of the Georgia Basin has been interpreted based on lithostratigraphy and biostratigraphy of the lower Nanaimo Group (Bickford and Kenyon, 1988; England, 1989; Hamblin, 2012), which suggested that basin subsidence began during the late Santonian–early Campanian (England and Bustin, 1998). An alternate early evolution history derived from sequence stratigraphic correlations (Kent et al., 2020) and detrital zircon geochronology is that the Georgia Basin underwent multiple phases of subsidence, deposition, and non-deposition/erosion, and that allogenic influences controlling sedimentation and sediment accumulation varied through time and space, creating a subsidence and uplift history that was complex with multiple potential hiatuses in the Comox (Turonian–Santonian hiatus) and Nanaimo (Jurassic–Turonian hiatus) sub-basins (Huang et al., 2019).

For simplicity, the lithostratigraphy of units of the lower Nanaimo Group are described from base to top after Muller and Jeletzky (1970), Mustard (1994), and Hamblin (2012), and are shown in Figure 3 and described below (see Hamblin, 2012 for further information):

Comox Formation

The Comox Formation, the basal lithostratigraphic unit of the Nanaimo Group, was introduced by Clapp (1912a) for a succession of clastic sedimentary rocks with coal exposed near the Comox coal mines, southwest of Comox Harbour. A detailed section was not reported, and a type locality not specified. The Comox Formation is defined lithostratigraphically as the first coarse clastic unit directly overlying the basal non-conformity (Mustard, 1994), and comprises thick sandstone and conglomerate, and contains abundant and well-preserved plant fossils (e.g., McIver, 1994). The unit forms the base of the Nanaimo Group in almost all areas, rests on a sharp, high-relief angular unconformity, overlying the metamorphosed, stratified, Devonian to Jurassic rocks of the Wrangellia terrane (first noted by Richardson, 1872). The formation is generally 100–200 m thick and is variable due to filling topography on the underlying unconformity (Muller and Jeletzky, 1970); in some places, it appears to be absent and younger units overlie the basement, while in other areas its thickness ranges up to 350 m (Cathyl-Bickford, 2001). Bickford and Kenyon (1988) proposed three subdivisions of the formation within with Comox Sub-

Basin: the basal Benson conglomerate, Cumberland coal measures, and the uppermost Dunsmuir sandstone. No type sections were identified for any of these units.

The Benson Member (Benson Member of Cathyl-Bickford, 1993, 2001; Benson Formation of Clapp, 1914 and Clapp and Cooke, 1917) consists of poorly- to fairly-sorted, matrix- to clast-supported, pebble to cobble conglomerate (locally-derived clasts dominated by volcanic and felsic intrusive lithologies), set in a medium- to coarse-grained arkosic sandstone matrix. These are typically overlain by thick bedded, medium- to coarse-grained arkosic sandstone with minor interbedded siltstone and mudstone of the Dunsmuir Member in some localities (Cathyl-Bickford, 1993, 2001). In others, these are overlain by the Cumberland Member of Cathyl-Bickford (2001).

The Cumberland Member is comprised of sandstone, siltstone, and carbonaceous mudstone and coal, ranging in thickness from 0.2 to 160.4 m in the Comox Sub-basin (Cathyl-Bickford, 2001). The member was probably deposited as an alluvial plain and mires in a low-energy deltaic system (Cathyl-Bickford, 2001). The Cumberland Member contains well-preserved plant fossils. The unit interfingers with the underlying Benson Member where present. Where the Benson Member is not present, the Cumberland Member unconformably overlies basement volcanics of the Karmutsen Formation. The Cumberland Member is overlain by the Dunsmuir Member. A type section for the Cumberland Member is proposed in the western part of the middle canyon of the Browns River by Cathyl-Bickford (2001). It is 73.1 m thick (excluding a 0.75 m thick dacite sill). The rocks of the Cumberland Member are typically overlain by thick-bedded, medium- to coarse-grained arkosic sandstone with minor interbedded siltstone and mudstone of the Dunsmuir Member (Cathyl-Bickford, 1993, 2001).

The Dunsmuir Member is comprised of medium- to coarse-grained sandstone with lenses of siltstone, mudstone, and coal. The member ranges in thickness from 11.5 to 356 m in the Comox bub-Basin (Cathyl-Bickford, 2001). The unit was deposited in tidal inlets, submerged tidal deltas above wave base, back barrier lagoons and barrier bars or barrier islands within a high-energy deltaic system (Cathyl-Bickford, 2001). The unit contains abundant plant fossils of Santonian or Campanian age (Bell, 1957). A type section for the unit is proposed in the eastern part of the middle canyon of the Browns River by Cathyl-Bickford (2001). Coal is present in the Comox area to the north. There is generally an overall fining-upward succession, passing gradationally upward into the overlying Haslam (siltstone, middle Santonian), Extension (sandstone, uppermost Santonian to lowermost Campanian), and Protection (predominantly sandstone; lower upper Campanian) formations (Huang et al., 2019). In other areas, the Dunsmuir Member is overlain by the Cougarsmith or Puntledge members of rocks assigned to the Trent River Formation.

The Comox Formation has been interpreted to include high-energy deposition in alluvial fan to braided fluvial and coastal floodplain to shoreline facies, with an overall transgressive or deepening upward trend. Deposition may have been influenced by high-relief topography on the underlying unconformity surface (Ward and Stanley, 1982; Johnstone et al., 2006). Johnstone et al. (2006) described three distinct facies typical of deposition on rocky shorelines with cliffed headlands and protected coves: locally-derived conglomerates representing gravel-dominated fans built out from coastal cliffs and gullies; well-sorted sandstone facies reflecting deposition on storm-dominated shorelines; and fine grained units reflecting deposition in protected embayment settings.

The Comox Formation contains zircon with Paleozoic ages that are likely derived directly from Paleozoic rocks of the Sicker and Butte Lake groups or recycled from the underlying Carboniferous Forth Lake Formation. Late Triassic to Middle Jurassic-aged zircons likely shed from uppermost Triassic to Jurassic igneous rocks of the West Coast Crystalline Complex, Island Intrusive Suite, and/or Bonanza Group, while Late Jurassic to Cretaceous-aged zircons are interpreted to be possibly from the central Coast Mountain Batholith (Mustard, 1994; Mustard et al., 1995; Mahoney et al., 1999, 2021; Katnick and Mustard, 2003; Matthews et al. 2017; Alberts et al. 2021; Bovin et al., 2022).

The Comox Formation has previously been assigned a variety of age ranges: broadly Santonian to Maastrichtian based on plant macrofossils (Bell, 1957); mid- to late Santonian based on molluscan biostratigraphy (e.g., Ward, 1978; Haggart, 1991b; Haggart and Graham, 2018) and palynomorphs (Crickmay and Pocock, 1963); late Santonian to early Campanian based on marine fossils (*Sphenoceramus naumanni* subzone of *Eubostrychoceras elongatum* zone of Jeletzky, 1970); and Turonian to Coniacian based on detrital zircons (Black et al., 2003; Gehrels et al., 2008). The youngest indicators of age in the unit are Campanian-aged detrital zircons in the Comox Formation (Huang et al., 2019). However, being almost entirely terrestrial, the lower limit of the Comox Formation is poorly constrained because of the lack of age-diagnostic marine fossils (Mustard, 1994).

In summary, the Comox Formation is interpreted to have been mainly deposited within the mid- to late Santonian, with the exception of the Coniacian strata (Mustard, 1994) based on an age corroborated by radiometric (U-Pb) dating of an upper Comox Formation (Dunsmuir Member) tuff near Quinsam, Vancouver Island (Kenyon et al., 1992). However, being almost entirely terrestrial, the lower limit of the Comox Formation is poorly constrained because of the lack of age-diagnostic marine fossils (Mustard, 1994). Macrofossils discovered in the southern part of the basin suggest that the Comox Formation on Saanich Peninsula ranges into the Turonian (Haggart, 1991a, 1994) or approaches in age the potentially equivalent beds of the Sidney Island Formation (Haggart et al., 2005). The youngest indicators in the unit are Campanian-aged detrital zircons (Huang et al., 2019). Thus, collectively, the Comox Formation ranges in age from Turonian to Campanian.

Overlying the Comox Formation are the Haslam, Extension, and Protection formations. Maximum depositional ages from detrital zircon geochronology are similar for these overlying formations and have some overlap with the maximum depositional age of the Comox Formation as well (Huang et al., 2019). This indicates that deposition of these units was not necessarily sequential, and that they were locally near-contemporaneously deposited. Such rapid accumulation is typical in convergent margin basins (Huang et al., 2019 and references therein). These units, as well as intervening units (Pender Formation), are discussed below, as some of the age interpretations herein span into and through the Santonian and Campanian.

Haslam Formation

The stratotype of the Haslam Formation is at Haslam Creek (Clapp, 1912b). The Haslam Formation of the Nanaimo Sub-basin is equivalent to the lower Trent River Formation of the Comox Sub-basin, but Muller and Jeletzky (1970) and Mustard (1994) favoured using the term Haslam Formation in their single-basin nomenclature. The Haslam Formation is of late Santonian to early Campanian age and dominated by grey to dark grey siltstone and mudstone with thin interbeds of fine to coarse grained sandstone. The unit thickens from 100–200 m in a southerly direction (Clapp and Cooke, 1917; Ward, 1978), has a gradational and conformable contact with the underlying Comox Formation, and is sharply overlain by the Extension Formation. In the Duncan/Cowichan area, there are places where the Comox Formation is not present due to underlying unconformity relief, and the Haslam Formation rests directly on underlying basement rocks (Clapp and Cooke, 1917). Fine-grained facies are dark grey, organic-rich, laminated, and typically calcareous with common concretions (Clapp, 1914), but also bioturbated. Shelly fossils are also present in distinct calcarenite beds in some locations (Clapp, 1914).

In the southern Nanaimo Group depositional area, an extensive assemblage of turbidites are correlative with the Haslam Formation (Ward, 1978). Lithologically, the turbidite and non-turbidite facies of the Haslam Formation are distinct; Ward (1978) differentiates the non-turbiditic rocks as belonging to a Haslam Creek Member and the turbiditic rocks to a Cowichan Member. In the Comox Sub-basin, only the non-turbiditic Haslam Creek Member is present under this interpretation.

The Haslam Formation contains the upper Santonian *Eubostrychcoceras elongatum* zone divided into the *Sphenoceramus naumannii* subzone and *Eupachydiscus haradai* subzone (e.g., Jeletzky, 1970; Haggart and Graham, 2018; Huang et al., 2022) and is further distinguished by the foraminiferal *Rugoglobigerina* zone (McGugan, 1962).

The Haslam Formation is interpreted to represent low-energy deposition in a marine shelf to relatively deep slope depositional facies. Muller and Jeletzky (1970) suggested a relatively nearshore shelf setting. Paleocurrent data is sparse but suggests westerly depositional flows, similar to the rest of the overlying Nanaimo Group, suggesting that the significant local topography which influenced localized Comox deposition had been eroded during Haslam Formation time (Ward and Stanley, 1982).

Extension Formation

The Extension Formation is of early Campanian age and includes 100–200 m of thick-bedded, clast-supported pebble to cobble conglomerate and medium- to coarse-grained arkosic sandstone. These rocks conformably overlie those of the Haslam Formation. Conglomerates are generally moderately sorted and contain sub-rounded clasts dominated by chert and volcanic lithologies. Up-section, there is a decrease in conglomerate and increase in sandstone as an expression of an overall fining-upward trend toward a gradational upper contact with the finer-grained overlying Pender Formation. In the Nanaimo area, thin coal seams are present in sandstone and siltstone facies near the base of the formation. Bickford and Kenyon (1988) and Mustard (1994) recognized a basal Northfield Member of interbedded siltstone, fine sandstone and minor coal of a unit referred to as the East Wellington Sandstone by Clapp (1914), and an upper Millstream Member of clast-supported, sub-angular to sub-rounded quartz conglomerate with minor sandstone. At surface, many Extension Formation sandstones and conglomerates are cemented by quartz and calcite (Cathyl-Bickford, 1993). A few thin beds characterized as grading from shaley sandstone to sandy siltstone (Hamblin, 2012) and minor coal lenses were observed by Clapp (1914). Coals are highly volatile and bituminous (Muller and Jeletzky, 1970). The Extension Formation is interpreted to include high-energy deposition in deeper submarine canyon and fan facies in northern areas, and shallow marine to coastal to braided fluvial depositional environments in the Nanaimo area in association with coal. Paleocurrent indicators suggest predominantly westward directionality with considerable scatter, potentially influenced in some areas by topographic relief on the underlying Nanaimo regional unconformity.

Pender Formation

The Pender Formation is of early Campanian age and represents a succession 100–200 m thick of siltstone and mudstone with common interbeds of fine-grained sandstone equivalent to the Cranberry and Newcastle formations of Clapp (1914) and the Ganges Formation of Clapp and Cooke (1917). The lower contact is generally gradational and conformable from the underlying Extension Formation, and the upper contact is likewise gradational and conformable into the overlying Protection Formation. Fine-grained facies are dark grey, organic-rich, and laminated where not bioturbated. Thin, interbedded sandstones are generally sharp-based, laminated, and rippled displaying eleven partial Bouma turbidite sequences. On a formation scale, there is a thinning- and fining-upward trend from the underlying Extension

Formation, followed by a general thickening- and coarsening-upward trend into the overlying Protection Formation. Isolated, thin coal seams are present in the finer-grained beds in the Nanaimo area. Cathyl-Bickford (1993) and Mustard (1994) described a basal Cranberry Member corresponding to the Cranberry Formation of Clapp (1914) consisting of 50–200 m of fine- to coarse-grained sandstone with minor siltstone and coal, and an upper Newcastle Member based on the Newcastle Formation of Clapp (1914) comprised of ~100 m of dark grey, carbonaceous mudstone with thin sandstones and thick seams of highly volatile bituminous coal (Muller and Jeletzky, 1970). Paleocurrent data is sparse for the Pender Formation, which has been interpreted to represent low-energy deposition in relatively deep marine shelf and slope settings in most areas, but shallow to marginal marine, coastal, and fluvial floodplain deposits occur in the Nanaimo area where coal is present.

Protection Formation

The Protection Formation of early to late Campanian age is a ~200 m-thick succession characterized by pale grey, thick-bedded, arkosic sandstones with minor bioturbated carbonaceous mudstone interbeds, thickening in a southeasterly direction. Cathyl-Bickford (1993) and Mustard (1994) identified three members: a lower Cassidy Member consisting of 80–105 m of thick-bedded, fine to coarse grained arkosic sandstone, a middle Reserve Member comprised of 40–60 m of sandy siltstone with coal and fine to medium grained lithic sandstone, and an upper McMillan Member defined as 90 m of thick-bedded, medium to coarse grained arkosic sandstone. Beds typically fine upward from erosional bases, and include trough cross bedding, ripple cross lamination, and convolute lamination. Conglomeratic or granulestone lags are common as is surficial silica cement (Clapp and Cooke, 1917). These distinctive sandstones were famously quarried on Newcastle Island for building stone and grinding stones, including for international export to San Francisco in the late 19th century (Richardson, 1872). Thinning and fining upward sequences on the scale of tens of metres are common, and the lower contact of the formation is usually sharp, whereas the upper contact is gradational. The Protection Formation is interpreted to represent high-energy deposition along a relatively deep marine shelf to sub-marine fan as evidenced by associated facies in most areas, but shallow marine shelf and coastal depositional environments also occur in the Nanaimo area. Paleocurrent indicators suggest a predominantly westward flow directionality.

Overlying the Protection Formation are the Cedar District (middle to upper Campanian), de Courcy (upper Campanian), and Northumberland (upper Campanian to ?lower Maastrichtian) formations (e.g., Bain and Hubbard, 2016; Mathews et al., 2017; McLachlan and Haggart, 2018). The Geoffrey, Spray, and Gabriola formations overlie these units completing the Upper Cretaceous succession spanning the Georgia Basin.

Longarm Formation and Nanaimo Group equivalents, northern Vancouver Island

Lower Cretaceous strata, including Longarm Formation equivalents, are only present in the Quatsino Sound region of Vancouver Island, and are comprised of greywacke, siltstone, and conglomerate derived from volcanic and older sedimentary rocks (e.g., Muller et al., 1974, 1981; Jeletzky, 1976). Although, unnamed braded fluvial deposits at the basement of the Comox Sub-basin have presented an Albian maximum depositional age (Huang et al., 2019), consistent with the age inference based on palynomorphs of Blue Mountain on the Georgia Basin margin, lower Mainland BC (Mustard and Rouse, 1991). The Longarm Formation was originally described for strata belonging to the Queen Charlotte Group on the islands of Haida Gwaii (Sutherland Brown, 1968), and inferences of an indirect relationship with similar rocks on northwestern Vancouver Island were latter favoured due to an expansive geographic distance separating the packages (e.g., Jeletzky, 1976; Haggart and Tipper, 1994). In Quatsino Sound, these Longarm Formation equivalents overlap eastward onto a pre-Cretaceous erosion surface, and its total thickness probably does not exceed 1400 m. Marine fossils indicate a Valanginian to Barremian age for these strata (Jeletzky, 1976; Muller, 1977). Rocks correlated with the Queen Charlotte Group by Muller

(1974) were mapped as overlying the Longarm Formation equivalents disconformably. These rocks were subsequently assigned to the Coal Harbour Group (Jeletzky, 1976) and are comprised of approximately 300–1000 m of sandstone, conglomerate, siltstone, shale, and coal ranging from Aptian to Cenomanian in age (Jeletzky, 1976; Muller, 1977). Lower Cretaceous strata outcropping around Holberg Inlet and Apple Bay were correlated with the Longarm Formation based on biostratigraphic relationships (Muller et al., 1974; Jeletzky, 1976) and oxygen isotope excursion data (Rothwell and Stockey, 2013), although Valanginian–Barremian strata near the entrance to Quatsino Sound are similar lithologically to the Longarm Formation.

The Queen Charlotte Group contains only limited Upper Cretaceous equivalents to rocks of the Nanaimo Group in isolated intervals of the Hecate Depression (Haggart et al., 2009). Strata which have been correlated with the Nanaimo Group along northern Vancouver Island crop out in the northeastern Suquash Sub-basin. The strata were studied by Jeletzky (1969), Muller and Jeletzky (1970), and others. Most exposures are found near the town of Port Hardy. The strata comprise gently dipping, shallow marine to non-marine rocks that include medium- to coarse-grained sandstone and conglomerate, and siltstone and minor coal. The rocks rest with angular disconformity on Karmusten Formation volcanics. The ages of these Nanaimo Group equivalents are broadly Campanian based on marine molluscs (Jeletzky, 1970).

Dawson (1887) was the first to report on the Upper Cretaceous rocks of the northern Suquash area. Dawson (1890) would later propose the name 'Nanaimo Group' for the entire Upper Cretaceous succession spanning eastern Vancouver Island. Nanaimo Group strata preserved in the Suquash Sub-basin are described in Muller and Jeletzky (1970). Briefly, the strata begin with a 'basal greywacke' unit, correlative to the upper Trent River Formation of middle Campanian age. This is overlain by a 'variegated sandstone' unit of early-late Campanian age, and in turn overlain by a '*Metaplacenticeras occidentale* siltstone' unit correlative to the Cedar District Formation based on presumed affinity with the placenticeratid zonal index ammonites (Ward, 1978; Ward et al., 2012). Only present in some localities, this unit is overlain with a disconformity by a 'upper greywacke' unit, correlative to the Geoffrey Formation, and then an 'upper siltstone' unit that is latest Campanian to early Maastrichtian in age correlative to the Spray Formation.

Previous work on the paleovegetation of the Comox Formation

Bell (1957) studied Comox Formation plant material in existing Geological Survey of Canada collections. On the basis of species number, conspecificity, or species affinity with those elsewhere, Bell (1957) interpreted the age of the Comox Formation to be within the range of Santonian to Maastrichtian (Muller and Jeletzky, 1970). Macrofloral assemblages preserved in the Comox Formation were later determined by Jonsson and Hebda (2015) to be indicative of floodplain or wetland settings influenced by brackish water. Jonsson and Hebda (2015) found that the Saanich Member macroflora consists of a diverse assemblage of angiosperms and gymnosperms with much of the diversity within the angiosperms. Many plant fossil taxa are unique to the Nanaimo Group, adding to the evidence for a unique phytogeoprovince on the west coast of North America that developed as a result of a barrier to floral migration between the paleocontinent and the Vancouver Island precursor during the Late Cretaceous. The Saanich Member macroflora and associated sediments suggest deposition in a fluvial to marginal marine setting including floodplain, estuarine, and lagoonal environments.

The few published palynological studies for the Upper Cretaceous of Vancouver Island and adjacent mainland are limited by the poor understanding of lithostratigraphy and correlations and floral endemism.

In some studies, the lithostratigraphic unit examined is not even identified, and consequently, there are very few published palynological studies of the Comox Formation. In the Vancouver area, Crickmay and Pocock (1963) described Campanian, Paleocene, and Eocene strata. The microfloral assemblages they describe from the Comox Formation were rich in trilete spores with relatively poor recovery of saccate Gymnosperm pollen. Angiosperm pollen of simple forms (e.g., *Triporites, Tricolpites*) were abundant, but polyporoid types were absent. The Comox Formation was considered by Crickmay and Pocock (1963), as reported by Srivastava (1967), to be of probable Santonian age and the former authors regarded the "Nanaimo series of Vancouver Island" to range from the Santonian to Maastrichtian (Crickmay and Pocock, 1963, p. 1937).

As reported in Muller et al. (1973), W.S. Hopkins examined spores and pollen from coaly beds near Keogh River (GSC Plant Loc. No. 8026; shoreline 0.2 miles east of Keogh River), then assigned to the Suquash Formation. Hopkins documented *Proteacidites thalmannii* and *Proteacidites* spp. (*Proteacidites* is a basionym of *Tschudypollis*) as well as *Aquilapollenites* sp., and tentatively inferred an age of Campanian or Maastrichtian because the pollen and spores were degraded and further refinement of age interpretation was not possible. The complete list of species, collected by G.M. Dawson (1889), were originally re-identified by Bell (1957) from the same locality.

Rouse (1957) and Rouse et al. (1990) examined Upper Cretaceous spore and pollen material from the Comox Formation exposed on eastern Vancouver Island. Rouse (1957) considered the Comox Formation to correspond with the Campanian stage of the European Cretaceous, whereas Rouse et al. (1990) later determined the age of the unit to be Santonian. The assemblage contained abundant spores and a diversity of angiosperm pollen, including *Proteacidites thalmannii*. The overlying Extension-Protection Formation and correlative beds on Orcas Island (Brother Creek Member), north and south shore and Wolfson Creek east of Powell River, yielded an assemblage determined to be Campanian in age and contained taxa distinct from the underlying Comox Formation beds, with the exception of *P. thalmannii* pollen that occurs in both units.

Other studies focused on more inland areas comparing palynofloral assemblages to those of coastal BC. Rouse (1967) discussed pollen and spore assemblages as well as leaf impressions in the Parsnip River Valley of central BC. The leaf assemblage indicated a Maastrichtian to Danian age. A latest Cretaceous–earliest Paleogene age for these fossils was comparable to assemblages reported from the Edmonton Formation of Alberta and from the Hell Creek, Lance, and Fox Hills formations of the United States Western Interior, as well as several species in common with the Nanaimo Group of eastern Vancouver Island, albeit younger.

Rouse et al. (1970) analyzed palynological assemblages from Upper Cretaceous and lower Tertiary (Paleogene) rocks in BC and Alberta noting major differences in the evolution of floras between coastal and interior localities. The Santonian to Campanian coastal palynoassemblage was found to be dominated by ferns, herbaceous angiosperms, and *Proteacidites* (*Tschudypollis*), whereas coeval assemblages from western Alberta were typified by different fern spores and pollen from probable herbaceous angiosperms and *Aquilapollenites*. These differences led the authors to suggest the existence of two floristic provinces during Santonian to Campanian time, possibly due to the geographical barrier of the western Cordillera. The Upper Cretaceous assemblages studied by Rouse et al. (1970) include one from the Protection Formation (overlying the Comox Formation) of the Nanaimo Group and equivalent strata on the coast of Santonian–Campanian age. The assemblages consist mainly of fern spores and angiosperm pollen, with a notable paucity of gymnosperm pollen.

No previous work documents dinoflagellate cysts (dinocysts) from the Comox Formation of the Georgia Basin. The only published reports on dinocysts from the Nanaimo Group are from recent work by McLachlan et al. (2018, 2019, 2021), McLachlan and Pospelova (2021) and McLachlan (2021), that focus on the late Campanian Northumberland Formation on Hornby Island, and the Maastrichtian to Selandian strata of the Oster Bay Formation, also in the Comox Sub-basin. McLachlan et al. (2018) document exceptionally well-preserved late Campanian dinocysts on Hornby Island, including the first occurrences of chronostratigraphic indicator cyst taxa while McLachlan and Pospelova (2021) and McLachlan et al. (2021) focussed on the marine assemblage turnover across the Cretaceous/Paleogene boundary from middle Oyster Bay Formation sediments. Although these studies could provide a basis for comparison, the strata are all considerably younger than the Comox Formation. More work is needed to establish a reference framework for dinocysts in Nanaimo Group marine sediments.

METHODS

Twenty-three outcrop rock samples were collected by Alec Sproule, M.Sc. candidate at Simon Fraser University, Burnaby, BC, under the supervision of Dr. Shahin Dashtgard. Samples comprise 100–200 g of whole rock collected from fine-grained units interpreted as deposited in shallow marine, rather than terrestrial, environments to increase the likelihood of preservation of dinocysts. When sampling, care was taken to sample unexposed rock to maximize preservation potential and reduce external contamination. Ten samples (ORS21 PS1 to ORS21 PS10) were collected from along the Oyster River in the Comox Sub-basin (Fig. 4; Table 1). The lithology of these samples includes sandstone, mudstone, and coal. Thirteen samples of mudstone and sandstone were collected from strata exposed on northern Vancouver Island, including nine from the Suquash Sub-basin (SQM#, FRB#, OGL#, and PMO#; Fig. 5; Table 1) and four from Lower Cretaceous strata (SBR# and HCO#; Fig. 5; Table 1). All samples from the Comox and Suquash sub-basins were taken from the lower 250 m of their respective basin fills. Ammonite material was recovered from the Suquash Sub-basin by Joseph Haegert of Victoria, BC, from approximately 50.677428° N latitude and 127.344156° W longitude. The specimens were reposited within the paleontological collections of the Royal British Columbia Museum, Victoria, BC, and prepared, identified, and photographed by Dr. Sandy McLachlan.

Table 1: List of samples, GSC curation number (C-#), Global GeoLabs Ltd. Record number (R-#), latitude and longitude, unit, locality, and lithology. Refer to the Geological Survey of Canada Sample Management Database (SMS) for further information on samples.

Sample name	GSC Curation number (C-#)	Record number Global Geolabs Ltd.	Latitude	Longitude	Unit	Locality (sub-basin)	Lithology and meterage (m) in measured section
ORS21 PS1	C-641984	R-3914-14	49.86509	125.31854	Benson Mbr, Comox Fm[b]	Comox SB	Sandstone, 1.8 m
ORS21 PS2	C-641985	R-3914-15	49.86442	125.31696	Benson Mbr, Comox Fm[b]	Comox SB	Sandstone, 35 m
ORS21 PS3	C-641986	R-3914-16, R-3934-6 [a]	49.86555	125.31559	Benson Mbr, Comox Fm[b]	Comox SB	Mudstone, ~54 m
ORS21 PS4	C-641987	R-3914--17	49.86571	125.31507	Benson Mbr, Comox Fm[b]	Comox SB	Muddy sandstone, 64.1 m
ORS21 PS5	C-641988	R-3914-18, R-3934-5[a]	49.86690	125.3117	Comox Fm[b]	Comox SB	Mudstone, 88.2 m
ORS21 PS6	C-641989	R-3914-19	49.86787	125.31114	Comox Fm[b]	Comox SB	Sandstone, 102 m
ORS21 PS7	C-641990	R-3934-6, R-3914-20[a]	49.86787	125.31114	Comox Fm[b]	Comox SB	Sandstone, 105 m
ORS21 PS8	C-641991	R-3914-21	49.87340	125.30315	Cumberland Mbr, Comox Fm[b]	Comox SB	Mudstone, 178.2 m
ORS21 PS9	C-641992	R-3914-22	49.876244	125.298457	Cumberland Mbr, Comox Fm[b]	Comox SB	Coal, 178.5 m
ORS21 PS10	C-641993	R-3914-23	49.87413	125.30314	Cumberland Mbr, Comox Fm[b]	Comox SB	Muddy Coal, 198.5 m
SBR1-FS1	n/a	R-3914-8, R-3934-1[a]	50.722765		Longarm Formation equivalents	Stranby River	Sandstone
SBR2-FS1	n/a	R-3914-10, R-3934-3[a]	50.722765	128.082378	Longarm Formation equivalents	Stranby River	Sandstone

HCO4-FS1	C-641982	R-3914-2	50.612409	127.798439	Longarm Formation equivalents	Hashamu Creek Outcrop	Mudstone
HCO5-PS1	C-641983	R-3914-5	50.613027	127.798606	Longarm Formation equivalents	Hashamu Creek Outcrop	Mudstone
SQM-FS2 (GSC slide label SQM1-FS1)	C-641973	R-3914-12	50.645166	127.254293	Nanaimo Group Equivalents	Suquash coal mine, S of Port Hardy	Mudstone
SQM1-FS2	C-641974	R-3914-13	50.645139	127.254809	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Mudstone
SQM-PS3	C-641975	R-3914-9, R-3934-2[a]	50.63892	127.240567	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Mudstone
SQM6-FS1	C-641976	R-3914-6	50.642544	127.249342	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Mudstone
SQM10-FS1-A	C-641977	R-3914-7	50.63657	127.24057	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Sandstone
FRB-FS1	C-641978	R-3914-3	50.685861	127.357705	Nanaimo Group equivalents	Shoreline near Fort Rupert	Sandstone
OGL-OCP3 FS1	C-641979	R-3914-11	50.608721	127.147182	Nanaimo Group equivalents	Orca Gravel Loader site N of Port McNeil	Sandstone
PMO1-FS1	C-641980	R-3914-4	50.602999	127.086727	Nanaimo Group equivalents	Northern Shoreline of Port McNeil	Mudstone
PMO2-PS1	C-641981	R-3914-1	50.602593	127.092399	Nanaimo Group equivalents	Northern Shoreline of Port McNeil	Sandstone

[a] two record numbers indicate duplicate processing of the same sample for quality control; [b]lithostratigraphy has not been confirmed due to limits in correlation.

Samples were processed at Global GeoLabs Ltd. in Medicine Hat, Alberta. Samples were prepared for palynology following extraction techniques outlined by Traverse (2007). Briefly, the process included washing, acid digestion, oxidation with Schulze's solution, and staining with Safranin O; residues were mounted with polyvinyl and liquid bioplastic. Some of the samples were processed in a duplicate batch for quality control (Table 1). All samples analyzed for pollen and spores are functionally unsieved (>10 µm retained). Kerogen, unsieved, >20 µm, and >45 µm size fractions were analyzed for dinocysts where indicated. Five samples were processed in duplicate (SBR2-FS1, SBR1-FS1, ORS21 PS5, ORS21 PS7, ORS21 PS3) to assess the possibility of contamination by modern pollen rain and/or during preparation. These samples were selected due to the preservation of exceptionally well-preserved *Alnus* (or *Alnipollenites*) pollen preserved in the first processed batch.

Observations of terrestrial palynomorphs were made chiefly by Dr. Jennifer M. Galloway at the Geological Survey of Canada, Calgary, Alberta, using an Olympus BX53® transmitted light microscope with oil immersion at 400× and 1000× magnification. Digital images were captured using an Olympus SC50 camera and CellSense® software under differential interference contrast (Nomarski interference contrast) and oil immersion. Microscope slides are stored at the Geological Survey of Canada, Calgary, Alberta. A qualitative approach was herein used for palynological analyses for the purposes of biostratigraphic age determination based on terrestrial pollen and spore analysis. Thermal Alteration Index values follow the scale of Pearson (1984) and were assessed on unoxidized (kerogen) and unstained material. England Finder coordinates are reported for diagnostic taxa. Taxonomic authorities are listed in Appendix 1 at the end of this report.

Dinocysts in preparations assessed as candidates to contain dinocysts by Galloway during pollen and spore analysis were observed and reported by Dr. Sandy McLachlan, University of Minnesota (samples SQM PS3, ORS21-PS1 through -PS10) and Dr. Manuel Bringué, Geological Survey of Canada, Calgary, Alberta (samples FRB-FS1, OGL-OCP3 FS1, PMO1-FS1, PM02-PS1, HCO4-FS1, HCO5-PS1, and ORS21 PS5). Observations by McLachlan were made along with outlying pollen and spores using a Nikon E200 transmitted-light microscope and objective-mounted Samsung A5 camera at 500× magnification under oil immersion in brightfield, and a quantitative approach was applied for relative abundance calculations and paleoenvironment inferences were specimen counts >100 palynomorphs could be reached for selected samples. Observations by Bringué were made using a Zeiss M2 transmitted light microscope and associated camera operated using Zen 3.5 software at 400× and 1000× magnification under oil immersion in brightfield, phase contrast, and differential interference contrast.

RESULTS

Of the twenty-three samples processed and analyzed for terrestrial palynology, twelve were sufficiently productive for terrestrial pollen and spores as to allow interpretation of depositional age (Table 2). These samples contain pollen, spores, fungal remains, algae, and dinocysts. Seventy-eight terrestrial pollen and spore taxa were observed and four types of non-pollen palynomorphs (excluding dinocysts) were encountered (Appendix 1). Preservation ranges from exceptional to poor (Plate 1). Many of the spores and pollen remain 'undifferentiated'. The authors recommend that a more complete and systematic taxonomic treatment be applied to this material; it is possible that new species or genera are present.

Samples containing dinocysts (FRB-FS1, OGL-OCP3 FS1, PMO1-FS1, PM02-PS1, HCO4-FS1, HCO5-PS1, and ORS21-PS5) as determined by Galloway during her analysis of the preserved pollen and spores assemblages were provided to McLachlan and Bringué for detailed analyses. Of these seven samples analyzed for dinocysts (Table 2), only three contained specimens that could be identified to the genus or species level (Appendix 2). In these three samples, only a few specimens were encountered (maximum of thirteen specimens per sample), and only one taxon could be identified at the species level. The remaining four samples were effectively devoid of marine palynomorphs. Five of a further series of ten samples (SQM PS3, ORS21-PS1 through ORS21 PS4, and ORS21-PS6 through -PS10) analysed by McLachlan were found to be productive for dinocysts, the most diverse assemblage of which yielded twelve genera and at least seventeen species (Table 2). Dinocyst preservation was fair to (generally) poor; most observed specimens degraded and/or fragmented (Plate 2). For each sample, the unsieved and kerogen slides (when available) were scanned entirely at 400x, and additional slides were scanned if available.

Table 2: Summary of palynological assessments of the samples

Sample name	GSC Curation number	Unit	Locality (SB; sub-basin)	Lithology and meterage (m) in measured section	Comments pollen and spore analyses	Comments dinocyst analyses	Notes
ORS21 PS1	C-641984	Benson Mbr, Comox Fm[b]	Comox SB	Sandstone, 1.8 m	?Paleocene or Albian	Barren of marine palynomorphs	Y3C2 σ detrital zircon age of 114.4 ±1.0 Ma (Aptian) in strata overlying ORS21 PS1 (5 m).
ORS21 PS2	C-641985	Benson Mbr, Comox Fm[b]	Comox SB	Sandstone, 35 m	Effectively barren	Barren of marine palynomorphs	Y3C2 σ detrital zircon age of 118.6 ± 0.4 Ma (Aptian) in strata overlying ORS21 PS2 (38 m)
ORS21 PS3[a]	C-641986	Benson Mbr, Comox Fm[b]	Comox SB	Mudstone, ~54 m	Maastrichtian or younger but possibly due to contamination. Second run effectively barren for palynomorphs	One specimen of. *Florentinia* cf *clavigera*; early Cenomanian–early Maastrichtian	Maastrichtian indicators *Ericipites* and *Chenopodipollis*, as well as *Alnipollenites* pollen, probably due to contamination
ORS21 PS4	C-641987	Benson Mbr, Comox Fm[b]	Comox SB	Muddy sandstone, 64.1 m	Contamination by modern pollen rain? Age cannot be determined	Barren of marine palynomorphs	
ORS21 PS5[a]	C-641988	Comox Fm[b]	Comox SB	Mudstone, 88.2 m	Contamination by modern pollen rain? Age cannot be determined. Second run with no contamination by modern pollen but effectively barren for palynomorphs	Barren of marine palynomorphs	Y3C2 σ detrital zircon age of 90.1 ± 1.4 Ma (Turonian) from strata overlying ORS21 PS5 (~89 m)
ORS21 PS6	C-641989	Comox Fm[b]	Comox SB	Sandstone, 102 m	Turonian to Maastrichtian	At least 14 taxa; 29% of assemblage; early Cenomanian–Campanian based on *Exochosphaeridium majus* and *Florentinia* cf. *clavigera*	Detrital zircon age from below this interval returned an Y3Zo (youngest three grains overlapping at 2σ error) age of 87.7 ± 2.9 Ma. A detrital zircon Y3Zo age from strata ~100 m above ORS21PS6 returned an age of f 86.4 ± 3.1 Ma. These age constraints limit of youngest depositional ages of bounding strata limit ORS21 PS6 to be Coniacian

ORS21 PS7[a]	C-641990	Comox Fm[b]	Comox SB	Sandstone, 105 m	late Albian-early Cenomanian? Abundant dinocysts.	At least 17 taxa; 64% of assemblage; early Cenomanian–Campanian based on *Exochosphaeridium majus* and *Florentinia* cf. *clavigera*	
ORS21 PS8	C-641991	Cumberland Mbr, Comox Fm[b]	Comox SB	Mudstone, 178.2 m	late Albian-early Cenomanian? Or younger	Isolated specimens of *Canningia* cf. *inconspicua* and ?*Exochosphaeridium* sp.	
ORS21 PS9	C-641992	Cumberland Mbr, Comox Fm[b]	Comox SB	Coal, 178.5 m	Effectively barren	Barren of marine palynomorphs	
ORS21 PS10	C-641993	Cumberland Mbr, Comox Fm[b]	Comox SB	Muddy Coal, 198.5 m	Campanian or younger	Barren of marine palynomorphs	
SBR1-FS1[a]	n/a	Longarm Formation equivalents	Stranby River	Sandstone	Not analyzed	Not analyzed	
SBR2-FS1[a]	n/a	Longarm Formation equivalents	Stranby River	Sandstone	Not analyzed	Not analyzed	
HCO4-FS1	C-641982	Longarm Formation equivalents	Hashamu Creek Outcrop	Mudstone	Contamination by modern pollen rain	Effectively barren of marine palynomorphs	
HCO5-PS1	C-641983	Longarm Formation equivalents	Hashamu Creek Outcrop	Mudstone	Kerogen slide only; contamination by modern pollen rain	Effectively barren of marine palynomorphs	
SQM-FS2 (GSC label SQM1-FS1)	C-641973	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Mudstone	Campanian or younger	Not analyzed	
SQM1-FS2	C-641974	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Mudstone	Early to middle Campanian or younger	Not analyzed	
SQM-PS3	C-641975	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Mudstone	Middle Campanian or younger	Isolated specimens, at least 7 dinocyst taxa; early Santonian–late Campanian	
SQM6-FS1	C-641976	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Mudstone	Campanian or younger	Not analyzed	
SQM10-FS1-A	C-641977	Nanaimo Group equivalents	Suquash coal mine, S of Port Hardy	Sandstone	Campanian-Maastrichtian	Not analyzed	
FRB-FS1	C-641978	Nanaimo Group equivalents	Shoreline at Fort Rupert	Sandstone	Effectively barren	Late Berriasian-early Aptian	
OGL-OCP3 FS1	C-641979	Nanaimo Group equivalents	Orca Gravel Loader site N of Port McNeil	Sandstone	Age cannot be determined	Late Barremian-early Cenomanian	
PMO1-FS1	C-641980	Nanaimo Group equivalents	Northern Shoreline of Port McNeil	Mudstone	Santonian or younger	Late Berriasian-early Aptian	
PMO2-PS1	C-641981	Nanaimo Group equivalents	Northern Shoreline of Port McNeil	Sandstone	Contamination by modern pollen rain	Effectively barren of marine palynomorphs	

[a]sample processed twice for quality control; [b]lithostratigraphy has not been confirmed due to limits in correlation

Detailed sample analysis results

The sample name is as follows: collectors sample name/code, GSC Curation number, R-number (Global Geolabs Ltd. Preparation number). For samples that were processed in duplicate for quality control, the collector's and GSC Curation number are the same, but the R-number that denotes the processing batch differs. Dinocyst nomenclature follows that of Fensome et al. (2019b). For palynological quantitative analysis, a sample size of at least 200 specimens is often considered adequate (e.g., Schiøler et al., 1997; McLachlan et al., 2018). However, due to low recovery in most preparations, counts in excess of 100 specimens for a given group (either pollen and spores or dinocysts) were only reached in Oyster River samples ORS21 PS6, ORS21 PS7, and ORS21 PS8. The legend for palynomorph abundance reporting is as follows: rare (R) = 1–2, scarce (S) = 3–5, common (C) = 6–9, abundant (A) = ≥10. In some cases, the number of dinocyst taxa encountered are listed prior to the abundance reporting code. England Finder coordinates are provided for biostratigraphically important taxa, as well as for other taxa in the case of exemplary specimens. Plate information is provided for figured specimens. Taxonomic authorities are listed in Appendix 2 at the end of this report.

Comox Sub-basin | Comox Formation samples

Sample ORS21 PS1, C-641984, R-3914-14 unsieved unless noted

Notes: Thermal Alteration Index 2- to 1+; dinocysts absent.

Coniferous pollen
Cupressaceae-Taxaceae (A)
Cycadopites follicularis (S)
?*Ephedripites* +20 µm fraction N39/3 (R)
Eucommidites troedessonii (S)

Angiosperm pollen
Liliacidites spp. (R)
?*Myricipites* sp. G22/1 (R) (Pl. 1, fig. o)
Retitricolpites (S)
Tricolpites N40/4 (R)

Spores
Baculatisporites comaumensis U37/2 (R) (Pl. 1, fig. ad)
Biretisporites potoniaei (R)
Cicatricosisporites (R)
Cingutriletes (C)
Converrucosisporites J40/3, M35/3 (C) (Pl. 1, fig. ah)
Deltoidosporites diaphana (R)
Deltoidosporites hallei (S)
Dictyophyllidites harrisii (R)
Echinosporis (R)
Foveosporites (R)
Laevigatosporites ovatus (R)
Leptolepidites verrucatus (R)
Osmundacidites wellmannii (R)
?*Plicatella* +20 µm fraction Q38/1 (R)
Polypodiaceoisporties? *fossulatus* O39/2, U37/2, N40/4, R44/1, S39/4 (C) (Pl. 1, fig. ab, af)
Undifferentiated reworked spores (S)
Undifferentiated spores (A)
Undifferentiated cingulate spores (S)

Non-pollen palynomorphs
Foraminiferal linings (R)
Fungal spores (R)
Pterospermella (R)

Comments: Tentative identification of a specimen referred to *Myricipites. Myricipites* occurs in Paleocene strata of the Bonnet Plume Formation (Zone 3 of Rouse and Srivastava, 1972). *Myricipites* (type *M. harrissii* (Couper 1953) Dutta and Sah 1970) is commonly considered to be a typical 'Cenozoic' taxon (Vajda and

Raine, 2003; Vajda and McLoughlin, 2007). Its tentative identification in this preparation suggests a Paleocene age but there are no other Paleocene indicator taxa present in the preparation. Other taxa (e.g., *Liliacidites, Tricolpites*) are indicative of an Albian age (Galloway et al., 2012).

Sample ORS21 PS2, C-641985, R-3914-15 unsieved unless noted

Notes: Thermal Alteration Index 2- to 3; abundant charcoal; effectively barren; dinocysts absent.

Coniferous pollen
Cupressaceae-Taxacaeae (R)

Spores
Deltoidosporites psilostoma (R)
Laevigatosporites ovatus (R)
Unknown palynomorphs (R)

Comments: age cannot be determined.

Sample ORS21 PS3, C-641986, R-3914-16 unsieved unless noted

Notes: Thermal Alteration Index 0; excellent preservation; a lot of dark coloured debris; apparent contamination from modern pollen rain. Dinocysts present. This sample was run twice as a quality control check (see below).

Coniferous pollen
Cerebropollenites mesozoicus (S)
Cupressaceae-Taxaceae (A)
Cyadopites follicularis (S)
Undifferentiated bisaccate pollen +45 µm fraction M17/0 (S)

Angiosperm pollen
Alnipollenites (*Alnus*) +45 µm fraction H46/2 (A)
?*Chenopodipollis* (R)
?*Simplicepollis* or ?*Ericipites* (R) (see comments)
Undifferentiated periporate (4 pores), annuli absent or weakly developed, scabrate (S)
Undifferentiated reticulate tricolpate pollen (R)
Undifferentiated striate tricolpate pollen (R)
Undifferentiated tricolpate pollen (R)

Spores
Cyathidites australis (R)
Laevigatosporites ovatus (Pteropsida monolete spores) (S)
Undifferentiated reworked spores (R)
Undifferentiated spores (S)

Non-pollen palynomorphs
Dinocysts (R)
Fungal spores (R)

Dinocysts

Florentinia cf. *clavigera* +45 µm fraction P14/4 (1; R)

Comments: *Chenopodipollis* Krutzsch 1966 is documented in the upper Maastrichtian Hell Creek Formation of North Dakota (Nichols, 2002). *Simplicepollis* Harris 1965 occurs as obligate tetrahedral tetrads in which the individual grains are inaperturate to weakly tricolpate (complete description in Nichols and Brown, 1992). This genus is distinguished from *Ericipites* Wodehouse 1922 or the synonymous genus *Ericaceoipollenites* Potonié 1960 (both of which have colporate apertures) in having poorly, developed non-colporate apertures. Apertures could not be distinguished in the specimen herein observed. *Simplicepollis* occurs in the upper Maastrichtian Hell Creek Formation of North Dakota (Nichols, 2002). *Ericipites* is an Upper Cretaceous taxon. It occurs, for example, in the Maastrichtian López de Bertodano Formation of Antarctica (Bowman et al., 2016). Age interpretation for this sample would therefore be Maastrichtian or younger based on the presence of ?*Chenopodipollis* and/or ?*Ericipites*/?*Simplicepollis* pollen in the preparation. However, a Maastrichtian age determination for the Benson Member of the Comox Formation is inconsistent with all previous work on the age of this unit. It is possible that the presence of ?*Chenopodipollis* and/or ?*Ericipites*/?*Simplicepollis* pollen is the product of contamination, possibly evidenced by the co-occurrence of abundant and the well-preserved *Alnipollenties* (*Alnus*) pollen in this preparation in relation to taxa comparable to age-diagnostic *Chenopodipollis* and *Ericipites*/*Simplicepollis*, which also did not occur following re-processing.

A single cyst assigned to *Florentinia* cf. *clavigera* was observed on the slide of the > 20 µm fraction. Reports of the species range from early Cenomanian (97.18 Ma; Bijl, 2023 after Dodsworth, 2000; and calibrated against the Geologic Time Scale 2012 of Gradstein et al., 2012) to early Maastrichtian (Foucher and Robaszynski, 1977).

Sample ORS21 PS3, C-641986, R-3934-6 unsieved unless noted

Notes: This sample was re-run at the lab as a quality control check. The unsieved preparation that was analyzed also contains abundant black debris and preservation is poor. The preparation is effectively barren for palynomorphs. *Chomotriletes* is present in scare abundance. *Alnipollenties, Chenopodipollis* and/or *Ericipites* specimens noted in ORS21 PS3, C-641986, R-3914-16 are absent, providing evidence they were indeed contamination. Therefore, age cannot be determined for sample ORS21 PS3, C-641986.

Sample ORS21 PS4, C-641987, R-3914-17 unsieved unless noted

Notes: Thermal Alteration Index 0; a lot of dark-coloured debris (probable inertinite); dinocysts absent.

Coniferous pollen
Cupressaceae-Taxaceae (A)
Cyadopites follicularis (R)
Laricoidites magnus (*Larix*) (R)
Undifferentiated bisaccate pollen +20 µm fraction K21/0 (S)

Angiosperm pollen
Alnipollenites (*Alnus*) +20 µm fraction X20/2 (A)
Undifferentiated psilate, tricolpate pollen (R)

Spores
Deltoidosporites diaphana (R)
Deltoidosporites hallei (R)
Laevigatosporites ovatus (Pteropsida monolete spores) (S)

Non-pollen palynomorphs
None

Comments: Contamination from modern pollen rain may be a possibility given the abundance of *Alnipollenites* (*Alnus*). Not analyzed for dinocysts. Age cannot be determined.

Sample ORS21 PS5, C-641988, R-3914-18 unsieved unless noted

Notes: Thermal Alteration Index 0; a lot of dark coloured debris (including probable inertinite); contamination from modern pollen rain? Dinocysts absent. This sample was processed twice as a quality control check.

Coniferous pollen
Cerebropollenites mesozoicus (Tsuga) (C)
Cupressaceae-Taxaceae (S)
Laricoidites magnus (*Larix*) (R)
Undifferentiated bisaccate pollen +20 µm fraction E16/3 (C)

Angiosperm pollen
Alnipollenites (*Alnus*) (A)

Spores
Deltoidosporites hallei (S)
Laevigatosporites ovatus (Pteropsida monolete spores) (C)
?*Retitriletes* +20 µm fraction H17/3 (R)
Undifferentiated reworked spores (S)
Undifferentiated cingulate psilate spore, concave sides, laesurae extend to margin of inner body (R)
Undifferentiated palynomorphs (S)

Non-pollen palynomorphs
Callimothallus sp. +20 µm fraction H17/3 (30, C)
Elongate fungal spores P5387-18C T32/3 (2, R)
Fungal fruiting body (S)

Comments: Contamination from modern pollen rain is a possibility. The samples was analyzed for dinocysts, but was barren of marine palynomorphs. Although a constrained age cannot be determined, the material cannot be older than Late Cretaceous as the genus *Callimothallus* ranges from Late Cretaceous to Holocene (Worobiec et al., 2020).

Sample ORS21 PS5, C-641988, R-3934-5 unsieved unless noted

Notes: This second preparation contained abundant black debris (including probable inertinite). Contamination by modern pollen rain (e.g., *Alnus, Tsuga*) was not evident. An unknown reticulate angiosperm pollen with a TAI of 0 was present; a specimen of *Tricolpites*, also with a TAI of 0 was present. The large undifferentiated cingulate psilate spore with concave sides was present. The sample was otherwise barren of palynomorphs. Age cannot be determined.

Sample ORS21 PS6, C-641989, R-3914-19 unsieved unless noted

Notes: Thermal Alteration Index 3; a lot of debris and phytoclasts; dinocysts present.

Coniferous pollen
Cerebropollenties mesozoicus (R)
Cupressaceae-Taxaceae (R)
Cycadopites follicularis (C)
Vitreisporites pallidus (R)

Angiosperm pollen
Tschudypollis (R)
Unknown tricolpate pollen

Spores
Baculatisporites comaumensis (R)
Cingultriletes (R)
Deltoidosporites hallei (A)
Deltoidosporites psilostoma (R)
Gleicheniidites senonicus (S)
Laevigatosporites ovatus (R)
Osmundacidites wellmannii (R)
Polypodiaceoisporties? *fossulatus* (R)
Ruffordiaspora australiensis (R)
Stereisporites antiquasporites +20 µm fraction U27/2, H24/3, M45/4) (S)
Undifferentiated spores (C)

Non-pollen palynomorphs
Elongate fungal spores J34/4, N38/1; +20 µm fraction Q37/2 (S)
Dinocysts (A)

Dinocysts
?*Achomosphaera* spp. +20 µm fraction M25/1 (A)
Alterbidinium sp. C41/3; +20 µm fraction H20/2 (C)
Cleistosphaeridium sp. G29/3; +20 µm fraction U16/3 (A)
?*Cribroperidinium* sp. +20 µm fraction N25/3, M25/1 (S)
Exochosphaeridium spp. D40/2, L43/2 (A)
Exochosphaeridium majus N45/3; +20 µm fraction L25/0, R44/3 (C)
?*Florentinia* sp. W20/0) (S)
Florenitina cf. *clavigera* +20 µm fraction O18/2 (R)
Sentusidinium cf. *capillatum* F21/0; +20 µm fraction T37/4 (A)
Spiniferites spp. M37/3; +20 µm fraction Q34/3 (S)
Palaeohystrichophora infusorioides +20 µm fraction M27/1 (R)

Comments: Preservation is fair. Counts combined from both slides of the unsieved and of the >20 µm fraction totaled 236 trilete spores, twelve monolete spores, eleven bisaccate pollen grains, and seven elongate fungal spores. The spore-to-pollen ratio of the sample is ~96%, and the overall terrestrial-to-marine palynomorph ratio is ~71%. These values are indicative of a near-shore environment and/or one with terrigenous outflow.

Tschudypollis (basionym *Proteacidites*) ranges from the Senonian (informal; Coniacian, Santonian, Campanian, and possibly Maastrichtian), or Turonian or Santonian to the Maastrichtian (Srivastava, 1978; Sweet et al., 1990). The occurrence of *Tschudypollis* spp. pollen restricts the age of this assemblage to a range from Turonian to Maastrichtian. A detrital zircon age from below this interval returned an Y3Zo (youngest three grains overlapping at 2σ error) age of 87.7 ± 2.9 Ma. A detrital zircon Y3Zo age from strata ~100 m above ORS21 PS6 returned an age of 86.4 ± 3.1 Ma. These age constraints limit the youngest depositional ages of strata bounding sample ORS21 PS6 to be Coniacian (89.39 to 85.7 Ma) (Gale et al., 2020), and accords with the palynological age determination of Turonian–Maastrichtian.

Counts of marine palynomorphs combined from both slides of the unsieved and +20 µm fraction totaled 109. Probable dinocyst *Sentusidinium* cf. *capillatum* is most abundant (40%), followed by members of the *Achomosphaera-Spiniferites* group (18%), all *Exochosphaeridium* spp. (17%), *Cleistosphaeridium* sp. (10.1%), and *Alterbidinium* sp. (7%). Outlying taxa include ?*Cribroperidinium* sp., *Florentinia* cf. *clavigera*, ?*Florentinia* sp., and *Palaeohystrichophora infusorioides*. It should be noted that poor presentation may have resulted in a conflation error of *Achomospharea* spp. and *Cleistosphaeridium* sp. in some instances. The presence of a heterogenous assemblage with taxa representing at least fourteen species from at least three families indicates a setting conducive to a moderate degree of primary productivity.

Cysts comparable to *Exochosphaeridium majus* from the Late Cretaceous ranging from Cenomanian to Campanian (Clarke and Verdier, 1973; Peyrot, 2011) provide the greatest age constraint followed by *Florentinia* cf. *clavigera* ranging through Late Cretaceous from early Cenomanian (97.18 Ma; Bijl, 2023 after Dodsworth, 2000) to early Maastrichtian (Foucher and Robaszynski, 1977) and *Palaeohystrichophora infusorioides* extending from latest Early Cretaceous (late Albian, 103.67 Ma; Bijl, 2023 after Davey, 1979) to earliest Maastrichtian (71.23 Ma; Bijl, 2023 after Torricelli and Amore, 2003). The remaining assemblage constituents are representatives of otherwise long-ranging genera. *Alterbidinium* ranges from the Late Cretaceous (early Turonian) to early Oligocene. This range base is derived from the range chart translated for the "Wuyitake Formation" from He Chengquan (1991, p. 16, 226, fig. 4) and the corresponding age of the Wuyitake Formation given as early Turonian by Mingzhen Zhang et al. (2022, fig. 2). The early Oligocene range top is based on the "upper part of the fourth member of Shahejie Formation" as translated from He Chengquan (1991, p. 73) in light of the corresponding age of this interval given by Kashif et al. (2020, fig. 2). *Sentusidinium capillatum* was described by Davey (1975) from strata of Late Cretaceous (?Campanian) age. However, *S. capillatum* (= *Sentusidinium qingzangense* He Chengquan et al. 2005 *sensu* Riding, 2019) sees an additional report from Upper Jurassic (Kimmeridgian) strata in China (He Chengquan et al., 2005) underscoring a potentially long chronostratigraphic range for the species. The most broadly ranging genera are as follows: *Achomosphaera* from Early Cretaceous (early Aptian; Heilmann-Clausen in Heilmann-Clausen and Thomsen, 1995) to late Pliocene (Piacenzian; Head, 1997); *Cleistosphaeridium* from the Late Jurassic (see *C. tanzaniensis* Msaky 2011 comb. Wood et al. 2016) to early Pliocene (late Zanclean, 4.57 Ma; Bijl, 2023 after Wrenn and Kokinos, 1986). *Cribroperidinium* from Middle Jurassic (early Bajocian, 170.09 Ma; Bijl, 2023 after Riding and Thomas, 1992) to middle Micoene (early Serravallian, 13.4 Ma; Bijl, 2023 after after Matsuoka et al., 1987) or early Pliocene (?early Zanclean; Nagy, 1965); *Exochosphaeridium* from Late Jurassic (early Tithonian, 148.67 Ma; Bijl, 2023 after Bujak et al., 2022) to middle Miocene (late Langhian, 13.96; Bijl, 2023 after Fensome et al., 2008); *Florentinia* from Early Cretaceous (early Hauterivian, 129.99 Ma; Bijl, 2023 after Leereveld, 1997) to late Paleocene (late Thanetian, 56.14 Ma; Bijl, 2023 after Bijl et al., 2013); and the extant *Spiniferites* with its origins in the earliest Cretaceous (early Berriasian, 142.56 Ma; Bijl, 2023 after Monteil, 1993).

Sample ORS21 PS7, C-641990, R-3914-20 unsieved unless noted

Notes: Thermal Alteration Index 2+ to 3-; a lot of debris and phytoclasts; dinocysts present. This sample was prepared twice for quality control.

Coniferous pollen
?*Calliasporites* (R)
Cupressaceae-Taxaceae (C)
Cycadopites follicularis (R)

Angiosperm pollen
Retitricolpites (R)
Tricolpites X40/1 (R) (Pl. 1, fig. l)

Spores
?*Appendicisporites* sp. +20 µm fraction K42/2 (R)
Baculatisporites comaumensis (R)
Cicatricosisporites spp. (R)
Cyathidites minor (R)
Deltoidosporites hallei (C)
Gleicheniidites senonicus (R)
Laevigatosporites ovatus (R)
Selaginella complex W40/1 (R) (Pl. 1, fig. ac)
Stereisporites antiquasporites (S)
Undifferentiated reworked spores (R)
Undifferentiated cingulate spores Q36/3, M41/1, V24/2 (S)
Undifferentiated spores (R)

Non-pollen palynomorphs
Dinocysts (A)
Elongate fungal spores (R)
Callimothallus sp. +20 µm fraction W33/3 (R)
Pterospermopsis sp. M80/0, W12/2 (R)

Dinocysts (+20 µm fraction)
Achomosphaera sp. L20/1, M30/0 (11, A)
Alterbidinium sp. D19/2 (37, A)
Canningia cf. *inconspicua* EH45/0 (109, A)
Cleistosphaeridium sp. T15/4 (18, A)
Coronifera sp. M15/0 (18, A)
Exochosphaeridium spp. G25/0, K20/0 (54, A)
Exochosphaeridium majus M21/3 (1, R)
Hystrichodinium pulchrum Q20/1, T39/3, S43/0 (3, S)
Hystrichosphaeridium tubiferum J20/4 (1, R)
?*Florentinia* sp. O20/4 (4, S)
Florentinia cf. *clavigera* J23/0, S47/0 (4, S)
Sentusidinium cf. *capillatum* F37/0 (25, A)
?*Spinidinium* sp. E47/3, J14/3, O34/4 (12, A)
Spiniferites with septal membrane cluster M27/0, Q28/4 (8, C)

Spiniferites spp. F35/1, S46/0 (18, A)

Comments: Preservation is fair. An age estimate of late Albian to possibly early Cenomanian is based on a paucity and low diversity of tricolpate angiosperm pollen (Galloway et al., 2012). Palynomorph counts from slide P5387-20D of the >20 µm fraction totaled 110 trilete spores, twenty-six bisaccate pollen grains, thirteen monolete spores, two elongate fungal spores, and one *Callimothallus* sp. spore. The spore-to-pollen ratio of the sample is ~83%, and the overall terrestrial-to-marine palynomorph ratio is ~36%. Although the setting was still subject to strongly terrigenous influence, these values are indicative of a more distal depositional site relative to other samples examined from the Oyster River.

Counts of marine palynomorphs combined from both slides P5387-19B and P5387-19D totaled 109. Probable dinocyst *Canningia* cf. *inconspicua* is most abundant (34%), followed by all *Exochosphaeridium* spp. (17%), members of the *Achomosphaera-Spiniferites* group (15.2%), *Alterbidinium* sp. (12%), *Cleistosphaeridium* sp. (6%), and *Coronifera* sp. (6%). Outlying taxa include *Hystrichodinium pulchrum*, *Hystrichosphaeridium tubiferum*, *Florentinia* cf. *clavigera*, ?*Florentinia* sp., *Spinidinium* sp. It should be noted that poor presentation may have resulted in a conflation error of *Achomosphaera* spp. and *Cleistosphaeridium* sp. in some instances. Sample ORS21 PS7 yielded the greatest diversity, heterogeneity, and abundance of dinocysts in the studied suite. The presence of a heterogenous assemblage with taxa representing at least seventeen species and twelve genera from at least three families is suggestive of a high-productivity environment likely under stable, stratified conditions, and may be reflective of a transgressive phase at this interval in the Comox Formation section.

Cysts comparable to *Exochosphaeridium majus* from the Late Cretaceous ranging from Cenomanian to Campanian (Clarke and Verdier, 1973; Peyrot, 2011) provide the greatest age constraint followed by *Florentinia* cf. *clavigera* which ranges through the Late Cretaceous from early Cenomanian (97.18 Ma; Bijl, 2023 after Dodsworth, 2000) to early Maastrichtian (Foucher and Robaszynski, 1977). The remaining assemblage constituents are representatives of otherwise long-ranging genera: *Achomosphaera* from Early Cretaceous (early Aptian; Heilmann-Clausen in Heilmann-Clausen and Thomsen, 1995) to late Pliocene (Piacenzian; Head, 1997); *Alterbidinium* from the Late Cretaceous (early Turonian) to early Oligocene derived from the range chart from He Chengquan (1991, fig. 4) and the corresponding age of the Wuyitake Formation given as early Turonian by Mingzhen Zhang et al. (2022, fig. 2), and range top corresponding to the upper part of the fourth member of Shahejie Formation (He Chengquan, 1991; Kashif et al. 2020, fig. 2); *Cleistosphaeridium* from the Late Jurassic (see *C. tanzaniensis* Msaky 2011 comb. Wood et al. 2016) to early Pliocene (late Zanclean, 4.57 Ma; Bijl, 2023 after Wrenn and Kokinos, 1986); *Exochosphaeridium* from Late Jurassic (early Tithonian, 148.67 Ma; Bijl, 2023 after Bujak et al., 2022) to middle Miocene (late Langhian, 13.96; Bijl, 2023 after Fensome et al., 2008); *Florentinia* from Early Cretaceous (early Hauterivian, 129.99 Ma; Bijl, 2023 after Leereveld, 1997) to late Paleocene (late Thanetian, 56.14 Ma; Bijl, 2023 after Bijl et al., 2013); *Hystrichodinium pulchrum* from Middle Jurassic (late Bathonian, 165.5 Ma; Bijl, 2023 after Riding and Thomas, 1992) to Late Cretaceous (late Maastrichtian, 67.27 Ma; Bijl, 2023 after Costa and Davey, 1992); *Hystrichosphaeridium tubiferum* from Early Cretaceous (early Aptian, 118.12 Ma; Bijl, 2023 after Williams et al., 1993) to late Eocene (late Bartonian, 38.08 Ma; Bijl, 2023 after Bijl et al., 2013); *Sentusidinium capillatum* from Upper Jurassic (Kimmeridgian, *Sentusidinium qingzangense* of He Chengquan et al. 2005 *sensu* Riding, 2019) to Late Cretaceous (?Campanian; Davey, 1975); *Spinidinium* spanning the late Early Cretaceous (early Aptian Pöthe de Baldis and Ramos, 1983) to late Eocene (late Bartonian, 38.08 Ma; Bijl, 2023 after Bijl et al., 2013); and the extant *Spiniferites* with its origins in the earliest Cretaceous (early Berriasian, 142.56 Ma; Bijl, 2023 after Monteil, 1993).

Sample ORS21 PS7, C-641990, R3934-6 unsieved unless noted

Notes: The second preparation of this sample also contained abundant dinocysts. The preservation was poor, with a similarly high TAI of 2+ to 3. The preparation contained spore assemblages similar to the first run R-3914-20, including *Cyathidites minor* (R), *Deltoidosporites hallei* (A), *Stereisporites antiquasporites* (C), *Gleicheniidites senonicus* (S), as well as *Deltoidospora diaphana* (R), *Todisporites* (R), an undifferentiated *Cicatricosisporites* fragment (R), *Biretisporites potoniaei* (R), and *Lycopodiumsporites canaliculatus* (R). Pollen included *Monosulcites* (R), Cupressaceae-Taxacaeae (R), undifferentiated bisaccate pollen (R), and *Equisetosporites* (R, L24/1). The second preparation R-3934-6 is similar enough to the original preparation R-3914-20 that there can be confidence of sample labelling integrity and negligible contamination during handling and processing.

Srivastava (1968, p. 216) states that *Equisetosporites* Daugherty emend. Singh 1964 accommodates:

> "acolpate pollen grains; ellipsoid, sometimes narrower at one end; exine two layered; smooth nexine overlain by sexine; sexinous ridges unbranched, straight, 2 to 12 microns wide in the middle, narrowing at the longitudinal ends, low, gently rounded, running longitudinally, 8 to 25 in number; in a vertical section ridges semicircular in outline rather than angular, narrow furrows flanking the ridges abruptly, 1 to 3.5 microns wide, unbranched, straight; sometimes ridges criss-cross; ridges mostly coalescing just before reaching the longitudinal ends, a simple unsculptured area present at the longitudinal ends; four distinct areas of convergence of ridges present in some species, two such areas of convergence near each longitudinal end being opposite to nearly opposite"

The genus *Ephedripites* Bolkhovitina 1953 ex Potonié 1958 is frequently used to describe this pollen. However, the type species of *Ephedripites* Bolkhovitina 1953 was transferred by Bolkhovitina (1961) to the natural genus *Schizaea*. Srivastava (1968) argues that the genus *Equisetosporites* Daugherty emend. Singh 1964 has priority for this pollen type. Singh (1971) simply states that the genus *Ephedripites* is invalid. *Equisetosporites* is herein used.

Sample ORS21 PS8, C-641991, R-3914-21 unsieved unless noted

Notes: Thermal Alteration Index 2+ to 3-; a lot of debris; dinocysts present.

Coniferous pollen
Cupressaceae-Taxaceae (S)
Cycadopites follicularis (S)

Angiosperm pollen
Alnipollenites (R)
?*Fraxinoipollenites* K40/3 (R)

Spores
Converrucosisporites R30/4 (S)
Cyathidites australis (R)
Deltoidosporites diaphana (R)
Deltoidosporites hallei (R)
Laevigatosporites ovatus (R)
Microreticulatisporites uniformis (R)
Osmundacidites wellmannii (R)
Stereisporites antiquasporites (S)

Todisporites major (R)
Undifferentiated cingulate spores (C)
Undifferentiated spores (C)

Non-pollen palynomorphs
Dinocysts (R)
Uniserial foraminiferal linings +20 µm fraction T41/4 (2, R)

Dinocysts
Canningia cf. *inconspicua* P5387-21D H17/4 (2, R)
?*Exochosphaeridium* sp. P5387-21D Q20/0 (1, R)

Comments: A total of 123 trilete spores, eight monolete spores, and thirteen bisaccate pollen grains were observed on slide of the >20 µm fraction. A spore-to-pollen ratio of 91% is a strong indicator of a near-shore environment and/or terrigenous outflow. The Upper Cretaceous (Senonian) Patoot beds (Pautût) of western Greenland contain leaves referred to as belonging to *Fraxinus* (Berry, 1918). The first occurrence of *Fraxinoipollenites* (as *Fraxinoipollenites fragilis* Burger 1993) is from the ?Albian–Cenomanian in the upper part of the Huincul Formation of the Neuquén Group in Argentina (Vallati, 2002, 2013). This taxon occurs in Cretaceous strata from Australia (Burger, 1993). This sample appears to be broadly Late Cretaceous in age.

Only three dinocysts were present on slide of the >20 µm fraction indicating a low-productivity marine setting; one is questionably assigned to ?*Exochosphaeridium* sp. and the other two are specimens of *Canningia* cf. *inconspicua*. *Exochosphaeridium* spans the Late Jurassic (early Tithonian, 148.67 Ma; Bijl, 2023 after Bujak et al., 2022) to middle Miocene (late Langhian, 13.96; Bijl, 2023 after Fensome et al., 2008) while *C. inconspicua* is known the upper Aptian of England (Duxbury, 1983). An age inference could therefore be suggested as no older than early Aptian, although specimens that are comparable to a species described from an isolated report on the other side of the globe (Duxbury, 1983) can in no way provide a chronostratigraphic constraint. Furthermore, accuracy in diagnosis is compounded by limited material and the problematic plexus of intergradation among many areoligeracean forms within the '*Cyclonephelium* group' (Fensome et al., 2019a).

Sample ORS21 PS9, C-641992, R-3914-22 unsieved unless noted
Notes: Thermal Alteration Index 3+ to 3-; a lot of debris; very few palynomorphs and effectively barren; dinocysts absent.

Pollen
None

Spores
Deltoidosporites hallei (R)
Undifferentiated spores (R)

Non-pollen palynomorphs
None

Comments: Twenty-two trilete spores and one monolete spore were observed on slide of the >20 µm fraction. Age cannot be determined.

Sample ORS21 PS10, C-641993, R-3914-23 unsieved unless noted

Notes: Thermal Alteration Index 2- to 1+; a lot of debris; dinocysts absent.

Coniferous pollen
Cycadopites follicularis (R)
Undifferentiated bisaccate pollen (R)

Angiosperm pollen
Liliacidites (R)
Retitricolpites (R)
Siberiapollis Q23/2 (R)

Spores
Cyathidites australis (R)
Cyathidites minor (R)
Deltoidosporites hallei (R)
Dictyophyllidites harrisii V33/1 (R) (Pl. 1, fig. aa)
Gleicheniidites senonicus (R)
Undifferentiated spores (R)

Non-pollen palynomorphs
Chomotriletes M21/2 (R) (Pl. 1, fig. ai)

Comments: Only two bisaccate pollen grains and sixteen trilete spores were observed on slide of the >20 µm fraction. The Normapolles genus *Siberiapollis* was first described by Tschudy (1971) from upper Campanian rocks of Montana. Occurrences range into the Campanian (Tschudy, 1971, 1981; Srivastava, 1978). Its occurrence in this preparation limits the age to Campanian or younger.

Northeastern Vancouver Island | Longarm Formation equivalent samples

Sample SBR1-FS1, R-3914-8 unsieved unless noted

Notes: Due to poor recovery of palynomorphs, only a kerogen slide could be produced. This preparation is effectively barren. There was a single specimen of *Alnus* (or *Alnipollenites*) pollen, a bisaccate pollen grain, and a *Stereisporites* spore. Not analyzed for dinocysts.

Sample SBR1-FS1, R-3934-1 unsieved unless noted

Notes: This sample was processed in duplicate. Due to poor recovery of palynomorphs, only a kerogen slide could be produced. This second preparation was also effectively barren. There were no *Alnu*s (or *Alnipollenites*) grains, suggesting that their occurrence in R-3914-8 was due to contamination. Not analyzed for dinocysts.

Sample SBR2-FS1, R-3914-10 unsieved unless noted

Notes: Due to poor recovery of palynomorphs, only a kerogen slide could be produced. This preparation contained well-preserved *Alnus* (or *Alnipollenites*) pollen grains and was otherwise barren. Not analyzed for dinocysts.

Sample SBR2-FS1, R-3934-3 unsieved unless noted

Notes: This sample was processed in duplicate. Due to poor recovery of palynomorphs, only a kerogen slide could be produced. This preparation was effectively barren. The *Alnus* (or *Alnipollenites*) grains present in R-3914-10 are not present in this preparation, indicating that their occurrence in the first run was due to contamination. Not analyzed for dinocysts.

Sample HCO4-FS1, C-641982, R-3914-2 unsieved unless noted

Notes: Thermal Alteration Index 0; abundant black debris (probable inertinite); dinocysts absent.

Coniferous pollen
Cerebropollenties mesozoicus (Tsuga) (S)
Cupressaceae-Taxaceae (R)
Undifferentiated bisaccate pollen (R)

Angiosperm pollen
Alnipollenites (*Alnus*) (A)

Spores
Cyathidites australis (A)
Deltoidospora diaphana (R)
Laevigatosporites ovatus (Pteropsida monolete spores) (C)
Polypodopsida spores (R)

Non-pollen palynomorphs
Fungal spores (R)
Pediastrum fragment (R)

Comments: Contamination by modern pollen rain (*Alnus*). Non-marine. No dinocysts observed on either the unsieved slide (fully scanned) or other slides (quickly scanned).

Sample HCO5-PS1, C-641983, R-3914-5 unsieved unless noted

Notes: Thermal Alteration Index 0; kerogen slide only; dinocysts absent.

Comments: Contamination by modern pollen rain. Abundant *Alnipollenites* (*Alnus*) and *Cerebropollenites* (*Tsuga*) pollen and common bisaccate pollen. Fungal fruiting bodies present. Only one possible dinocyst was observed on the whole kerogen slide and could not be identified. The sample is non-marine. Age cannot be determined.

Suquash Sub-basin | Nanaimo Group equivalent samples

Sample SQM-FS2, C-641973, R-3914-12 unsieved unless noted

Notes: Thermal Alteration Index 2 to 2+; not analyzed for dinocysts.

Coniferous pollen
Cerebropollenites mesozoicus (R)
Classopollis classoides (R)
Cupressaceae-Taxaceae (C)
Cycadopites follicularis (S)
Monosulcites(S)

Virtreisporites pallidus (R)

Angiosperm pollen
?Marcellopites tolmanensis H24/1 (R) (Pl. 1, fig. q)
Siberiapollis M27/3 (R) (Pl. 1, fig. a)
Retitricolpites (R)
Undifferentiated tricolpate pollen T38/3 (R)
Undifferentated tricolpate pollen Q34/2 (R) (Pl. 1, fig. r)

Spores
Apiculatisporites(R)
Biretisporites potoniaei (S)
?*Contignisporites* (R)
Cyathidites australis (S)
Deltoidospora diaphana (C)
Deltoidospora hallei (A)
Deltoidospora psilostoma (C)
Dictyophyllidites harrisii (R)
Distaltriangulisporites perplexus (R)
Gleicheniidites senonicus (R)
Polypodiaceoisporties? *fossulatus* (R)
Stereisporites antiquasporites (C)
Verrucosisporites (R)

Non-pollen palynomorphs
Fungal spores (R)
Pterospermella (R)
Undifferentiated palynomorphs (A)

Comments: The presence of *Siberiapollis* spp. and *Marcellopites tolmanensis*? limits the sample to be Campanian or younger in age. *Marcellopites tolmanensis* Srivastava 1969b is the type species for *Marcellopites*. It is diagnosed as “triporate, oblate, angular aperturate; pores meridional or equatorial; amb triangular to circular, sides slightly concave to convex; sexine thick; infratextured to finely scabrate” by Srivastava (1969b, p. 986). *Marcellopites tolmanensis* is 33–40 µm in size and was described from Maastrichtian strata in Alberta, Canada, but this species ranges into the Campanian (in the Judith River Formation at Muddy Lake, Saskatchewan, Canada; correlatable with marine biostratigraphic interval ranging from the *Baculites gregoryensis* ammonite zone upward to the *Baculites compressus* ammonite zone) (Eberth et al., 1990).

Sample SQM1-FS2, C-641974, R-3914-13 unsieved unless noted
Notes: Thermal Alteration Index 1+ to 2-; not analyzed for dinocysts.

Coniferous pollen
Cupressaceae-Taxaceae (A)
Cycadopites follicularis (A)
Laricoidites magnus (R)
Sequoiapollenites spp. (R)
Monosulcites (S)

Perinopollenites elatoides (R)
Undifferentiated bisaccate pollen (C)

Angiosperm pollen
Liliacidites O27/4 (R) (Pl. 1, figs. g, h)
?*Senipites* O27/4 (R) (Pl. 1, fig. e)
?Senipites drumhellerensis T39/3 (R) (Pl. 1, fig. d)
Tricolpites M36/3 (R) (Pl. 1, fig. m)
Tschudypollis M18/4 (R)
Unknown angiosperm pollen O27/4 (R) (Pl. 1, fig. t)
Unknown angiosperm pollen Q34/2 (R) (Pl. 1, fig. r)

Spores
Apiculatisporites spp. (C)
Baculatisporites comaumensis (C)
Biretisporites potoniaei (S)
?*Cicatricosisporites* R38/1 (R) (Pl. 1, fig. ag)
Cingulitriletes clavus (R)
Cyathidites australis (S)
Cyathidites minor (S)
Deltoidosporites hallei (A)
Deltoidosporites psilostoma (R)
Dictyophyllidites harrisii (R)
Distaltriangulisporites maximus R38/1 (R)
Gleicheniidites senonicus (R)
Laevigatosporites ovatus (S)
Leptolepidites verrucatus (R)
Microreticulatisporites uniformis (R)
Osmundacidites wellmannii (S)
Retitriletes austroclavatidites (A)
Stereisporites antiquasporites (C)
Stereisporites (S) (Pl. 1, figs. y, z)
Undulatisporites undulapolus (R)
Polypodiaceoisporties? *fossulatus* (S)
Undifferentiated spores (R)
Undifferentiated cingulate psilate spore, concave sides, laesurae extend to margin of central body (S) U26/3 (Pl. 1, fig. ae) (the same spore as in sample ORS21 PS5, C-641988, R-3914-18)

Non-pollen palynomorphs
Fungal spores (A)

Comments: The occurrence of *Tschudypollis* pollen limits the age of the sample as Turonian to Maastrichtian. The occurrence of a ?*Senipites* pollen grain suggests an age of early to middle Campanian or younger because this genus (as *Senipites drumhellerensis*) occurs in the “Later Loranthaceous” suite of Jarzen and Norris (1975, p. 51) in the upper part of the Lea Park Formation and lower part of the Foremost Formation in the lower to middle Campanian. Braman and Sweet (2012) document *Senipites drumhellerensis* as appearing just before 75 Ma. At the time of their 2012 publication, 75 Ma fell within the lower upper Campanian, and remains so according to the latest time scale (Gale et al., 2020).

Senipites Srivastava 1969a, p. 62 (type species *Senipites drumhellerensis*) is described as:

> "tricolporate, oblate, anguiaperturate; colpi long, meridional, narrow, reaching half way or more towards the polar areas; pores vestibulate, conspicuous, with atrium, equatorial; amb triangular, sides straight to convex; sexine well defined thick, tectate, clavate or baculate, tectate or intectate".

Symplocoipollenites Potonié 1951 ex. 1960 has much shorter colpi that are either restricted in vestibulate pores or barely make an exit from such pores; in other respects, the pollen of *Symplocoipollenites* are very similar to *Senipites*. *Symplocoipollenites* Potonié 1951 ex. 1960 (p. 106) is described as:

> "lenticular (oblate) shape, polar axes shorter than equatorial axes, equator more or less triangular, exine granulate to regulate, outline finely crenulate; colpi short, with distinct vestibulum".

The type (*Symplocoipollenites vesitulum*) from the Miocene of Germany is 25–32 µm in size (holotype 27 µm) and finely granulate.

Sample SQM-PS3, C-641975, R-3914-9 unsieved unless noted
Notes: Thermal Alteration Index 1+ to 2-; dinocysts present.

Coniferous pollen
Bisaccate pollen undifferentiated (S)
Cerebropollenites mesozoicus (R)
Classopollis classoides (R)
Cupressaceae-Taxaceae (C)
Cycadopites follicularis (R)
Laricoidities magnus (R)
Sequoiapollenites spp. (R)

Angiosperm pollen
Alnipollenites J44/2 (R) (Pl. 1, fig. u)
Liliacidites (C)
Caryapollenites (R)
?Senipites drumhellerensis P38/1 (R) (Pl. 1, fig. c)
Siberiapollis P45/2 (R) (Pl. 1, fig. b)
Tschudypollis (R) (Pl.1, fig. k)
Kurtzipites no England Finder coordinates recorded (R) (Pl. 1, fig. f)
Retitricolpites (A)
Undifferentiated angiosperm pollen (C)
Undifferentiated porate angiosperm pollen S45/2 (R)
Undifferentiated reticulate triporate angiosperm pollen O15/2 (R)
Undifferentiated triporate angiosperm pollen
Undifferentiated tricolpate angiosperm pollen (R)

Spores
Apiculatisporites (S)
Baculatisporites comaumensis (C)

Biretisporites potoniaei (R)
Cicatricosisporites spp. (C)
Cingulitriletes (S)
Converrucosisporites N45/2 (C)
Cyathidites australis (S)
Deltoidosporites diaphana (A)
Deltoidosporites hallei (A)
Deltoidosporites diaphana (S)
Deltoidosporites psilostoma (S)
Dicytophyllidites harrisii (R)
Distaltriangulisporites maximus S26/4 (S)
Gleicheniidites senonicus (R)
Ischyosporites (S)
Leptolepidites verrucatus (S)
Osmundacidites wellmannii (C)
Retitriletes austroclavatidites (C)
Stereisporites antiquasporites (C)
Verrucosisporites rotundus N45/2 (C)
Verrucosisporites (R)
Undifferentiated palynomorphs (C)
Undifferentiated cingulate psilate spore, concave sides, laesurae extend to margin of central body (A) (the same spore as in sample ORS21 PS5, C-641988, R-3914-18 and sample SQM-1-FS2, C-641974, R-3914-13 and shown in Pl. 1, fig. ae)

Non-pollen palynomorphs
Dinocysts (C)
Fungal spores (R)

Dinocysts
?*Canningia* sp. Kerogen Q16/3 (1, R)
?*Diconodinium* sp., Kerogen Q30/0 (1, R)
?*Exochosphaeridium* sp. partial specimen, kerogen Q35/2; >20 µm fraction R44/3 (1, R)
Odontochitina sp. operculum, kerogen K36/3 (1, R)
?*Spinidinium* sp. Kerogen D40/0 (1, R)
?*Vozzhennikovia* sp. kerogen E47/0 (1, R)
Xenascus sp. Kerogen U39/0; Kerogen K29/3 (3, S)

Comments: The occurrence of ?*Senipites* and *Siberiapollis* pollen suggest an age of early or middle Campanian or younger. *Kurtzipites* pollen occurs in the "Early Loranthaceous" suite of Jarzen and Norris (1975, p. 50) that occurs in the middle part of the Lea Park Formation during the ?Santonian to lower Campanian. *Caryapollenites* Raatz 1937 ranges into the Santonian, but is more common in Paleocene strata (White, 2006). For example, *Caryapollenites* is documented in strata as old as late Santonian with '*Betula' claripites* Wodehouse 1933 in the Canadian High Arctic (Axel Heiberg and Ellesmere islands) (Hickey et al., 1983). *Caryapollenites* is also documented from the Gil'chin and Dim dinosaur localities in Russia from strata of Maastrichtian age (Markevich et al., 2010). The presence of this lineage therefore restricts the sample to be Santonian or younger. The occurrence of *Tschudypollis* pollen indicates an age of Turonian to Maastrichtian. Collectively, the angiosperm pollen suggest an age of Campanian or younger. Both *Proteacidites* (as *P. auratus*) (basionym of *Tschudypollis*) and *Senipites* pollen are recorded in Maastrichtian-aged strata of the Bonnet Plume Formation, northeastern Yukon (Rouse and Srivastava, 1972).

Dinocyst preservation is generally fair with nine specimens observed representing seven taxa. Generic placement is questionable for most due to suboptimal preservation, orientation, or fragmentation. The genus *Odontochitina* extends from the late Hauterivian (127.72 Ma; Bijl, 2023 after Williams et al., 1993) to the terminal Maastrichtian (66.04 Ma; Bijl, 2023 after Masure et al., 1998). Similarly, the genus *Xenascus* ranges from early Albian (110.17 Ma; Bijl, 2023 after Leereveld, 1995) to late Campanian (72.17 Ma; Bijl, 2023 after Masure et al., 1998). Other genera of less confidence are much longer ranging: *Canningia* from Late Jurassic (Tithonian; Cookson and Eisenack, 1960) to early Danian (65.88 Ma; Bijl, 2023 after Willumsen, 2012); *Diconodinium* extending from the early Aptian (118.84 Ma; Bijl, 2023 after Helby and McMinn, 1992) to late Oligocene (Chattian; Oleinik, 1975); *Exochosphaeridium* spanning the Late Jurassic (early Tithonian, 148.67 Ma; Bijl, 2023 after Bujak et al., 2022) to middle Miocene (late Langhian, 13.96; Bijl, 2023 after Fensome et al., 2008); *Spinidinium* Early Cretaceous (early Aptian; Pöthe de Baldis and Ramos, 1983) to middle Eocene (late Bartonian, 38.08; Bijl, 2023 after Bijl et al., 2013); and *Vozzhennikovia* Late Cretaceous (early Santonian; Aurisano, 1984 *sensu* Sliujs et al., 2009) to middle Eocene (late Bartonian 38.08; Bijl, 2023 after Bijl et al., 2013). Although many of the taxa are of questionable assignment, a Late Cretaceous age is most probable ranging from early Santonian to late Campanian based on the presence of *Vozzhennikovia* (if reliable) and *Xenascus* sp.

Sample SQM6-FS1, C-641976, R-3914-6 unsieved unless noted

Notes: Thermal Alteration Index 2-; preservation poor; not analyzed for dinocysts.

Coniferous pollen
Cycadopites follicularis (C)
Sequoiapollenites (R)
Perinopollenites elatoides (R)

Angiosperm pollen
Alnipollenites (R)
Clavatipollenites (R)
Siberiapollis (R)
Liliacidites (C)
Momipites R34/1 (S) (Pl. 1, fig. w)
Retitricolpites (S)
Trudopollis R26/2 (R) (Pl. 1, fig. n)
Undifferentiated angiosperm pollen (R)
Undifferentiated reticulate angiosperm pollen (R)

Spores
Apiculatisporites (R)
Appendicisporites (R)
Baculatisporites comaumensis (S)
Biretisporites potoniaei (R)
Cicatricosisporites spp. (R)
Cingulitriletes (R)
Cinguiltriletes clavus (R)
Cyathidites australis (A)

Deltoidosporites diaphana (R)
Deltoidosporites hallei (A)
Gleicheniidites senonicus (C)
Ischyosporites (R)
Osmundacidites wellmannii (R)
Polypodiaceoisporties? *fossulatus* (R)
Retitriletes austroclavatidites (R)
Stereisporites antiquasporites (C)
Undifferentiated cingulate psilate spore, concave sides, laesurae extend to margin of inner body (Pl. 1, fig. a) (the same spore as in sample ORS21 PS5, C-641988, R-3914-18 and sample SQM-1-FS2, C-641974, R-3914-13 and shown in Pl. 1, fig. ae Sample SQM-PS3, C-641975, R-3914-9)
Unknown spore (R)

Non-pollen palynomorphs
Fungal spores (S)
Unknown algal remains? R22/4 (R) (Pl. 1, fig. aj)
Undifferentiated non-pollen palynomorphs (R)

Comments: The occurrence of *Siberiapollis* pollen in this preparation suggest an age of Campanian or younger. The full range of *Trudopollis* (*sensu* Krutzsch; see discussion) is middle Turonian to late Eocene, with most abundant occurrences in lowermost Upper Cretaceous rocks of north-central Europe (Jansonius and Hills, 1976). Tschudy (1981) states that the genus *Trudopollis* ranges from Cenomanian to basal Eocene, although most *Trudopollis* specimens appear in the Cretaceous. Jarzen and Norris (1975) document *Trudopollis* as appearing in the upper middle Campanian in the Foremost Formation preserved in the Amoco B-1 Youngstown well in Drumheller, Alberta. Together, the occurrence of *Siberiapollis* and *Trudopollis* suggest an age of middle Campanian or younger.

Sample SQM10-FS1-A, C-641977, R-3914-7 unsieved unless noted
Notes: Thermal Alteration Index 0 to 1-; not analyzed for dinocysts.

Coniferous pollen
Cupressaceae-Taxaceae (A)
Cycadopites follicularis (C)
Sequoiapollenites N24/1 (R) (Pl. 1, fig. x)
Undifferentiated bisaccate pollen (R)

Angiosperm pollen
Alnipollenites R32/1 (A) (Pl. 1, fig. v)
?*Clavatipollenites* (R)
?*Ericipites* (R)
?*Gunnaripollis* R32/1 (R) (Pl. 1, fig. p)
Liliacidites (A)
Momipites (C)
Retitricolpites (A)
Tschudypollis (basionym *Proteacidites*) (R) (Pl. 1, fig. j)
Tschudypollis thalmannii N24/1 (R) (Pl. 1, fig. i)
Undifferentiated periporate angiosperm pollen (R) (Pl. 1, fig. s)
Undifferentiated tricolporate angiosperm pollen (R)

Undifferentiated tricolpate pollen N24/1 (R)

Spores
Apiculatisporites (S)
Baculatisporites comaumensis (S)
Cingulitriletes clavus (R)
Cyathidites australis (R)
Deltoidosporites diaphana (A)
Deltoidosporites hallei (A)
Deltoidosporites psilostoma (R)
Dictyophyllidites harrisii (R)
Distaltriangulisporites maximus (R)
Distaltriangulisporites perplexus (R)
Echinosporis (R)
Gleicheniidites senonicus (R)
Laevigatosporites ovatus (R)
Osmundacidites wellmannii (S)
Retitriletes austroclavatidites (S)
Stereisporites antiquasporites (C)
Stereisporites (R)

Comments: As a genus, *Tschudypollis* first occurs in western Canada (in the Amoco B-1 Youngstown well) as part of the "Early Triporate" suite of Jarzen and Norris (1975, p. 49) in the upper Colorado Group and lower Lea Park Formation in the Turonian to ?lower Santonian. Of note, *Betulaceoipollenites* sp. (a scabrate form with large, protruding annulate and vestibulate pores) and *Tricolporopollenites* sp. 1 (a relatively large grain with slit-like ora and equatorial differentiated of exine infrastructure) of Jarzen and Norris (1975) also occur in this suite. The presence of *Tschudypollis* spp. in this preparation limit the age of the sample to be Turonian to Maastrichtian in age.

Tschudypollis thalmannii (basionym *Proteacidites thalmannii* Anderson 1960) is restricted to Turonian–Maastrichtian strata in western North America in general. However, Braman and Sweet (2012) calibrated first occurrences of this taxon in the northern part of the North American Western Interior Sedimentary Basin with ammonite biozones and magnetostratigraphy to report *T. thalmannii* as appearing at 87 Ma. At the time of publication in 2012, 87 Ma fell into the uppermost Coniacian, and according to Gale et al. (2020), 87 Ma remains within this Cretaceous stage that ranges from 89.39–85.7 Ma.

Gunnaripollis Srivastava 1969b is described by Srivastava (1969a, p. 984) as:

> "isopolar; six-colpate, meridional, three alternate colpi long, reaching poles, other three alternate colpi short; polar axis shorter than equatorial axis; sexine thick, tectate; ornamentation reticulate, retipilate, etc."

It is documented in Maastrichtian strata from Alberta, Canada, but this species ranges into the Campanian. In the Judith River Formation at Muddy Lake, Saskatchewan, Canada, it can be correlated with a marine biostratigraphic interval ranging from the *Baculites gregoryensis* ammonite zone upward to the *Baculites compressus* ammonite zone (Eberth et al., 1990).

Together, the occurrence of *Tschudypollenties thalmannii* and ?*Gunnaripollis* indicate that the sample ranges in age from Campanian to Maastrichtian.

Sample FRB-FS1, C-641978, R-3914-3 unsieved unless noted

Notes: Thermal Alteration Index 2+ to 3-; effectively barren of pollen and spores; dinocysts present.

Pollen and spores

This preparation is effectively barren of terrestrial pollen and spores. Rare spores of *Deltoidospora psilostoma*, *D. hallei* and an unknown spore are present. *Cycadopites* and *Monosulcites* pollen are rare (one occurrence each).

Non-pollen palynomorphs

Dinocysts (A)

Dinocysts

?*Apteodinium* sp. (1, R) (Pl. 2, fig. a)
Ceratiaceae fragments (3, S)
Pseudoceratium pelliferum (7, C) (Pl. 2, fig. d–f)
Odontochitina sp. (2, R) (Pl. 2, fig. g)

Comments: Age cannot be determined based on pollen and spores. This sample yielded a total of thirteen dinocysts preserved in the unsieved and the >45 µm fractions. *Pseudoceratium pelliferum*, the only taxon identified at the species level, indicates an age of late Berriasian to early Aptian with the oldest reported range base at 140.34 Ma (Bijl, 2023 after Habib and Drugg, 1983) and youngest last occurrence at 118.12 Ma (Bijl, 2023 after Williams et al., 1993) (see also Stover et al., 1996 and Galloway et al., 2022). However, the degradation of these specimens suggests some influence of allochthonous deposition or sediment reworking. Even though the specimen of *Odontochitina* sp. could not be identified to the species level, the genus extends from the late Hauterivian (127.72 Ma; Bijl, 2023 after Williams et al., 1993) to the terminal Maastrichtian (66.04 Ma; Bijl, 2023 after Masure et al., 1998). The other taxa could not be identified with certainty and are long-ranging. Age interpretation based on dinocysts for this sample is therefore Barremian to Campanian. In addition, the dominance of ceratiacean cysts (and absence of other families) might suggest a near-shore depositional environment.

Sample OGL-OCP3 FS1, C-641979, R-3914-11 unsieved unless noted

Notes: Thermal Alteration Index 0 and for rare degraded unidentifiable palynomorphs in the preparation the Thermal Alteration Index is 2+; abundant black debris; dinocysts present.

Coniferous pollen

Cerebropollenites mesozoicus (R)
Cupressaceae-Taxaceae (A)
Undifferentiated bisaccate pollen (R)

Angiosperm pollen

Alnipollenites (C)
Chenopodipollis (R)
Retitricolpites (R)

Spores

Deltoidospora hallei (R)
Unknown spores (R)

Unknown spores with a TAI of 2+ (R)

Non-pollen palynomorphs
Dinocysts (R)

Dinocysts
Possible *Exochosphaeridium* sp. or *Coronifera* sp. (1, R) (Pl. 2, fig. c)
Odontochitina sp. (1, R)
Vesperopsis sp. (3, S) (Pl. 2, figs. h, i)

Comments: Age cannot be confidently interpreted based on pollen and spores. The occurrence of a single Chenopodiaceae pollen grain likely represents contamination, but there are reports of *Chenopodipollis* spp. pollen (fossil Chenopodiaceae) in Maastrichtian–Danian rocks in Canada (Muller, 1981). Leopold (1969) documents *Chenopodipollis* spp. pollen from the upper Paleocene.

Dinocyst preservation was poor and only five specimens were observed. No taxon could be identified to the species level. Members of *Odontochitina* extend through the Cretaceous from the late Hauterivian (127.72 Ma; Bijl, 2023 after Williams et al., 1993) to the terminal Maastrichtian (66.04 Ma; Bijl, 2023 after Masure et al., 1998). However, the presence of *Vesperopsis* sp. in the preparation suggests a late Barremian (122.68 Ma; Bijl, 2023 after Williams et al., 1993) to early Cenomanian (97.24 Ma; Bijl, 2023 after Fensome et al., 2008) age for the sample given the range of the latter genus. However, the confidence level of the dinocyst-based age interpretation is low since it corresponds to the recovery of only four, highly degraded specimens.

Sample PMO1-FS1, C-641980, R-3914-4 unsieved unless noted

Notes: Thermal Alteration Index 0; abundant black debris; preservation poor; dinocysts present.

Coniferous pollen
Cerebropollenites mesozoicus (C)
Cupressaceae-Taxaceae (A)
Cycadopites follicularis (C)
Monosulcites (S)
Undifferentiated bisaccate pollen (A)

Angiosperm pollen
Alnipollenites (A)
Caryapollenites (R)
Retitricolpites (S)
Tricolpites (R)
Undifferentiated angiosperm pollen (S)

Spores
Acanthotriletes (R)
Baculatisporites comaumensis (S)
Biretisporites potoniaei (R)
Cicatricosisporites (R)
Cyathidites australis (R)
Cyathidites minor (R)

Deltoidospora diaphana (A)
Deltoidospora hallei (A)
Deltoidospora psilostoma (S)
Dictyophyllidites harrisii (R)
Distaltriangulisporites perplexus (R)
Foveosporites (R)
Gleicheniidites senonicus (S)
Laevigatosporites ovatus (C)
Ornamentifera (R)
Osmundacidites wellmannii (S)
Polypodiaceoisporties? *fossulatus* (R)
Retitriletes austroclavatidites (S)
Stereisporites antiquasporites (S)
Stereisporites regium (R)
Unknown spores (A)

Non-pollen palynomorphs
Dinocysts (R)
Fungal spores (C)

Dinocysts
Dinocyst preservation was fair but specimens were highly fragmented. Only one taxon could be identified to the species level.
Gonyaulacoid sp. indet. (1, R)
?*Nyktericysta* sp. (1, R) (Pl. 2, fig. b)
Odontochitina sp. (2, R)
Pseudoceratium pelliferum (3, S)
Senoniasphaera sp. (2, R)

Comments: The occurrence of *Caryapollenites* pollen in this preparation restricts the age of the sample to be late Santonian or younger. This is consistent with the presence of *Alnipollenites* pollen in the preparation, a taxon that ranges into the Upper Cretaceous (e.g., Kerr, 1974; Srivastava, 1981a). Given concern about possible preparation contamination for other samples, *Alnipollenites* and *Caryapollenites* could also be modern contamination. If they are, the remainder of the pollen and spore assemblage and in particular the simple angiosperm pollen suggests an Albian age (see Galloway et al., 2012) and is more aligned then with the dinocyst-based age interpretation of Barremian to early Aptian age for the sample.

The presence of *Pseudoceratium pelliferum* (late Berriasian–early Aptian; Bijl, 2023 after Habib and Drugg, 1983 and Williams et al., 1993) (see also Stover et al., 1996; Galloway et al., 2022) and *Odontochitina* sp. (early Hauterivian–late Maastrichtian; Bijl, 2023 after Masure et al., 1998 and Williams et al., 1993) in the preparation suggests a late Berriasian to early Aptian age for the sample. The other dinocyst taxa could not be identified with certainty and are long-ranging types.

Sample PMO2-PS1, C-641981, R-3914-1 unsieved unless noted
Notes: Thermal Alteration Index 0; abundant black debris; dinocysts present.

Coniferous pollen
Cerebropollenties mesozoicus (Tsuga) (A)

Cupressaceae-Taxaceae (A)
Undifferentiated bisaccate pollen (C)

Angiosperm pollen
Alnipollenites (A)

Spores
Cyathidites australis (R)

Non-pollen palynomorphs
None. No dinocysts in the kerogen or unsieved slides.

Comments: Contamination by modern pollen rain. Non-marine.

DISCUSSION

Comments on quality assurance and quality control of preparations

Five samples were processed for palynology in duplicate (SBR2-FS1, SBR1-FS1, ORS21 PS3, ORS21 PS5, and ORS21 PS7) to assess the possibility of contamination by modern pollen rain either during sample collection and/or contamination during processing. Samples SBR2-FS1 and SBR1-FS1 both yielded insufficient material for age assessment of the sample, and only the kerogen mounts were analyzed. However, re-processing them revealed that the *Alnus* (or *Alnipollenites*) pollen present in the first processed batch of these two samples (R-3914-8, 10) were absent from the second batch (R-3934-3, 1). This result raises the possibility of contamination by *Alnus* pollen in all of the material processed in the first batch R-3914-#. Because *Alnus*-type pollen (*Alnipollenites*) ranges into the Upper Cretaceous, this is not a particularly useful indicator of age and thus, contamination by this type does not necessarily obscure age interpretations. While the occurrence of *Alnus* contamination raises the possibility of contamination by other pollen types, no other pollen forms were found to occur in the same exceptionally well-preserved state as *Alnus* pollen, in abundance, and in almost all preparations, including otherwise barren preparations. *Alnus* is a cosmopolitan taxon in Canada, and contamination by this type could represent contamination by pollen rain and/or during processing. In one of the samples (ORS 21 PS5), *Tsuga* (or *Cerebropollenites*) pollen was common in the first batch of processed samples (R-3914-18) but absent in the second preparation (R-3934-5). *Tsuga* (hemlock) is common in the sample collection area of coastal BC but rare in southern and residential Alberta where Global GeoLabs Ltd. is located (Medicine Hat), providing evidence of contamination by regional pollen in rain for this sample. Contamination by modern pollen is recognizable by differential stain acceptance and preservation, even after internal cellular contents are removed by the oxidation step (see Stanley, 1966 and Heusser, 1983). Because the contamination can be identified, it is concluded that it does not substantially obscure interpretation of biostratigraphic age.

The Continental Margin Floristic Province

The samples herein analyzed contain well-preserved palynoflora characteristic of the Continental Margin floristic province (Fredericksen, 1987), with abundant *Tschudypollis* pollen and an absence of *Aquilapollenites* Rouse 1957 emend. Braman 2013 and other taxa that typify the Normapolles and *Aquilapollenites* floristic provinces. However, the samples herein analyzed are unique from the Continental Margin floristic province with the addition of common *Kurtzipites* spp. pollen. There are also spore taxa (e.g., Pl. 1, fig. ae) in these samples that remain undifferentiated in this report and may be unique to this floristic province or endemic to the region.

In the continental margin setting of BC and parts of California, Upper Cretaceous palynoassemblages contain largely endemic taxa, characterized by an abundance of *Proteacidites* (*Tschudypollenites*) group as the most abundant angiosperm pollen element, rare to absent *Aquilapollenites* pollen, an absence of *Callistopollenites* Srivastava 1969a, and rare members of pollen of the Normapolles group (Frederiksen, 1987). *Aquilapollenites* is an extinct morphogenus of angiosperm pollen that was abundant during the Late Cretaceous and that contained around 80 species typified by their triprojectate structure. Colpi occupy the terminus of the equatorial projections, making *Aquilapollenites* tricolpate (Traverse, 1988). Most species of *Aquilapollenites* became extinct at the end of the Cretaceous, but a few species survived across the Cretaceous-Paleogene boundary (e.g., Choi, 1984; Braman 2013). *Callistopollenites* has a tricolporate morphology and a distinctive striate sculpture (Srivastava, 1972). Normapolles pollen are a group of diverse angiosperm pollen characterized by a complex triaperturate morphology. The paucity or absence of *Aquilapollenites, Callistopollenites*, and Normapolles group pollen in the continental margin of BC and parts of California is postulated to be due to isolation from floras to the east as a result of oceanic and mountain barriers, but also due to the more tropical climate experienced in the paleocoastal setting relative to more inland sites (Frederikson, 1987). If the terranes of continental BC were indeed translated northward (>1000 km) in the Late Cretaceous (~90–60 Ma) ('Baja BC' hypothesis), this phytogeoprovince would reflect parent plants growing in a substantially more southern and temperate location than their western interior counterparts.

Notes on taxonomy and biostratigraphy

To further discuss the assemblages in the material examined, some notes on taxonomy are required.

Alnipollenites pollen

Pollen of *Alnipollenites* occurs in the Santonian and Campanian in Japan (Takahashi, 1974; Miki, 1977) and there are numerous Maastrichtian and Paleocene records of *Alnus*-like pollen from North America and Europe (Stanley, 1965; Elsik, 1968; Norton and Hall, 1969; Oltz, 1969; Snead, 1969; Felix and Burbridge, 1973; Srivastava, 1975; Jarzen, 1982; Crane and Stockey, 1987). Pollen characteristic of *Alnus* dates back to the Santonian (Hickey et al., 1983), late Maastrichtian (Hopkins, 1973), or Paleocene (McIntyre and Ricketts, 1989) in the Canadian Arctic, the Santonian or Turonian of Alberta (Jarzen and Norris, 1975), and as old as Albian in Russia (Sedova, 1964; Panova, 1964).

Based on comparison of preparations processed in different batches (R-3914 and R-3934), the presence of much of the *Alnus*/*Alnipollenites* pollen in R-3914 is likely due to contamination (*Alnus*).

Caryapollenties and *Momipites pollen*

The original diagnosis and taxonomy of *Caryapollenites* is outlined in Nichols and Ott (1978). Krutzsch's (1961, p. 310) emendation of the genus notes the juglandaceous structure of the exine and apertures, and the existence of a polar thin area that may be developed as a circular or triangular spot or ring ("solution field"), a weak or thin pollen wall with a tendency to develop folds, structure of exine, and structure of apertures.

Caryapollenties Raatz 1937 ex Potonié 1960 emend. Krutzsch 1961 is documented in strata of Santonian age in the Canadian Arctic (Hickey et al., 1983), but most records of this pollen in the Arctic (e.g., Spicer et al., 1987; Norris and Miall, 1984) or mid-latitudes of North America (e.g., Jarzen, 1982; Demchuk , 1990) are known from strata dated as Paleocene in age (e.g., Braman and Sweet, 2012). Jarzen and Norris (1975, p. 50) document *Caryapollenites* (as *Caryapollenites* sp. cf. *C. veripites*) in their "Early Loranthaceous" pollen suite that first occurs in the middle Lea Park Formation in the Amoco B-1 Youngstown well drilled in Drumheller, Alberta, in strata dated as ?Santonian to lower Campanian.

Momipites Wodehouse 1933 emend. Nichols 1973 and *Caryapollenite*s are both juglandaceous pollen (Muller, 1981) and are differentiated on the basis of size, shape, polar exine structure, and isopolarity or heteropolarity of pore position (Nichols and Ott, 1978). Heteropolarity of pore position is the most distinctive feature of the modern pollen genus *Carya* and the fossil (ancestral) pollen *Caryapollenite*s (Nichols and Ott, 1978). The degree of heteropolarity serves to differentiate *Caryapollenites* species, with incomplete heteropolarity of pore position being an indication of an older lineage (Nichols and Ott, 1978 and references therein). The genus *Caryapollenites* appears to have been derived from the basic form of *Momipites* by changes in the size and development of heteropolarity in pore position (Nichols and Ott, 1978). *Momipites*, in turn, could have been derived from a pollen with *Engelhardia*-like morphology (Nichols and Ott, 1978).

Momipites coryloides Wodehouse 1933 is the type for *Momipites*; although the holotype of *Momipites* has not been located. *Momipites* pollen has pores on the equator. Nichols (1973, p. 106) emended the diagnosis of *Mompites* to:

> "triporate pollen, rarely with two or four pores; oblate to suboblate; amb generally semi-angular to sub-angular. Pores located equatorially, circular to meridionally elongate, with distinct atrium, non-aspidate. Exine about 1-1.5 µm in thickness; psilate to faintly scabrate or foveolate. Exine with or without various structural modifications: thinning or tri-ratdiate thickening at the poles, random or non-random folding. Size variable in different species, about 15–40 µm".

The diagnosis is further emended by Frederiksen and Christopher (1978) to exclude species *microcoryphaeus*, *triradiatus*, and *triorbicularis* goups (see Jansonius and Hills, 1976).

Kurtzipites

Anderson (1960) erected the genus *Kurtzipites* for oblate pollen with triangular or crescent-shaped nexinous thickenings at polar extremities of apertures. The original diagnosis for *Kurtzipites* by Anderson (1960, p. 24) is as follows:

> "oblate, triporate pollen with hexagonal, subcircular or subtriangular outline in polar view; pores equatorial, lolongate, and with a triangular or crescent-shaped opaque thickening on polar sides pointing towards the pores".

Leffingwell (1971, p. 50), recognized that *Kurtzipites* is actually a tricolporate pollen with few doubtful tricolpate examples and emended this diagnosis to:

> "tricolporate pollen, although some species may be either indistinctly tricolporate or tricolpate(?); colpi short, meridionally oriented, extending from one-fourth to one-half of grain radius; pores atriate; grain shape, oblate, rounded triangular in polar view; exine scarbrate; the nexine about the pore may be uniformly thick, or variable thickness, or not thickened at all; when the pore exine is thickened, a characteristic, more or less triangular thickening is often developed near the polar extremities of the colpi".

Srivastava (1981b, p. 869) revised this diagnosis to include pollen that is:

> "tricolporate or tricolporoidate(?); colpi short on somewhat aspidote (or alternative spelling; aspidate; pollen having a prominently protruding thickening of the exine around a pore) or narrowly rounded amb

> corners; pores atriate (pollen having a space within the aperture of a compound pore that has a much larger endopore than ectopore, so that the pore canal widens towards the interior of the grain), situated at colpi center; amb subtriangular to subcircular, rarely triangular, oblate, sides convex or straight, rarely concave; exine two-layered; nexine normally thicker around pores; sexine very thin, tectate; infratectal layer generally not seen; supratectal sculpture finely granulose, spinulose".

The holotype of the type species, *Kurtzipites trispissatus*, is folded and shows generic characteristics only vaguely represented (Anderson, 1960; Srivastava, 1981b).

The oldest records of *Kurtzipites* pollen are late Campanian in North America (New Mexico and Colorado) (Newman, 1986) and broadly Campanian in China (Zhang, 1993). It was a typical element during the Santonian in western North America (Frederiksen, 1987). This pollen type extends into the early Paleocene in the southern part of the Western Interior of the United States (New Mexico and Colorado; Tschudy et al., 1984) and rare reports are documented in strata as young as Oligocene in a pollen assemblage preserved in a subsurface cutting sample of Rattlesnake Hills Well 1, Benton County Washington State (Newman, 1969). Although, Srivastava (1981b, p. 869) considered this record to be "doubtful" and that the specimens may be reworked from older strata as the known stratigraphic range of *Kurtzipites* is Campanian to lower Paleocene (Srivastava, 1981b). Srivastava (1981b, p. 869) also considered the specimens in McIntyre (1974, pl. 22, figs. 18, 19) from the Campanian–Maastrichtian of the Horton River area, Northwest Territories, Canada, to be "doubtful" because the nexinous thickenings are not visible in those illustrations, indicating that the specimens may not belong to *Kurtzipites*. In Alberta, the species *Kurtzipites andersonii* is restricted to an interval within the lower Horseshoe Canyon Formation that preserves the Campanian-Maastrichtian boundary. This species has been reported from the latest Campanian, Maastrichtian, and Paleocene of Alaska, United States (Ridgeway et al., 1997), as well as Alberta and Saskatchewan, Canada (Srivastava, 1981b; Jerzykiewicz and Sweet, 1988; McIver et al., 1991; Lerbekmo and Braman, 2005; Lerbekmo and Sweet, 2008; Braman and Sweet, 2012; Eberth and Braman, 2012; Srivastava and Braman, 2013).

Myricipites

Myricipites harrisii, the type species for *Myricipites*, is described by Dutta and Sah (1970, p. 47-48) as:

> "size range 18–35 µm; amb triangular to roundly triangular; 3-aperturate, angulaperturate, distinctly porate, pores more or less circular to sometimes lalongate, crassimarginate; exine fairly thick, surface sculpture psilate to minutely scabrate".

This taxon was described from strata of Paleocene–Eocene age, Shillong Plateau, Meghalaya. The type species for *Myricipites* Wodehouse 1933 is *M. dubius*. Its description from Wodehouse (1933, p. 505) is as follows:

> "pollen approximately spheroidal. Pores three, generally protruding, of the 'tarsus' pattern. Texture smooth".

Myricipites occurs in Paleocene strata of the Bonnet Plume Formation (Zone 3 of Rouse and Srivastava, 1972). *Myricipites* is commonly considered to be a typical "Cenozoic" taxon (Vajda and Raine, 2003; Vajda and McLoughlin, 2007). The genus *Myricapollenites* (synonymous with *Myricipites*?) is documented in strata of Maastrichtian age at the Gil'chin and Dim dinosaur localities in the Russia Far East (Markevich et al., 2010), and is common in strata of late Maastrichtian age at the Kundur and Sakhalin Island dinosaur localities and rare in strata of early and middle Maastrichtian age before becoming common in strata of late Maastrichtian age at the Beringovsky and Kakanaut sites in Russia (Markevich and Bugdaeva, 1999).

The holotypes of *Triorites harrisii* Couper 1953, *Haloragacidites trioratus* Couper 1953, and *Casaurinidites cainozoicus* Cookson 1954 differ subtly in morphology, but these taxa are commonly treated as belonging to *Myricipites* (see Raine et al., 2011 for a full list of synonyms for *M. harrisii*).

Differentiation of *Corylus* from *Myrica* pollen is challenging under light microscopy, even for modern specimens. Therefore, these types are often grouped (Edwards, 1981). Differentiation of fossil pollen of these groups is similarly challenging. Therefore, the taxonomy, morphology, and biostratigraphy of pollen with *Corylus*-like morphology are described below.

Coryluspollenites (Potonié) Raatz 1937 is an obligate junior synonym of *Corylipollenites*, and both are considered junior synonyms of *Myricipites* Wodehouse 1933 (Jansonius and Hills, 1976). *Pollenites coryphaeus* Potonié 1931 is invalid due to a lack of generic diagnoses. Thus, although the name *Pollenites coryphaeus* had been effectively published in 1931, the name had not been validly published. This makes possible the later validation (by combined description) of the species when it was assigned to the new genus *Corylipollenites*. Although *Corylipollenites* was validly published in Potonié (1934), no holotype was explicitly designated. The combined description was accompanied by one figure (pl. 2, fig. 10) and the specimen it illustrated has all the hallmarks of *Platycarya* pollen. Jansonius et al. (1998) maintain as lectotype the specimen figured and effectively published in 1931 as *Pollenites coryphaeus* for *Corylipollenites* Potonié 1934. That specimen is very similar to the type of *Triporopollenite*s, which may later be conceived as a junior taxonomic synonym of *Corylipollenites* (Jansonius et al., 1998). Potonié (1960) considers the genus *Corylipollenites* as a junior synonym *Myricipites* Wodehouse 1933. *Coryloidites* Potonié et al. (1950, p. 53) is a *nomen nudum*. The type species of *Corylipollenites* is *Coryli?-pollenites coryphaeus* (Potonié 1931) ex Potonie 1934. Potonié (1960) incorrectly assumed the name *Coryli?-pollenites* to be void because he had attached a question mark to the prefix *Coryi-*. However, the International Code of Botanical Nomenclature states that such a mark of taxonomic uncertainty is not cause for making the name invalid (Jansonius et al., 1998).

Corylipollenites Potonié (1934, p. 53) is described as:

> "pollen ovoid or nearly spherical; amb ± convexly triangular, sideview ± oval; outline smooth; exine punctate to maculate, two-layered; the three exitus can best be described as foveae or as pori vestibule; pore circular, in part with a smallish lip-like exine ridge ("Wulst"); this ridge shows in top view as a double ring, in optical section as an invagination; exoexine apparently not thickened in this pore-ring or annulus. Size is 14–34 µm".

Corylipollenites (sometimes in literature as *Coryluspollenites*) is common in Paleocene strata (e.g., Yi et al., 2003). This genus also occurs in strata of Maastrichtian age at Toteşti sites 7 and 8 in the Haþeg Basin of Romania (Van Itterbeck et al., 2005).

Similar confusion plagues *Myrica*-type pollen, with various spellings and differentiations in the literature ranging from *Myricaceoipollenites, Myricaceaepollenites, Myricites*, and *Myrcipites* (Jansonius and Hills, 1976). The taxon *Myrcipites* is herein used.

Siberiapollis

Normapolles is an extinct angiosperm pollen group that arose in the Cenomanian and persisted until the Oligocene, although with a reduction in diversity in the Eocene. The term Normapolles was introduced by Pflug (1953, p. 14) to include a group of fossil pollen form-genera characterized by "bizarre" apertures.

Normapolles grains have been found inside fossilized flowers of the family Juglandaceae (Sims et al., 1999). The Normapolles group is extremely useful for identification of stages of the Upper Cretaceous and lower Paleocene strata. Their genera are relatively easy to identify, most species have short time ranges, and many are abundant. This group is therefore extremely useful for correlation and age interpretation (Tschudy, 1981).

Normapolles pollen members are characterized by a triangular amb and an internally complex pore structure with deep canals. These forms are described by Batten and Christoper (1981, p. 359) as:

> "oblate, mostly triporate or brevitricolp(or)ate pollen having complex, commonly protruding apertures and typically a triangular amb, although some are more or less circular in polar view".

Over 160 genera have been described as part of the Normapolles complex (Polette and Batten, 2017), including *Trudopollis*, *Kurtzipites*, and *Siberiapollis*.

Normapolles were widespread during the Late Cretaceous in southern and eastern North America, Europe, and Siberia. This distribution is known as the Normapolles floristic province. In North America, Normapolles pollen have been found as far north as the Northwest Territories (Tschudy, 1981) and in the Bonnet Plume Formation in the Yukon (Rouse and Srivastava, 1972). Land westward of the mid-continental epeiric sea was occupied by the plants that produced distinctly different pollen belonging to the *Aquilapollenties* floristic province. While the mid-continental sea was a barrier to plant migration, members of the Normapolles floristic province are found in samples from west of the sea. For example, in the Coniacian–Santonian Mesaverde Group of New Mexico, pollen of a single Normapolles genus represented more than 20 percent of the angiosperm pollen present (Tschudy, 1976).

Siberiapollis is a Normapolles pollen genus limited to western North America and Siberia (Tschudy, 1981). The genus *Siberiapollis* Tschudy 1971 was proposed to encompass relatively large triporate grains with variable surface sculpture, including reticulate sculpture. Nichols (2002) transferred *Proteacidites thalmannii* into *Tschudypollis* for triporate, reticulate pollen with annulate pores, arguing that it was morphologically distinct form Southern Hemisphere *Proteacidites* and therefore a new genus was required for North American forms. Srivastava and Braman (2013), however, note that Nichols (2002) did not compare *P. thalmannii* or *Tschudypollis* to *Siberiapollis*, the latter two of which are both triporate and can be annulate as well as reticulate. *Siberiapollis* is a much larger triporate pollen and hence *P. thalmannii* var. *major* of Srivastava (1966, p. 536, pl. 7, fig. 7) is transferred to *Siberiapollis* by Srivastava and Braman (2013), and the new combination *Siberiapollis major* (Srivastava 1966) was erected. The slide containing the holotype was badly degraded and a specimen could not be located. A neotype was designated by Srivastava and Braman (2013) accordingly. *Siberiapollis* is herein used for large triporate grains with a reticulate to verrucate ornamentation (following D. Braman, pers. Comm., March, 2022). Based on calibration to ammonite biozones, Braman and Sweet (2012) report reticulate *Siberiapollis* grains as first appearing at 83 Ma (early Campanian in 2012), and verrucate forms appearing at 78.5 Ma (early middle Campanian in 2012). According to Gale et al. (2020), 83 Ma and 78.5 Ma fall within the early and early middle Campanian (83.65 to 72.17 Ma) respectively.

Trudopollis

Trudopollis Pflug 1953 has the type species of *Trudopollis pertrudens* described from the Eocene of Germany (Pflug, 1953). The diagnosis of the genus from Pflug (1953, p. 98) is as follows:

> "germinal apparatus threefold; pores equatorial; pore canal index less than 0.25; interloculum always present; endexine thick, often with endanulus; amb convexly or straight triangular; oculus common, but not protruding from the amb; germinal with annulus, or praevestibulum, or cubiculum; solution merida common."

Potonié (1960, p. 126) emended the diagnosis to:

> "pollen suboblate, equator ± triangular to rounded, internal cavity usually ± circular; the three germinals ± protruding because of exinal thickenings; details of the germinal structure still unclear; exine with internal pattern, exolamella smooth or faintly roughened."

According to Krutzsch (1961), the "emendation" by Potonié (1960) was not based on new examination of the original material, and hence contains misleading information. Krutzsch emended the genus *Trudopollis* to exclude those species with an endexinal solution channel over the poles (those species with platea) and possessing circular or oval exogerminal (rather than vertical slit-shaped exogerminals). The excluded species were placed in the genus *Pompeckjoidaepollenites*. Krutzsch in Góczán, Groot, Krutzsch and Pacltová (1967, p. 512) therefore designated a lectotype and proposed the following emended diagnosis:

> "Figura flat-lenticular to oval lenticular, amb triangular to subcircular. Wall composed of several layers, always two main subdivisions discernable, often with a separation or interloculum. Surface always more or less distinctly minutely sculptured. Wall also in part with columellae layers or other structure. With three equatorial germinals at the radial corners. Exogerminals with tumescens, annulus, or similar thickenings that in part protrude prominently into the outline; internally almost always with structure (radially baculate punctate, etc.) which may end freely at the pore canal or at the vestibulum of variable size or may be fully or partially covered by a lamella. Pore canal index less than 0.3. Endospores externally a vertical slit that is more or less symmetrical to the equator; endospores in part with a slight thickening around the atrium which may vary in shape and which usually is rather deeply concave. No solution-areas running over the poles. In part the endspore may also be asymmetrical to the equator. Oculi present, or at least rudimentary."

Skarby (1968) did not recognize a "pore canal index" of less than 0.25 and the presence of an "interloculum" as diagnostically significant on the generic level; the presence of an "endanulus" or "solution-merida" are only significant on the species level. Thus, she considered *Trudopollis* to be a junior synonym of *Extratriporopollenties* Pflug emend. Skarby 1968. However, Tschudy (1981, p. 288) noted that the genus emended as Skarby (1968) "serves no useful purpose" because "no North American author has published serious taxonomic studies of the Normapolles genera has recorded *Extratriporopollenties* specimens from North America", and "in those instances that good photographs have been provided of specimens attributed to *Extratriporopollenites*, some obviously pertain to Normapolles genera *sensu* Góczán et al. (1967) such as *Trudopollis*, or *Basopollis*".

Hultberg et al. (1984) use Fourier shape analysis of grains identified as *Extratriporopollenties, Oculopollis*, and *Trudopollis.* They note that while typical specimens can be identified, intermediate forms cannot, even from the same pollen anther, further calling into question the validity of designations as meaningful.

Tschudypollis (basionym *Proteacidites*)

With respect to the *Proteacidites* group pollen, whose abundance defines the Continental Margin floristic province, most Upper Cretaceous pollen species from Siberia and North America that have been assigned to *Proteacidites* are morphologically different both from modern pollen of the family Proteaceae and from the pollen genus *Proteacidites sensu stricto*, whose type species is from the Southern Hemisphere (Srivastava, 1969; McLeroy, 1971; Martin, 1973; Martin and Harris; 1974; Memon, 1983). Even the pollen grains preserved in material from the Northern Hemisphere that are morphologically similar to the type species of *Proteacidites* are more likely to belong to the family Symplocaceae than to Proteaceae (Rouse, 1962; McLeroy, 1970, 1971), and at least some '*Proteacidites*' pollen of the Northern Hemisphere may have belonged to—or been derived from—the Normapolles group (Tschudy, 1971; Wolfe, 1976). Therefore, no definite Proteaceae pollen has been identified in Upper Cretaceous deposits of Siberia or North America. To reflect this, the name *Proteacidites* is now a basionym for the taxon *Tschudypollis* Nichols 2002, while *Siberiapollis* Tschudy 1971 is used for larger triporate grains with a reticulate to verrucate ornamentation (following D. Braman, pers. comm., March, 2022). As a transfer of North American '*Proteacidites*' pollen to *Tschudypollis*, and some to *Siberiapollis*, occurred in 2002, discussion of the literature pertaining to previous palynological work in the study area necessarily includes discussion of pollen considered as *Proteacidites*. Therefore, the morphological differentiation of *Proteacidites* pertains to those specimens, as well as to *Tschudypollis*, and are summarized and discussed below.

Pollen in extant Proteaceae are eurypalynous; they have diverse forms of apertures, exine structure, and sculptural patterns. Apertural morphology is the distinguishing feature of fossil proteaceous-like pollen (Martin, 1973; Martin and Harris, 1974; Dettmann and Jarzen, 1996). Ultrastructural characters are manifested in apertural morphology due to the presence or absence of exine breakdown, particularly nexine breakdown (nexine solution *sensu* Martin, 1973) at the apertural margins (Dettmann and Jarzen, 1996). Dettmann and Jarzen (1996) delineate six apertural types for Proteaceous pollen, referred to below.

The genus *Proteacidites* Couper 1950 ex. Couper 1953, emend. Martin and Harris 1974 was originally circumscribed for only porate pollen (Cookson, 1950; Couper, 1953). *Proteacidites* (type *P. adenanthoides*) is described by Martin and Harris (1974, p. 108) as:

> "free, isopolar or subisopolar, triorate, occasionally diorite. Grain triangular to sub-triangular, sides concave to convex between ora in polar view. Exine clearly differentiated into nexinous and sexinous layers. Sexine baculate, clavate or tuberculate, forming a variable pitted-reticulate or pseudoreticulate sculpture in surface view".

Couper (1953, p. 42) comments that "this genus is proposed for the reception of fossil pollen of proteaceous affinities which cannot be more accurately placed". Many colpoid proteaceous pollen have also been described under this genus, without emendation to the genus. Srivastava (1969) suggested that only porate pollen be described under *Proteacidites*, while the genus *Beaupreaidites* is emended to accommodate colpoid pollen having a reticulate, retipilate, or verrucate sexine after Potonié (1960) and Jarzen (1982) stated that *Beaupreaidites* belongs to Proteaceae. Apertures are vestibulate, amb is triangular with blunt to rounded angles and more or less straight sides. In contrast, the apertures of the type species of *Proteacidites*, as well as other species originally described under *Proteacidites*, are not colpoid. Martin and Harris (1974, p. 109) note that the structure of the aperture of this genus is diagnostic, and they emend the diagnosis of *Proteacidites* as follows:

> "pollen grains triporate; angular, semilobate, subangular or semi-angular in polar view; oblatoid to oblate, paraisopolar to more or less isopolar in equatorial view. Exine reticulate to foveolate, rugulose or sometimes verrucose or ± psilate, with obvious columellae, simpli- to pluricolumellate; angularaperturate; pores sometimes facing obliquely into proximal hemisphere, circular or nearly so, not annulate and without postatria; ektexine marginally incurved over more or less protruding or more rarely truncate aperture;

> endexine, thick or tapering into aperture, smooth internally or if slightly irregular then foveolate in a narrow zone round the pore. Size of grain, small to rather large or large".

These authors exclude *P. thalmannii* Anderson 1960 from the genus, as this form has short colpi (it must then be assigned to *Beaupreaidites*). *Proteacidites retusus* Anderson 1960 is also excluded as it possesses an endannulus and is vestibulate. Martin and Harris (1974) suggest that it appears closer in affinity to brevicolpate forms described elsewhere, such as *Siberiapollis* (Tschudy, 1971) or *Symplocoipollenites* Pontonié 1951. The authors also exclude *P. terrazum* Rouse 1962 on the basis that it possesses annuli and very short colpi, and thus is more akin to *Siberiapollis*.

Beaupreaidites Cookson 1950 ex Couper 1953, emend. Martin 1973 is retained for pollen with "type 1" apertures of Dettmann and Jarzen (1996). These apertures are described by Dettmann and Jarzen (1996, p. 106) as follows:

> "colpoid with irregular margins resulting rom a thinning of exine; footlayer (nexine 1) and tectum (outer sexine) are broken into numerous segments by broad fissures or channels in apoporal regions; tectum extends beyond the foot layer to form the apertural margin; this disaggregation of the apertural tectum and foot layer (nexine) results in the aperture resembling a gaping pore with an irregular margin."

Beaupreaidites ranges from the lower to middle Campanian to recent (Dettmann and Jarzen, 1996). In modern material, this taxon is considered as *Beauprea* (Pocknall and Crosbie, 1988). Cookson (1950) proposed the genus name *Beaupreaidites* to reflect fossil pollen with an obvious botanical affinity to *Beauprea*; the only known extant Proteaceae genus to have tricolpoid pollen. While her description was later broadened by Srivastava (1969) to accommodate colpoid pollen with reticulate, retipilate, or verrucate sexine, *Beaupreaidites* species that resulted from Srivastava's emendation were in fact colporate or colporidate and bear no resemblance to modern *Beauprea* (Martin, 1973). It is possible that the more "notched" varieties of Anderson's (1960) *Proteacidites thalmannii* specimens are more appropriately assigned to *Beaupreaidites* (Martin and Harris, 1974).

Dettmann and Jarzen (1996) consider *Proteacidites* pollen to have "type 5" apertures. Type 5 apertures of Dettmann and Jarzen (1996, p. 108) are described as:

> "pores with entire margins formed from a thinning, incurved exine. The tectum (outer sexine) and foot layer (nexine 1) thin towards to pore margin which is lined by granular endexine (nexine 2). The foot layer is traversed by irregular disposed channels, but there is no obvious nexine solution".

According to Dettmann and Jarzen (1996), *Proteacidites* also has an endexine comprising the aperture membrane, is porate, contains ektexine and endexine wall stratification, and has radially symmetrical pollen grains. *Proteacidites* pollen ranges from the Coniacian–Santonian to recent (Dettmann and Jarzen, 1996).

Proteacidites thalmannii Anderson 1960 is described by Anderson (1960, p. 21) as:

> "oblate, triporate pollen grains with an irregularly reticulate sculpture; triangular to elongate-triangular, with straight to slightly convex sides in polar view; pore structure variable, circular to lolongate; elongate pores sometimes pointed at the ends and having a 'notchlike' outline in polar view; exine clearly differentiated into two layers, the endexine thickening around the pores to form an endannulus; sculpture coarsely and often irregularly reticulate, becoming finer in the polar areas".

In the description, Anderson (1960) notes that the diameter of *P. thalmannii* ranges from 7–29 µm, pore diameter is 2–4 µm, the endannulus is variable, as much as 4 µm wide; and the exine is about 1.5 µm thick. Anderson (1960) notes that the grains in the material they examined differ in the coarseness of their reticulum and have variation in pore structure that may warrant two separate species. Many grains are transitional between end members of the 'notched' [meaning more colpoid? or colpoidporate?; this author's notes] and 'circular' pore types, and two species did not seem warranted from the standpoint of natural affinity to Anderson (1960). Drugg (1967) identified *P. thalmannii* as ranging from 22–41 um in diameter from the Maastrichtian to Danian strata of the Upper Moreno Formation of Escarpado Canyon, California. The forms documented by Srivastava (1969) from the Edmonton Group in Alberta measure around 30 µm, and the size range for this species is extended by him to range from 17–41 µm.

Tschudypollis was erected as a *genus novum* by Nichols (2002) from occurrences in the upper Maastrichtian Hell Creek Formation in North Dakota. The type species is *Tschudypollis retusus* comb. Nichols 2002. The species is described by Nichols (2002, p. 443) as follows:

> "pollen triporate, isopolar, oblate, amb triangular with bluntly rounded corners; pores circular to lolongate, annulate; exine two layers, extexine and endexine subequal in thickness except at pores, which are endexinally thickened; sculpture reticulate, reticulum homobrochate to heterobrochate, where heterobrochate tending to be finer toward the poles. Size ~20–40 µm."

Nichols (2002) argues that *Tschudypollis* is morphologically distinct from Southern Hemisphere *Proteacidites*. Thus, *Proteacidites*, as used at least for North American forms, is now a basionym for *Tschudypollis*. This means that all aforementioned discussion on the morphological differentiation of *Proteacidites* (as was broadly applied), now applies to specimens assigned to *Tschudypollis*. Practically, and herein, *Tschudypollis* is used for triporate, reticulate pollen with annulate pores, and are smaller than *Siberiapollis*.

While the morphology of *Tschudypollis* bears resemblance to fossil and modern species of the family Proteaceae, the resemblance is considered by Nichols (2002) and others (Martin, 1973; Martin and Harris, 1974) to be superficial. There is also similarity to some members of the fossil pollen group Normapolles, but those genera have more complex aperture structure than *Tschudypollis*. The botanical affinity of the North American species attributed to *Proteacidites*, and now *Tschudypollis*, is not known. From a phytogeographic perspective, it is unlikely that *Tschudypollis* is related to the Southern Hemisphere family Proteaceae. Cookson and Erdtman (in Erdtman, 1966) show that North American fossil Proteaceous pollen is different morphologically than modern species, specifically, the endannulate pore structure. Nichols (2002) favours the inference of Tschudy (1971) that North American species assigned to *Proteacidites* belong to the Normapolles group of fossil pollen, although this remains unproven.

Nichols (2002) rejects that *Tschudypollis* (and taxa previously identified as *Proteacidites* in North America), at least those in the Western Interior (where *Tschudypollis* is abundant in the Hell Creek Formation from which this genus was erected), have affinity with the Symplocaceae (as suggested by Rouse, 1962 and others), on the basis of apertural difference. Pollen of Symplocaceae have apertures that are triporate and never tricolporate. The species discussed by Rouse (1962), McLeroy (1971), and Frederiksen (1987) occurred in exotic terranes that were not part of North America during Cretaceous time within the Continental Margin floristic province of Frederiksen (1987). Therefore, even using the term *Tschudypollis* for material from northern Vancouver Island could be improper as it may be ultimately distinct, but not discernible using transmitted light microscopy, from specimens described by Nichols (2002) in the United States Western Interior.

In the Upper Cretaceous, proteaceous pollen are restricted to the Senonian (informal; the final part of the Cretaceous comprising the Coniacian–Campanian and possibly Maastrichtian) through Maastrichtian in the Northern Hemisphere and are conspicuously absent in Paleogene microfloral assemblages. In the Southern Hemisphere, this pollen type extends into the Paleogene (Tertiary) (Srivastava, 1969c and references therein). *Proteacidites thalmannii* (now *Tschudypollis thalmannii*) ranges into the Turonian in Western Canada (Turonian–early Campanian; Norris et al., 1975), and North America in general (Turonian–Paleocene; Lupia, 1999). In BC, *T. thalmannii* ranges from the Santonian to Campanian (Rouse et al., 1990), and this age range is also reported for Alberta (Santonian–early Campanian; Jarzen and Norris, 1975; Payenberg et al., 2002). On the North Slope of Alaska, *T. thalmannii* is restricted to the Maastrichtian (Frederiksen, 1990). *Tschudypollis thalmannii* does not range into the Paleocene in a study of the palynofloral response across the Cretaceous-Paleogene boundary event in Western Canada (Alberta and Saskatchewan, and Northwest Territories; Sweet et al., 1990). Braman and Sweet (2012) calibrate first occurrences of pollen in the northern part of the North American Western Interior Sedimentary Basin with ammonite biozones and magnetostratigraphy. They report *T. thalmannii* as appearing at 87 Ma. At the time of publication in 2012, 87 Ma fell into the uppermost Coniacian, and according to Gale et al. (2020), 87 Ma remains within this Cretaceous stage that ranges from 89.39–85.7 Ma. The occurrence of *T. thalmannii* in preparations herein analyzed can therefore be considered to be indicative of a Turonian-Maastrichtian age, but an early Paleocene age cannot be excluded.

Comment on spores

Biostratigraphic age interpretation for Upper Cretaceous strata has focused on angiosperm taxa because they rapidly diversified at this time making them very useful as stratigraphic indicators (e.g., Braman, 2013). As a result of this focus, spores have generally not been treated with the same detail. In the samples prepared for the present study, well-preserved spores also occur that may have some biostratigraphic utility. Taxonomic treatment of them is recommended.

Polypodiaceoisporites

Polypodiaceoisporties fossulatus is described by Jamarillo and Dilcher (2001) and occurs in strata of middle Eocene age in Columbia (Jamarillo and Dilcher, 2001, pl. 3, figs 9–12). Jamarillo and Dilcher (2001) note that their specimen cannot be placed definitively into the genus *Polypodiaceoisporties* Potonié 1951 ex. Potonié 1956. As such, Jamarillo and Dilcher (2001) placed their specimens in this genus provisionally because they are similar but have a reticulate distal face. Specimens in the material herein examined also appear to have ornamentation on the distal face and are thus also provisionally placed in this genus. The age range of this taxon is not constrained in North America.

Comment on dinocysts

Dinocyst assemblages in the seven samples from the Suquash Sub-basin and Hashamu Creek analyzed by Bringué were all depauperate and the few specimens observed were very poorly preserved (Plate 2). Identification to the species level was only possible for one species, *Pseudoceratium pelliferum*, while all other taxa could be identified down to the genus level at best (*Odontochitina* sp., *Senoniasphaera* sp., and *Vesperopsis* sp.), or tentatively placed at the generic (?*Apteodinium* sp., possible *Exochosphaeridium* or *Coronifera* sp.) or familial or higher (Ceratiaceae, Gonyaulacoid) level, making biostratigraphic interpretations broad and unreliable. The consistently poor preservation of dinocysts in these seven samples contrasts with the generally fair to excellent preservation of pollen grains and spores in the same samples (except sample FRB-FS1 in which only dinocysts were present). This strongly suggests that most, if not all, dinocysts from these samples were reworked (eroded) from older strata, transported (likely by rivers) and redeposited at the time of mudstone formation. Sample SQM-PS3, analyzed by McLachlan, yielded the most dinocysts from the Suquash Sub-basin representing at least seven taxa: ?*Canningia* sp., ?*Diconodinium* sp., ?*Exochosphaeridium* sp., *Odontochitina* sp., ?*Spinidinium* sp., ?*Vozzhenikovia* sp., and *Xenascus* sp. Although specimens were isolated, the preservation was fair.

Many taxa were left as questionable or in open nomenclature due to suboptimal orientation and/or preservation of limited material. One species left in open nomenclature of potential biostratigraphic utility is *Florentinia* cf. *clavigera*, which occurs in samples ORS21 PS3, ORS21 PS6, and ORS21 PS7 from the Comox Formation exposed along the Oyster River. *Florentinia clavigera sensu* Peyrot (2011, pl. 1, fig. 11) bears an uncanny resemblance to this material. *Florentinia* is characterized by large pre- and post-cingular processes with "multiple endings coming from a single mesotabular base" (Fensome and Williams, 2019, p. 53) in relation to a more slender cingular series, whereas the distribution of processes in *Coronifera* is more uniform save for a prominent antapical process common to both genera (Duxbury, 1980; Goodman and Witmer, 1985). In this sense, some specimens bear a superficial similarity to that of *Coronifera minor* Yu Jingxan and Zhang Wangping 1980 emend. Mao Shaozhi and Norris 1988 in the overall uniformity. However, the processes are more broadly based, and while most taper to acuminate terminations, there are instances where those of the pre- and post-cingular series are wider, becoming distally multifurcate. The probable dinocyst *Sentusidinium* cf. *capillatum* is a major constituent left in open nomenclature as observation of the exact nature of its archeopyle is inconclusive, while a subspherical ambitus and setose ornament are clearly apparent (see Wood et al., 2016).

Comparison to previous work

Rouse et al. (1970) studied the palynology of the Comox and Protection formations. They identify a coastal assemblage that includes palynoflora from the Comox Formation (their sample C-1A) and the Protection Formation (their sample C-1B). They determined their assemblage to be of Santonian to Campanian age containing the following palynomorphs: *Gleicheniidites senonicus*, *Intrapunctatosporis ellipsoideus*, *Reticulatisporites agathoecus*, *Stereisposirtes* cf. *cingulatus* subsp. *cingulatus*, *Anemia cristata* var. *fenestrata*, *Anemia striosporites*, *Deltoidospora microforma*, *Hymenophyllumsporites papillous*, *Intrapunctisporis plicatus*, *Proteacidites thalmannii*, *Proteacidites marginus*, *Beaupreadites elegansiformis*, *Symplococites sibericus*, *Tricolporopolelnites* sp., *Tricolpites* sp., *Triporites rhamnoides*, *Plantanus* sp., *Quercus fusiformipollenties, Aquilapollenites* sp., *Sparganium globipites,* and *Tricolpopollenites divergens*. Taxonomic authorities for these taxa are listed in Rouse et al. (1970).

The Santonian–Campanian assemblage from the Comox and Protection formations and equivalents along coastal BC consists mainly of fern spores and angiosperm pollen, with a notable paucity of gymnosperm pollen (Rouse et al., 1970). The most characteristic spores reported by Rouse et al. (1970) from their coastal assemblage are *Stereisporites* cf. *cingulatus* subsp. *cingulatus, Anemia cristata,* and *A. stirosporites*. The most common and characteristic angiosperm pollen are *Proteacidites thalmanni*, *Proteacidites marginus*, *Symplococites sibericus*, and *Tricolpopollenites divergens*. The occurrence of *Beaupreadites elegansiformis* is notable. Pollen of at least one species of *Aquilapollenties* also occurred in their analysis of Protection Formation material.

Rouse et al. (1990) studied samples of Upper Cretaceous sediments from the Gulf Islands, eastern Vancouver Island, and the shore of Lower Mainland BC in Burrard Inlet, Stanley Park, Vancouver. Preparations of strata from the Comox Formation, eastern Vancouver Island, yielded an assemblage interpreted to be Santonian in age containing the following spores: *Gleicheniidites senonicus, Cyathidites minor, Deltoidospora rhytisma, Microretriculatisporites irregularis, Acanthotriletes typicus, Perotriletes* *granulatus, Stereisporites cingulatu*s subsp. *cingulatus, Cibotiumsporites concavus*; and, pollen: *Sparganiaceaepollenites polygonalis, Proteacidites thalmanii, Engelhardtia spackmaniana, Triatriopollenites manifestus, T. granifer, Tricolpites laesus,* and *Tr. minutus*. Preparations of strata of the Extension-Protection formations (now Extension, Pender, and Protection formations; Ward, 1978), eastern Vancouver Island, and correlative beds on Orcas Island, Brother Creek Member, north and south shore of Burrard Inlet, and Wolfson Creek east of Powell River, yielded an assemblage interpreted as being Campanian in age containing the following spores: *Deltoidospora microforma, Hymenophyllumsporites papillosus*, *Appendicisporites cristata* forma *fenestrata*, *Cicatricosisporites striosporites*, *C. dorogensis*, *C. striatus;* and, pollen: *Cycadopites follicularis, Monosulcites* cf. *sabal*, *Liliacidites* spp., *Proteacidites thalmannii*, *P. marginus*, *P. bellus*, *Cupaneidites reticularis*, *Cu. major*, *Tricolpites fusiformipollenites*, *T. rhamoides*, and, *Tricolporopollenites punctatus.* With the exception of *P. thalmannii*, the palynomorphs from the Extension-Protection Formation and correlatives are distinct from those of the Comox Formation.

Many of the taxa encountered in the present study are in common with this previous work, most notably abundant *Tschudypollis* (*Proteacidites*). *Siberiapollis* may also have occurred in the body of previous work but would have been likely identified as *Proteacidites* in works that preceded definition of this taxon by Tschudy (1971).

A deviation in the herein examined material from characteristic Continental Margin floristic province flora and previous work is the common occurrence of *Kurtzipites* spp.; pollen which was a common element in the *Aquilapollenites* floristic province exemplified throughout southern Alberta during the Santonian to Maastrichtian (Frederiksen, 1987; Braman, 2001). *Kurtzipites* has likely affinities to Betulaceae, Carpinaceae, or Corylaceae that have broad geographical and ecological ranges today (Srivastava, 1981b). *Kurtzipites* spp. Occurred (sometimes referred to as the *Fibulapollis*; see Srivastava, 1981b) in the Maastrichtian of Arctic Canada (e.g., Felix and Burbridge, 1973). Rouse et al. (1975) also reported *Fibulapollis* (that may have been *Kurtzipites*) from the Lions Gate Member (Campanian) of the Burrard Formation in the Vancouver area. *Kurtzipites*, while generally restricted to the Western United States and Canada by Late Cretaceous epeiric seas, is recorded in sub-subsurface samples of the upper Campanian Fruitland Formation of the San Juan Basin and outcropping Maastrichtian Raton Formation of the Raton Basin of New Mexico (Tschudy, 1973). These occurrences indicate that the geographic range of *Kurtzipites* extended southward into the Southern United States, and northward into the Canadian Arctic, and that its occurrence in Upper Cretaceous strata of Vancouver Island could indicate provenance from either, or both, southern and/or northern landmasses, in addition to eastern provenance across the mountain barrier.

Parent plants that produced dispersed *Kurtzipites* pollen appeared to have occupied most of western North America within the Santonian to Maastrichtian *Aquilapollenites* floristic province (Frederikson, 1987; Braman, 2001). *Kurtzipites* pollen was considered to have been absent in the Continental Margin floristic province (Campanian–Maastrichtian but as old as Santonian in southwestern BC; *sensu* Frederikson, 1987) and the western San Joaquin Valley (late Campanian–late Maastrichtian) but present in the Suan Juan Basin (late Campanian). While *Kurtzipites* was an integral part of the Maastrichtian pollen assemblages associated with the *Aquilapollenites* floristic province, it was considered to have been absent from the Normapolles floristic province and has not been documented south of the equator (Srivastava, 1981b). Because this pollen genus was otherwise geographically widespread, but restricted stratigraphically, it could be used as an index fossil (Srivastava, 1981b). Occurrences of *Kurtzipites* in North America show that most localities with this genus occur within the limits of the regressive late Maastrichtian epeiric sea that occupied most of the *Aquilapollenites* floristic province at this time.

However, *Kurtzipites* and *Aquilapollenites* did not share the same paleoecological niche. Oltz (1969, 1971) showed that *Kurtzipites* never grouped with *Aquilapollenites* (using cluster analysis), indicating that the source area of *Kutzipites* pollen was different than that of *Aquilapollenites*. Based on similar pollen morphology, *Kurtzipites* may have affinities to modern Betulaceae, Carpinaceae, and Corylaceae. *Kurtzipites*-producing plants may have occupied inland areas relative to the coastal ones that were apparently favourable for *Aquilapollenites*-producing plants. *Kurtzipites* did not become extinct at the end of the Cretaceous, and instead continued into the Paleocene, when it formed part of an extended recovery phase of angiosperms (with *Ulmoideipites*) in North America (Sweet and Braman, 2001) until it became extinct at the end of the early Paleocene (Srivastava, 1981b). In contrast, most species of *Aquilapollenites* became extinct at the terminal Cretaceous, suggesting that parent plants had different survival mechanisms and/or refugia during the end-Cretaceous event.

Age determination based on pollen and spores

Of the twenty-three samples analyzed, an age determination could only be made for twelve samples (Table 2). All of the samples are determined to be Cretaceous in age although the possibility of Paleocene material cannot be excluded for some of the samples (Table 2). Three of the samples may be as old as Albian (ORS21 PS1, ORS21 PS7, ORS21 PS8) while the other samples can only be placed as broadly Late Cretaceous. Sample ORS21 PS6 may be as old as Turonian, sample PMO1-FS1 may be as old as Santonian, and the other samples where an age determination could be made are inferred as being Campanian or younger. It is expected that these age interpretations will be refined with additional palynological research. The justification for age determinations for individual samples are provided in the results section, with some additional comments below.

Two pollen taxa that are commonly used for Late Cretaceous age interpretation in North America, *Aquilapollenites* and *Wodehouseia*, are absent from the examined assemblages. From Nanaimo Group strata, Rouse et al. (1970) documented at least one species of *Aquilapollenties* from the Protection Formation of the Nanaimo area, Vancouver Island. McLachlan et al. (2018) reported several triprojectates with *Aquilapollenties* floristic province affinity including *Mancicorpus tripodiformis*, *Parviprojectus trialatus*, and *Reticorpus delicatus* from the upper Campanian Northumberland Formation of Hornby Island. Sweet (2005) and McLachlan and Pospelova (2021) recovered isolated specimens of *Parviprojectus reductus* from the upper Maastrichtian–lower Danian of the Oyster Bay Formation, eastern Vancouver Island. Although limited, these occurrences provide clear indication that parent plants of these taxa, while rare, were present, in the Continental Margin floristic province.

Aquilapollenites is a typical Upper Cretaceous taxon in the Western Interior of North America, but its occurrence is geographically diachronous. The latest Cretaceous (Santonian to Maastrichtian) *Aquilapollenites* floristic province occupied the northern and western parts of North America, extending in an arc from Greenland to Alaska and southward into the southwestern United States. *Aquilapollenties* pollen is first documented in mid-paleolatitude strata in the Turonian of Canada (Norris et al., 1975) and west Siberia (Skuratenko, 1966), but is later represented in palynofloras by a diversity of forms in the Campanian and Maastrichtian in high northern latitudes (Stanley, 1970; Batten, 1984; Srivastava, 1981a). Diachroneity of the occurrence of this diagnostic pollen type is also noted within strata of western Canada (e.g., Braman, 2001). For example, the Milk River Formation material analyzed by Braman (2001) ranges in age from late Santonian to possibly early Campanian (based on ^{40}Ar-^{39}Ar ages and magnetostratigraphy that is used to infer an age for the Milk River Formation of 84.5 to 83 Ma; Obradovitch and Cobban, 1975; Obradovitch, 1993; Leahy and Lerbekmo, 1995; Montgomery et al., 1998). Species of *Aquilapollenites* pollen do not appear until within the fully marine Campanian Pakowki Formation and younger units in southern Alberta, where they become characteristic of the Pakowki and Foremost formations across much of the Western Interior Basin. Thus, only poor correlations are possible in Canada within the *Aquilapollenites* floristic province of eastern Russia and northern China for this time interval (Braman, 2001).

Wodehouseia pollen is also a typical Maastrichtian element in North America and eastern Asia (Nichols and Jacobson, 1982 and references therein; Nichols et al., 2010), but does extend into the Campanian (e.g., Budrin, 1969; Braman and Sweet, 2012; Braman, 2018). For example, *Wodehouseia* pollen (*W. avita, W. spinata*) occurs in uppermost Maastrichtian strata in the Western Interior Sedimentary Basin of Canada, and as *W. fimbriata, W. spinulosus, W. gracile, W. jacutense* in strata of Maastrichtian age in the Horton River area of the Northwest Territories (above 170 feet in section CR16B; McIntyre, 1974), and both *Wodehouseia* and *Aquilapollenties* pollen occur in strata of Maastrichtian age in the Yukon Territory (Sweet, 1978), and are dominant elements in Maastrichtian strata in the Arctic Islands of Canada (Ellef Ringnes and Amund Ringes islands; Hopkins, 1973). *Wodehouseia edmontonicola* is documented in strata dated to ~73 Ma (Campanian; Braman and Sweet, 2012) and *W. gracile* is documented in rocks of uppermost Campanian age (~73 Ma) in southern Alberta (Braman, 2018).

The absence of *Aquilapollenites* and *Wodehouseia* pollen in the samples analyzed herein could therefore indicate an age that is older than Campanian, or younger than the latest Cretaceous. An age older than Campanian accords with the youngest depositional age for the Oyster River locality samples (ORS21 PS1 to PS10) based on detrital zircons (Y3Zo; youngest three grains overlapping at 2σ error) that suggest Turonian (93.9–89.30 Ma; Gale et al., 2020) to Coniacian (89.30–85.7 Ma) age or possibly older. A detrital zircon Y3Zo age from strata ~100 m above ORS21PS6 returned an age of 86.4 ± 3.1 Ma. These temporal constraints limit the youngest depositional ages of ORS21 PS6 bounding strata to be Coniacian. It is also plausible that neither *Aquilapollenites* nor *Wodehouseia* were ever present or abundant on Vancouver Island during the Late Cretaceous due to its unique climate and isolated geographic setting (Frederiksen, 1987).

The occurrence of *Tschudypollis* (basionym *Proteacidites*) pollen characterizes the samples herein analyzed, as well as the Coastal Margin floristic province. *Tschudypollis* ranges from the Senonian (informal; Coniacian, Santonian, Campanian, and possibly Maastrichtian), or Turonian or Santonian to the Maastrichtian (Srivastava, 1978; Sweet et al., 1990), and therefore the occurrence of *Tschudypollis* spp. Pollen restricts the age of this assemblage to be Turonian to Maastrichtian. As with most taxa, its first (and last?) occurrence may be diachronous; Braman and Sweet (2012) calibrated a first occurrence of this genus as upper Coniacian in the northern part of the Canadian Western Interior Sedimentary Basin.

The Normapolles genus *Siberiapollis* is also common in the preparations. Occurrences of this taxon range into the Campanian (Tschudy, 1971, 1981; Srivastava, 1978), and thus limit the age of the samples to Campanian or younger. In Palynodata (White, 2006), there are only eight records of this taxon, none of which range into the Paleocene. This could indicate that *Siberiapollis* does not range past the Maastrichtian, or may also, at least in part, reflect its endemism.

Kurtzipites pollen occurs in the “Early Loranthaceous” suite of Jarzen and Norris (1975, p. 50) that occurs in the middle part of the Lea Park Formation during the ?Santonian to lower Campanian.

The full range of *Trudopollis* (*sensu* Krutzsch; see discussion) is middle Turonian to late Eocene, with most abundant occurrences in lowermost Upper Cretaceous rocks of north-central Europe (Jansonius and Hills, 1976). Tschudy (1981) states that the genus *Trudopollis* ranges from Cenomanian to basal Eocene, although most *Trudopollis* specimens appear in the Cretaceous.

Age determination based on dinocysts

For the Suquash Sub-basin, the dinocysts recovered from preparations FRB-FS1, OGL-OCP3 FS1, and PMO1-FS1 indicate ages ranging from late Berriasian to early Aptian (*Pseudoceratium pelliferum;* sample FRB-FS1), broadly middle Cretaceous (*Vesperopsis* sp.; sample OGL-OCP3 FS1), and late Hauterivian to late Maastrichtian (*Odontochitina* sp.; samples FRB-FS1, OGL-OCP3-FS1, PMO1-FS1) with deposition in a near-shore environment. The occurrence of a late Hauterivian to terminal Maastrichtian indicator as well as a late Berriasian–early Aptian indicator in sample FRB-FS1 (C-641978, R-3913-3) would suggest that this sample is restricted to being late Hauterivian to early Aptian in age. However, it is very likely that most of the aforementioned dinocysts are reworked from older strata, as their consistently poor preservation contrasts with the generally well-preserved pollen grains and spores.

If dinocysts are reworked, they cannot be used for biostratigraphic determination and age interpretations should rely preferably on pollen and spores, assumed to be deposited *in situ*. The exceptions for the Suquash Sub-basin are samples SQM-PS3 and PMO1-FS1 which presented few but well-preserved dinocysts with no apparent wall damage (Plate 2, Figure b), suggesting autochthonous deposition. Sample SQM-PS3 contained the taxa ?*Canningia* sp., ?*Diconodinium* sp., ?*Exochosphaeridium* sp., *Odontochitina* sp., ?*Spinidinium* sp., ?*Vozzhennikovia* sp., and *Xenascus* sp. A Late Cretaceous age is therefore inferred for SQM-PS3 ranging from early Santonian to late Campanian, the lower constraint based on the questionable presence of the peridinioid *Vozzhennikovia* and the upper based on that of the cerateacean *Xenascus* sp.

Of the ten samples processed from exposures of the Comox Formation along the Oyster River in the Comox Sub-basin, four samples (ORS21 PS3, ORS21 PS6, ORS21 PS7, and ORS21 PS8) contained dinocysts. Sample ORS21 PS3 presented an isolated specimen of *Florentinia* cf. *clavigera* indicative of a broadly Late Cretaceous age spanning some ~25 myr from early Cenomanian to early Maastrichtian. In both samples ORS21 PS6 and ORS21 PS7, *Exochosphaeridium majus* and *Florentinia* cf. *clavigera* served to provide the most reliable age constraint of early Cenomanian to Campanian. Sample ORS21 PS8 yielded only isolated examples of ?*Exochosphaeridium* sp. and *Canningia* cf. *inconspicua* together of little utility suggesting a very broad age range extending from early Tithonian to middle Miocene. On the whole, the Oyster River dinocyst assemblages indicate an age firmly within the Late Cretaceous.

Age determination based on ammonites

Jeletzky (1970) established the *Eubostrychoceras elongatum* zone within the lower Nanaimo Group, which he regarded as having its base situated in the upper marine beds of Comox Formation. Revised age interpretations see the species as constrained to the middle–late Santonian (Haggart and Graham, 2018). Jeletzky (1970) reported fauna associated with the *E. elongatum* zone from the Oyster River (GSC Loc. 69454), although it is unclear if these strata would be more appropriately assigned to the lower Trent River Formation. *Eubostrychoceras elongatum* is abundant in the eastern North Pacific extending from the Georgia Basin (e.g., Usher, 1952; Ward, 1978) to California (e.g., Haggart, 1984; Haggart and Ward, 1984).

Jeletzky (1970) regarded his '*Metaplacenticeras occidentale* siltstone' unit of the Suquash Sub-basin as correlative with the Nanaimo Group Cedar District Formation based on presumed affinity with the *Metaplacenticeras* cf. *pacificum* zone (Ward, 1978; Ward et al., 2012). The holotype of *M. occidentale* was collected by J.M. Dawson in 1885 from the vicinity of the mouth of the Keogh River (near GSC loc. 82962 and 82963) and subsequently described by Whiteaves (1889). It was also found in association with *Desmophyllites diphylloides*, another characteristically abundant ammonite within the Cedar District Formation assemblage from the Gulf Islands (Usher, 1952; Haggart, 1989). This is approximately the same location (lat. 50.677428° long. 127.344156°) where specimens assigned herein to *Metaplacenticeras* cf. *californicum* have been recovered more recently (Plate 4), likely from the same stretch of outcrop as Sample FRB-FS1.

The presence of *Metaplacenticeras* cf. *californicum* is consistent with an early to middle Campanian age supported by numerous molluscan fossil collections (J. Haggart pers. comm., July, 2022) including the original placenticeratid material referenced by Muller and Jeletzky (1970). Both *Metaplacenticeras pacificum* and *Hoplitoplacinticeras vancouverense* are of biostratigraphic significance in the strata of California and the Nanaimo Group of BC (e.g., Matsumoto and Popenoe, 1960; Popeno et al., 1960; Ward and Haggart, 1981; Haggart, 1984; Ward et al. 2012); the former species having been recognized on Denman Island, BC (e.g., Ward, 1978; Ward et al., 2012), and latter species from the exquisitely preserved fauna of the Cedar District Formation on Sucia Island, Washington State (Usher, 1952). These taxa correlate approximately beyond the North Pacific realm with the lower upper Campanian zones of the European index taxa *Hoplitoplacenticeras coesfeldiense* and *H. marroti* (e.g., Muller and Schenk, 1943; Mikhailov, 1951; Kennedy et al., 1992; Küchler, 2000; Kennedy and Summesberger, 2000; Corral et al., 2016).

CONCLUSIONS

Twenty-three samples were submitted for biostratigraphic age control; only twelve had sufficient preservation of pollen and spores to interpret an age. The four samples from the Longarm Formation equivalent strata of northeastern Vancouver Island were effectively barren of palynomorphs. Pollen indicators suggest an age of Santonian to Paleocene for the Suquash Sub-basin. Dinocysts preserved in one of the nine samples analyzed from the Suquash Sub-basin provided only a broad range from early Albian to late Campanian based on the presence of the genus *Xenascus*. Conversely, dinocysts in three other samples yielded a broad Early Cretaceous age, a Valanginian to early Aptian age, and a Barremian to Campanian age, albeit with a strong possibility of reworking. Ammonites recovered from the Suquash Sub-basin present the greatest biostratigraphic control in this study and support an early to middle Campanian age for strata from at least one locality.

Terrestrial palynological indicators for samples recovered from the Comox Formation within the Comox Sub-basin, eastern Vancouver Island, suggest ages ranging from as old as Albian to as young as Maastrichtian (or Paleocene), but the majority of these samples would appear to be younger than Campanian. The Oyster River suite presented the highest diversity and abundance of dinocysts overall, such that statistically significant sample sizes were reached from specimen counts in samples ORS21 PS6 and ORS21 PS7 allowing for relative abundance calculations indicative of a coastal high-productivity environment characterized by either upwelling or terrigenous nutrient input. Dinocysts from these samples contained a number of long-ranging, predominantly Cretaceous forms, although a late Cenomanian to Campanian age is evident.

The unique palynoflora preserved in the Vancouver Island material studied herein indicates remarkable isolation of plants during the Late Cretaceous from the western interior of North America and from other phytogeoprovinces at this time. This study contributes to the framework for discussion pertaining to the geographic isolation of Wrangellia during the Late Cretaceous and may help develop our understanding of both the floral context and the paleogeographic interpretation of Wrangellia and other allochthonous terranes of western North America. Similarly, investigation of the phytoplankton record stands to further elucidate the conditions present within the marine realm of the eastern North Pacific through the Cretaceous Period with added utility for interprovincial biotic correlation in light of regional macrofossil endemism.

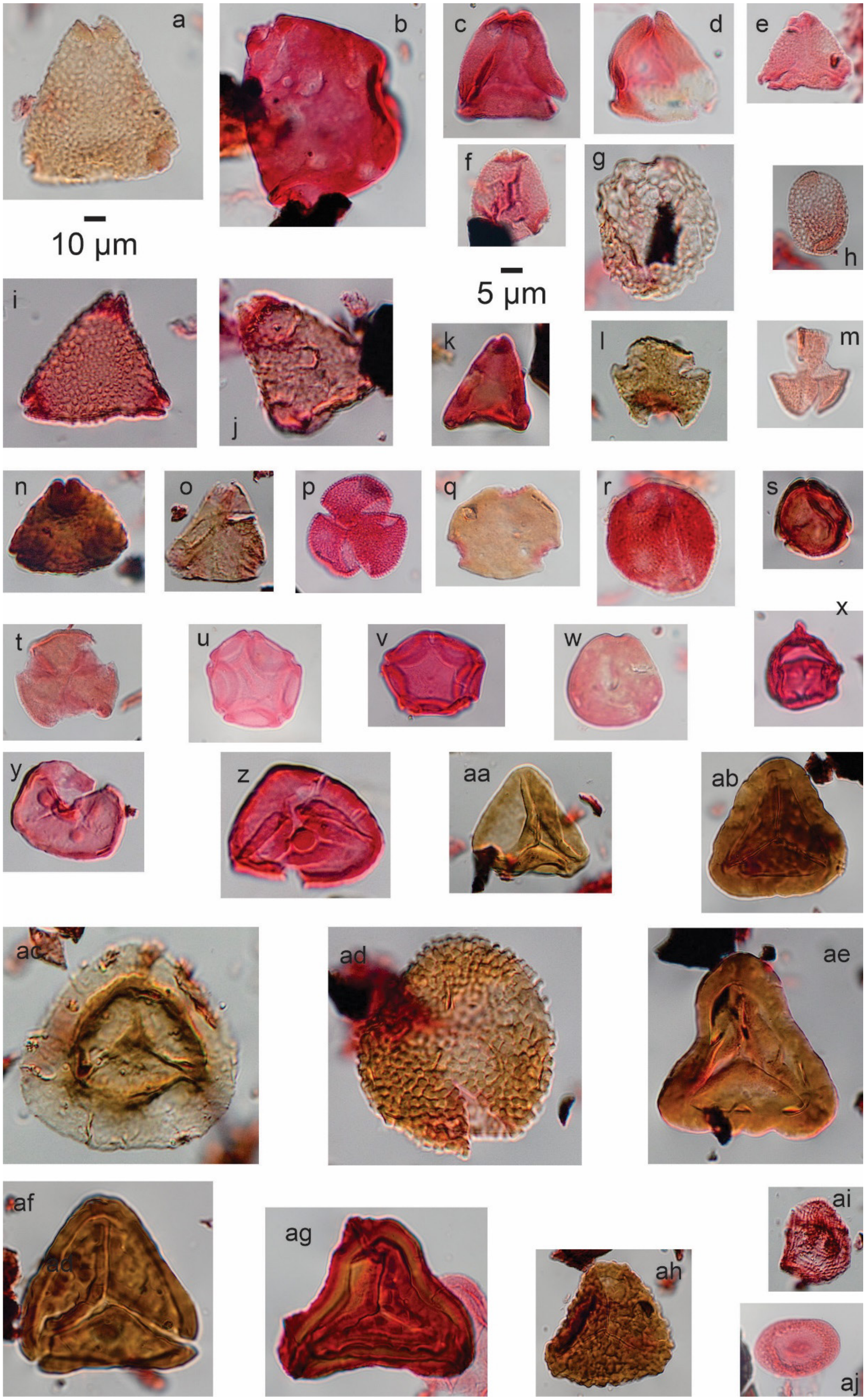
a
b
c
d
e
10 µm
f
g
h
5 µm
i
j
k
l
m
n
o
p
q
r
s
t
u
v
w
x
y
z
aa
ab
ac
ad
ae
af
ag
ah
ai
aj

Plate 1. Spores and pollen from the Comox Formation of the Comox Sub-basin, eastern Vancouver Island, and Nanaimo Group equivalent strata from the Suquash Sub-basin, northern Vancouver Island. All specimens photographed with differential interference contrast (Nomarski) illumination. For figures a and b, a 10 µm scale bar applies; for all other figures, a 5 µm scale bar applies. GSC Curation number (C-number), record number (R-number), sample number, England Finder coordinates. All images from the slide of the unsieved preparation.

a. *Siberiapollis* sp. C-641973, R-3914-12, SQM-FS2, M27/3
b. *Siberiapollis* sp. C-641975, R-3914-9, SQM-PS3, P45/2
c. *?Senipites drumhellerensis* C-641975, R-3914-9, SQM-PS3, P38/1
d. *?Senipites drumhellerensis* C-641974, R-3914-13, SQM1-FS2, T39/3
e. ?*Senipites* C-641974, R-3914-13, SQM1-FS2, O27/4
f. *Kurtzipites* sp. C-641975, R-3914-9, SQM-PS3, no England Finder coordinates
g. ?*Liliacidites* sp. C-641974, R-3914-13, SQM1-FS2, no England Finder coordinates
h. ?*Liliacidites* sp. C-641974, R-3914-13, SQM1-FS2, O27/4
i. *Tschudypollis thalmannii* C-641977, R-3914-7, SQM10-FS1-A P-387-7B, N24/1
j. ?*Tschudypollis* sp. C-641977, R-3914-7, SQM10-FS1-A, no England Finder coordinates
k. *Tschuydpollis* sp. C-641975, R-3914-9, SQM-PS3, no England Finder coordinates
l. *Tricolpites* sp. C-641990, R-3914-20, ORS21 PS7, X40/1
m. *Tricolpites* sp. C-641974, R-3914-13, SQM1-FS2, M36/3
n. *Trudopollis* sp. C-641976, R-3914-6, SQM6-FS1, R26/2
o. ?*Myricipites* sp. C-641984, R-3914-14, ORS21 PS1, G22/1
p. ?*Gunnaripolllis* sp. C-641977, R-3914-7, SQM10-FS1-A, R32/1
q. *?Marcellopites tolmanensis* C-641973, R-3914-12, SQM-FS2, H24/1
r. Unknown angiosperm pollen C-641974, R-3914-13, R-3914-12, SQM1-FS2, Q34/2
s. Unknown angiosperm pollen C-641977, R-3914-7, SQM10 FS1-A, no England Finder coordinates
t. Unknown angiosperm pollen C-641974, R-3914-13, SQM1-FS2, O27/4
u. *Alnipollenites* sp. C-641975, R-3914-9, SQM-PS3 J44/2
v. *Alnipollenites* sp. C-641977, R-3914-7, SQM10-FS1-A, R32/1
w. *Momipites* sp. C-641976, R-3914-6, SQM6-FS1, R34/1
x. *Sequoiapollenites* sp. C-641977, R-3914-7, SQM10-FS1-A, N24/1
y. *Stereisporites* sp. C-641974, R-3914-13, SQM1-FS2, no England Finder coordinates
z. *Stereisporites* sp. C-641974, R-3914-13, SQM1-FS2, no England Finder coordinates
aa. *Dicytophyllidites harrisii* C-641993, R-3914-23, ORS21 PS10, V33/1
ab. *Polypodiaceoisporties*? *fossulatus* C-641984, R-3914-14, ORS21 PS1, S39/4
ac. *Selaginella complex* C-641990, R-3914-20, ORS21 PS7, W34/2
ad. *Baculatisporites comaumensis* C-641984, R-3914-14, ORS21 PS1 U37/2
ae. Undifferentiated cingulate psilate spore, concave sides, laesurae extend to margin of inner body, C-641974, R-3914-13, SQM1-FS2, U26/3
af. *Polypodiaceoisporties*? *fossulatus*, C-641984, R-3914-14, ORS21, U37/2
ag. *Cicatricosisporites* sp., C-641974, R-3914-13, SQM1-FS2, R38/1
ah. *Converrucosisporites* sp. C-641984, R-3914-14, ORS21 PS1, M35/3
ai. *Chomotriletes* sp. C-641993, R-3914-23, ORS21 PS10, M21/2
aj. Unknown algal remains? C-641976, R-3914-6, SQM6-FS1, R22/4

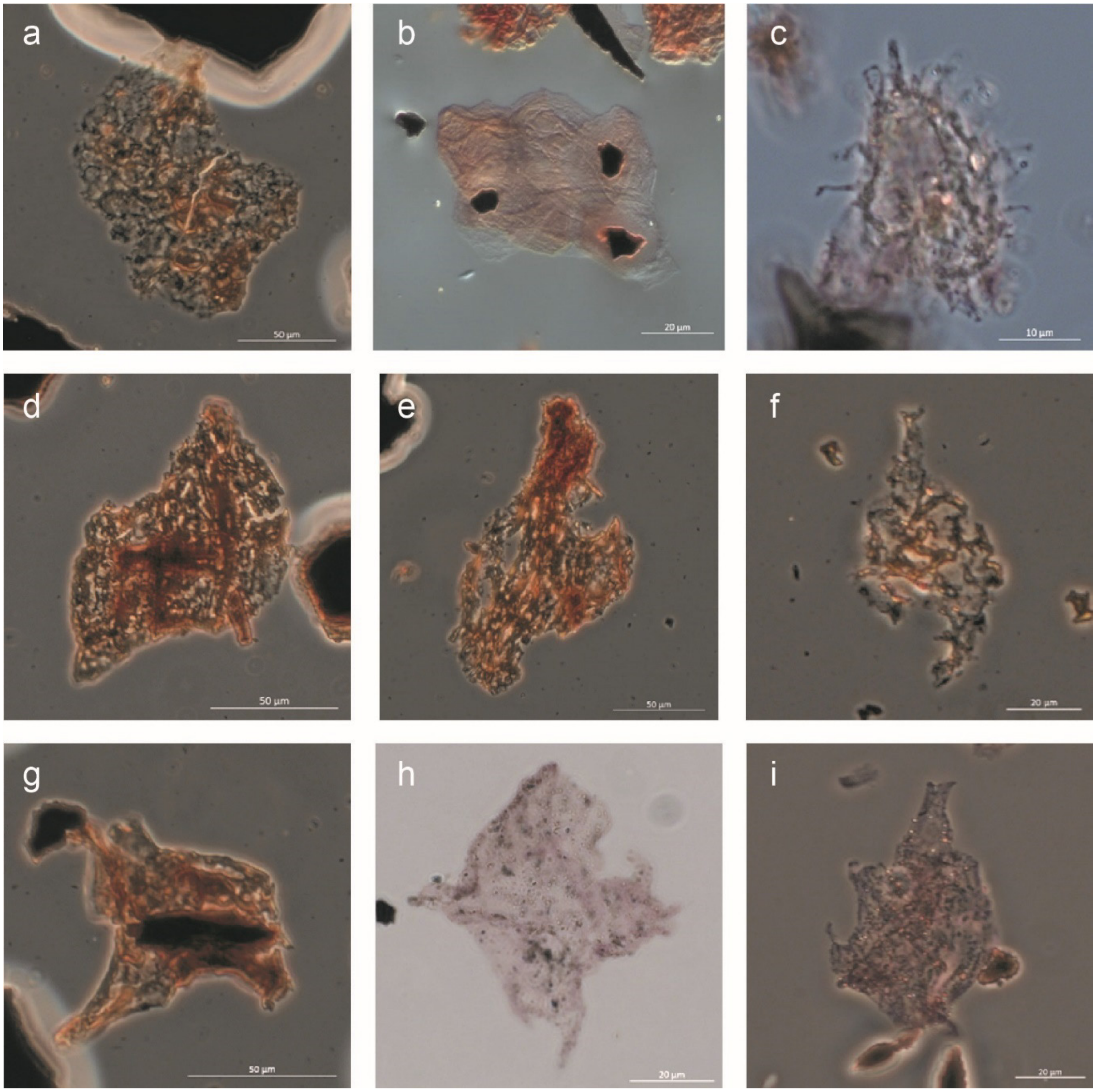

Plate 2. Dinoflagellate cysts from Nanaimo Group equivalent strata of the Suquash Sub-basin, northern Vancouver Island. All specimens photographed under phase contrast (PC), differential interference contrast (DIC), or brightfield (BF) illumination. Included are GSC Curation number (C-number), record number (R-number), sample number, fraction analyzed (+45 = >45 µm fraction; UN – unsieved fraction), England Finder coordinates, objective used, and illumination method (PC = phase contrast; DIC = differential interference contrast; BF= brightfield). Scale bar shown on individual figures.

a. ?*Apteodinium* sp. C-641978, R-3914-3, FRB FS1, +45, N27/1, 40×, PC
b. ?*Nyktericysta* sp. C-641980, R-3914-4, PMO1-FS1, UN, M46/1, 40×, DIC
c. Possible *Exochosphaeridium* sp. or *Coronifera* sp. C-641979, R-3914-11, OGL-OCP3 FS1, UN, G17/0, 63×, PC
d. *Pseudoceratium pelliferum* C-641978, R-3914-3, FRB FS1, +45, S36/3, 40×, PC
e. *Pseudoceratium pelliferum* C-641978, R-3914-3, FRB FS1, +45, F35/2, 40×, PC

f. *Pseudoceratium pelliferum* C-641978, R-3914-3, FRB FS1, UN, X23/0, 40×, PC
g. *Odontochitina* sp. C-641978, R-3914-3, FRB FS1, +45, Q40/0, 40×, PC
h. *Vesperopsis* sp. C-641979, R-3914-11, OGL-OCP3 FS1, UN, G16/2, 63×, BF
i. *Vesperopsis* sp. C-641979, R-3914-11, OGL-OCP3 FS1, UN, N46/0, 40×, PC

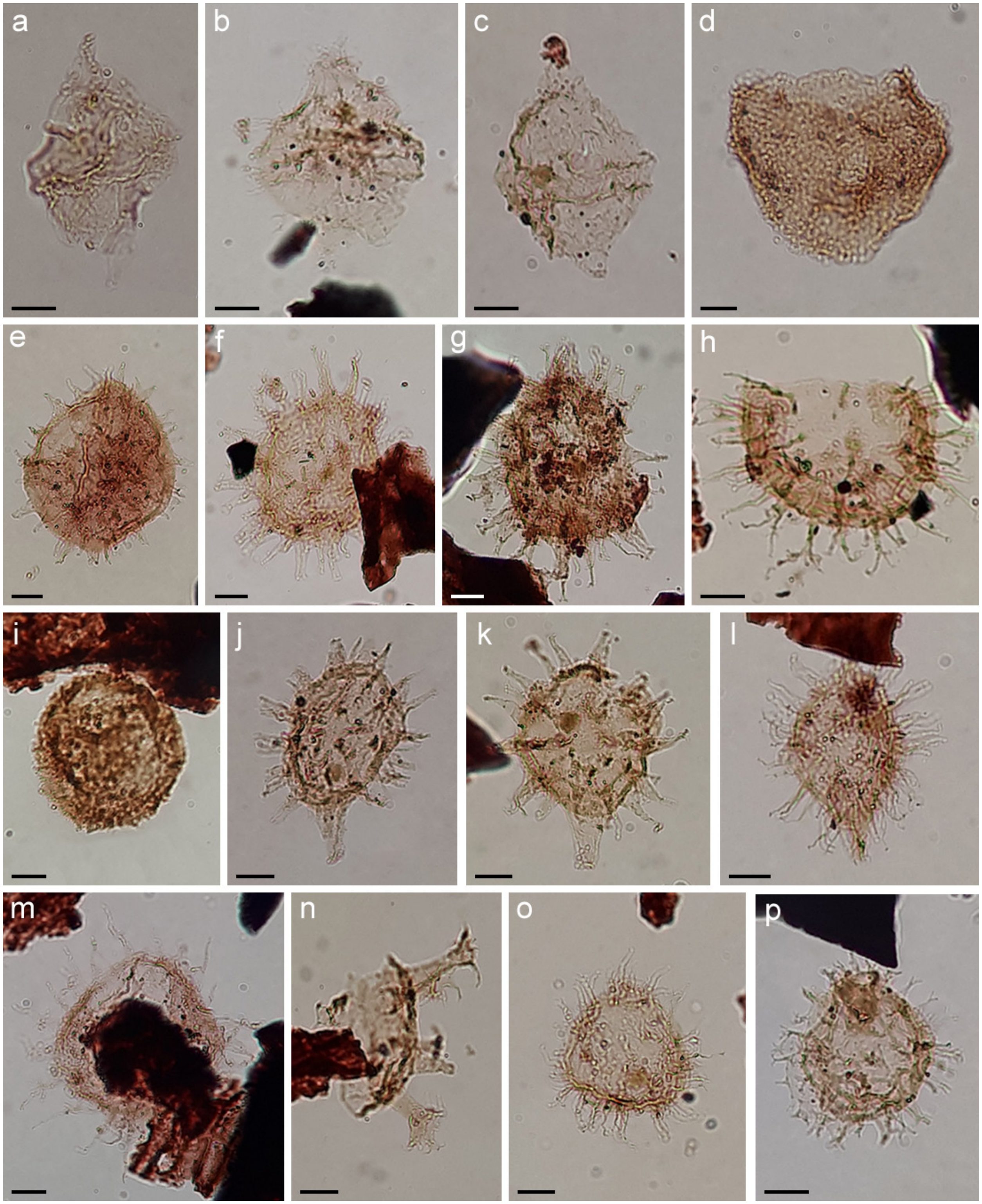

Plate 3. Dinoflagellate cysts from the Comox Formation exposed along the Oyster River (Comox Sub-basin, Nanaimo Group), eastern Vancouver Island. All specimens photographed under brightfield illumination from >20 µm sieved fraction. Included are GSC Curation number (C-number), record number (R-number), sample number, and England Finder coordinates. Scale bars = 10 µm.

a. *Alterbidinium* sp. C-641990, R-3914-20, ORS21 PS7, D19/2
b. ?*Spinidinium* sp. C-641990, R-3914-20, ORS21 PS7, E47/3
c. *Palaeohystrichophora infusorioides* C-641989, R-3914-19, ORS21 PS6, M27/1
d. *Canningia* cf. *inconspicua* C-641990, R-3914-20, ORS21 PS7, E45/0
e. *Exochosphaeridium* sp. C-641990, R-3914-20, ORS21 PS7, R18/0
f. *Exochosphaeridium majus* C-641989, R-3914-19, ORS21 PS6, L25/0
g. *Exochosphaeridium majus* C-641989, R-3914-19, ORS21 PS6, R44/3
h. *Cleistosphaeridium* sp. C-641989, R-3914-19, ORS21 PS6, U16/3
i. *Sentusidinium* cf. *capillatum* C-641989, R-3914-19, ORS21 PS6, T37/4
j. *Florentinia* cf. *clavigera* C-641990, R-3914-20, ORS21 PS7, S47/0
k. *Florentinia* cf. *clavigera* C-641990, R-3914-20, ORS21 PS7, J23/0
l. *Coronifera* sp. C-641990, R-3914-20, ORS21 PS7, M15/0
m. *Hystrichodinium pulchrum* C-641990, R-3914-20, ORS21 PS7, Q20/1
n. *Hystrichosphaeridium tubiferum* C-641990, R-3914-20, ORS21 PS7, J20/4
o. *Achomosphaera* sp. C-641990, R-3914-20, ORS21 PS7, M30/0
p. *Spiniferites* sp. C-641990, R-3914-20, ORS21 PS7, Q28/4

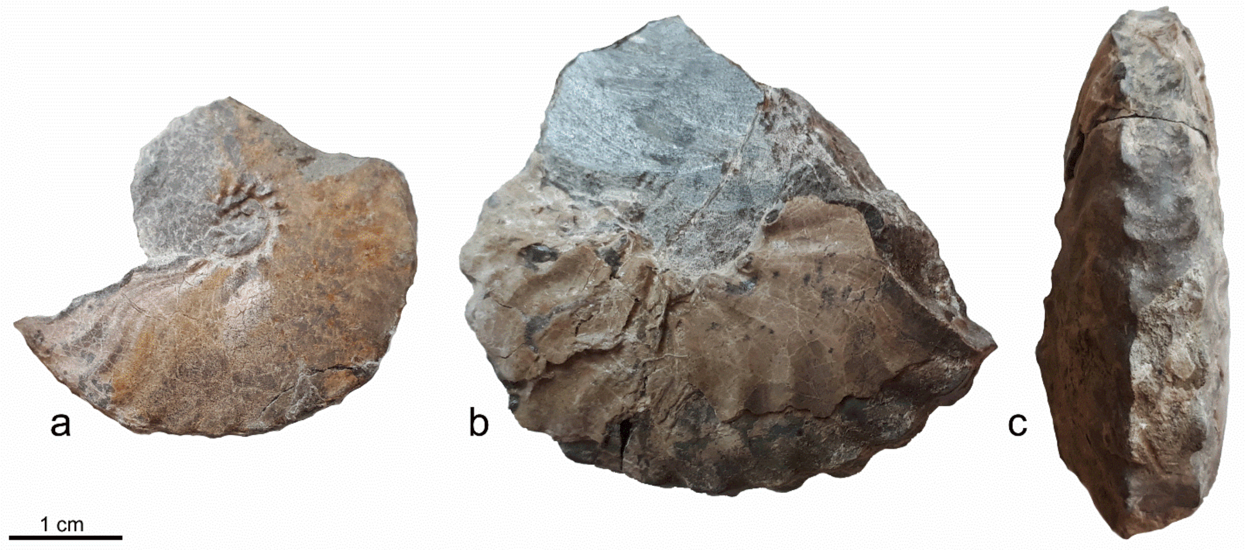

Plate 4: Specimens of the ammonite *Metaplacenticeras* cf. *californicum* recovered from a coastal outcrop of Nanaimo Group-equivalent strata west of the mouth of the Keogh River (approx. lat. 50.677428° long. 127.344156°), Suquash Sub-basin, northern Vancouver Island.

a. RBCM.EH2008.011.00480.001, left flank.
b. RBCM.EH2008.011.00486.001, right flank.
c. RBCM.EH2008.011.00486.001, ventral view.

Appendix 1

Table 1. Taxonomic authority for pollen, spores, and non-pollen palynomorphs

Genus and species	Taxonomic authority
Coniferous pollen	
Calliasporites	Dev 1961
Cerebropollenites mesozoicus	Nilsson 1958
Cyadopites follicularis	Wilson and Webster 1946
Equisetosporites	Daugherty, 1941, emend. Singh 1964
Eucommidites troedessonii	Erdtman 1948
Laricoidites magnus	(Potonié 1931) Potonié, Thomson and Thiergart 1950
Larix	Miller 1754
Monosulcites	Cookson 1947 ex. Couper 1953
Perinopollenites elatoides	Couper 1958
Sequoiapollenites	Thiergart 1938
Tsuga	Carrière 1855
Virtreisporites pallidus	(Reissinger 1950) Nilsson 1958
Angiosperm pollen	
Alnipollenites	Potonié 1932 ex. Potonié 1960
Alnus	Miller 1753
Caryapollenites	Raatz 1937 ex. Potonié 1960, emend. Krutzsch 1961
Chenopodipollis	Krutzsch 1966
Clavatipollenites	Couper 1958
Ericipites	Wodehouse 1922
Fraxinoipollenites	Burger 1993
Gunnaripollis	Srivastava 1969a
Kurtzipites	Anderson 1960
Liliacidites	Couper 1953
Marcellopites tolmanensis	Srivastava 1969b
Momipites	Wodehouse 1933
Myricipites	Wodehouse 1933
Nyssapollenites	Thiergart 1937
Retitricolpites	van der Hammen 1956 ex. Pierce 1961
Salix	Linnaeus 1753
Senipites	Srivastava 1969a
Senipites drumhellerensis	Srivastava 1969a
Siberiapollis	Tschudy 1971
Simplicepollis	Harris 1965
Trudopollis	Pflug 1953, emend. Krutzsch 1967
Tschudypollis (basionym *Proteacidites* Cookson, 1947 ex. Couper, 1953)	Nichols 2002
Tschudypollis thalmannii	(Anderson 1960) comb. Nichols (2002)
Tricolpites	Cookson 1947 ex. Couper 1953, emend. Potonié 1960
Spores	
Apiculatisporites	Ibrahim 1933
Appendicisporites	Weyland and Krieger 1953
Baculatisporites comaumensis	(Cookson, 1953) Potonié 1956
Biretisporites potoniaei	Delcourt and Sprumont1955
Callimothallus	Dilcher 1954 ex. Jansonius and Hills 1976
Cicatricosisporites	Potonié and Gelletich 1933
Cingulitriletes	Pierce 1961, emend. Dettmann 1963
Cingulitriletes clavus	(Balme 1957) Dettmann 1963
Contignisporites	Dettmann 1963
Converrucosisporites	Potonié and Kremp 1954
Cyathidites australis	Couper 1953
Cyathidites minor	Couper 1953
Deltoidospora diaphana	Wilson and Webster 1946
Deltoidospora hallei	Miner 1935
Deltoidospora psilostoma	Rouse 1959
Dictyophyllidites harrisii	Couper 1958
Distaltriangulisporites maximus	Singh 1971
Distaltriangulisporites perplexus	Singh 1971

Echinosporis	Krutzsch 1967
Foveosporites	Balme 1957
Gleicheniidites senonicus	Ross 1949
Ischyosporites	Balme 1957
Laevigatosporites ovatus	Wilson and Webster 1946
Leptolepidites verrucatus	Couper 1953
Lycopodiumsporites canaliculatus	Singh 1971
Microreticulatisporites uniformis	Singh 1964
Ornamentifera	Bolkhovitina 1966
Osmundacidites wellmannii	Couper 1953
Polypodiaceoisporites? fossulatus	Jamarillo and Dilcher 2001
Retitriletes austroclavatidites	(Cookson 1953) Döring, Krutzsch, Mai and Schulz in Krutzsch 1963
Ruffordiaspora australiensis	(Cookson 1953) Dettmann and Clifford 1992
Selaginella	Palisot de Beauvois, 1804
Stereisporites antiquasporites	(Wilson and Webster 1946) Dettmann 1963
Stereisporites regium	(Drozhastichich 1961) Drugg 1967
Todisporites major	Couper 1958
Undulatisporites undulapolus	Brenner 1963
Verrucosisporites	Ibrahim 1933, emend. Potonié and Kremp 1954
Verrucosisporites rotundus	Singh 1964
Non-pollen palynomorphs	
Chomotriletes	Naumova 1939 ex. Naumova1953
Pterospermella	Eisenack 1972
Pediastrum	Meyen 1929

Appendix 2

Table 2. Taxonomic authority for dinocysts identified in preparations

Taxon	Taxonomic authority
Achomosphaera	Evitt 1963
Alterbidinium	Lentin and Williams 1985, emend. Fensome et al. 2016
?*Apteodinium*	Eisenack 1958, emend. Lucas-Clark 1987
?*Canningia*	Eisenack and Cookson 1960, emend. McLachlan et al. 2019
Canningia cf. *inconspicua*	Duxbury 1983, comb. Fensome et al. 2019
Cleistosphaeridium	Davey et al. 1966, emend. Eaton et al. 2001
?*Coronifera*	Cookson and Eisenack 1958, emend. Mao Shaozhi and Norris 1988
?*Cribroperidinium*	Neale and Sarjeant 1962, emend. Helenes 1984
?*Diconodinium*	Eisenack and Cookson 1960, emend. Morgan 1977
Exochosphaeridium	Davey et al. 1966, emend. Helenes 2000
Exochosphaeridium cf. *majus*	Lejeune-Carpentier 1940, comb. Peyrot 2011
Florentinia cf. *clavigera*	Deflandre 1937, emend. Davey and Verdier 1976
?*Florentinia*	Davey and Verdier 1973, emend. Duxbury 1980
Hystrichodinium pulchrum	Deflandre 1935
Hystrichosphaeridium tubiferum	Ehrenberg 1837, emend. Davey and Williams 1966
?*Nyktericysta*	Bint 1986, emend. Fensome et al. 2009
Odontochitina	Deflandre 1937, emend. Núñez-Betelu and Hills 1998
Palaeohystrichophora infusorioides	Deflandre 1935
?*Pseudoceratium*	Gocht 1957, emend. Helby 1987
Pseudoceratium pelliferum	Gocht 1957, emend. Dörhöfer and Davies 1980
Senoniasphaera	Clarke and Verdier 1967
Sentusidinium cf. *capillatum*	Davey1975 comb. Wood et al. 2016
?*Spinidinium*	Cookson and Eisenack 1962, emend. Quattrocchio and Sarjeant 2003
Spiniferites	Mantell 1850, emend. Sarjeant 1970
Vesperopsis	Bint 1986, emend. Mao Shaozhi et al. 1999
?*Vozzhennikovia*	Lentin and Williams 1976, emend. Sluijs et al. 2009
Xenascus	Cookson and Eisenack 1969, emend. Stover and Helby 1987

Appendix 3

Table 2. Taxonomic authority for ammonites identified and referenced from the study areas

Taxon	Taxonomic authority
Desmophyllites diphylloides	(Forbes 1846) Haggart 1989
Eubostrychoceras elongatum	(Whiteaves 1903) *sensu* Usher 1952
Metaplacenticeras cf. *californicum*	Anderson 1958
Metaplacenticeras occidentale	(Whiteaves 1889) Jeletzky 1970
Metaplacenticeras cf. *pacificum*	(Smith 1900) Anderson 1958

ACKNOWLEDGEMENTS

JMG would like to thank Dr. Dennis Braman (formerly of the Royal Tyrell Museum) and M.Sc. candidate Nidhi Patel (Brandon University) for assistance with identification of some of the palynomorphs. SMSM would like to thank Dr. Jim Haggart (Geological Survey of Canada – Vancouver) for assisting with ammonite identification. MB is grateful to Rob Fensome (Geological Survey of Canada – Atlantic) for his help in identifying some dinocyst specimens. We thank Dr. Keith Dewing for an internal peer-review of this report.

REFERENCES

Alberts, D., Gehrels, G.E., Nelson, J., 2021. U-Pb and Hf analyses of detrital zircons from Paleozoic and Cretaceous strata on Vancouver Island, British Columbia: constraints on the Paleozoic tectonic evolution of southern Wrangellia. Lithosphere 2021, Article ID 7866944, 20 p.

Anderson, R.Y., 1960. Cretaceous–Tertiary palynology, eastern side of the San Juan Basin, New Mexico. New Mexico State Bureau of Mines and Mineral Resources, Memoir 6, 59 p.

Aurisano, R.W., 1984. Three new dinoflagellate species from the subsurface Upper Cretaceous Atlantic Coastal Plain of New Jersey. Journal of Paleontology 58, 1–8.

Bain, H.A., Hubbard, S.M., 2016. Stratigraphic evolution of a long-lived submarine channel system in the Late Cretaceous Nanaimo Group, British Columbia, Canada. Sedimentary Geology 337, 113–132.

Batten, D.J., 1984. Palynology, climate and the development of Late Cretaceous floral provinces in the Northern Hemisphere: A review. In: Benchley, P. (Ed.), Fossils and climate. John Wiley & Sons, Inc. Chichester, p. 127–164.

Batten, D.J., Christopher, R.A., 1981. Key to the recognition of Normapolles and some morphologically similar pollen genera. Review of Palaeobotany and Palynology 35, 359–383.

Bell, W.A., 1957. Flora of the Upper Cretaceous Nanaimo Group of Vancouver Island, British Columbia; Geological Survey of Canada, Memoir 293, 1–84.

Berry, E.W., 1918. The history of Linden and Ash. The Plant World 21, 163–175.

Besems, R., 1993. Dinoflagellate cyst biostratigraphy of Tertiary and Quaternary deposits of offshore NW Borneo. Geological Society of Malaysia, Bulletin of the Royal Society 33, 65–93.

Bickford, C.G.C., Kenyon, C., 1988. Coalfield geology of eastern Vancouver Island (92F). British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 1988-1, pp. 441–450.

Bijl, P.K., 2022. DINOSTRAT: a global database of the stratigraphic and paleolatitudinal distribution of Mesozoic–Cenozoic organic-walled dinoflagellate cysts. Earth System Science Data 14, 579–617.

Bijl, P.K., Sluijs, A., Brinkhuis, H., 2013. A magneto- and chemostratigraphically calibrated dinoflagellate cyst zonation of the early Paleogene South Pacific Ocean. Earth-Science Reviews 124, 1–31.

Black, L.P., Kamo, S.L., Williams, I.S., Mundil, R., Davis, D.W., Korsch, R.J., Foudoulis, C., 2003. The application of SHRIMP to Phanerozoic geochronology; a critical appraisal of four zircon standards. Chemical Geology 200, 171–188.

Boivin, M.-P., Matthews, W., Coutts, D., Hubbard, S., 2022. Improved provenance constraints for Nanaimo Group sediments, British Columbia, Canada, through zircon LA-ICP-MS depth-profiling. Tectonics 41, e2021TC007106.

Bolkhovitina, N.A., 1961. Fossil and Recent spores of the family Schizaeaceae. Trudy Geologicheskogo Instituta. Akademiya nauk SSSR, 40, 218 p. (in Russian)

Bowman, V.C., Francis, J.E., Askin, R.A., Riding, J.B., Swindles, G.T., 2016. Latest Cretaceous–earliest Paleogene vegetation and climate change at the high southern latitudes: palynological evidence from Seymour Island, Antarctic Peninsula. Palaeogeography, Palaeoclimatology, Palaeoecology 408, 26–47.

Braman, D.R., 2001. Terrestrial palynomorphs of the upper Santonian-?lowest Campanian Milk River Formation, southern Alberta. Palynology 25, 57–107.

Braman, D.R., 2013. Triprojectate pollen occurrences in the Western Canada Sedimentary Basin and the group's global relationships. Royal Tyrrell Museum of Palaeontology, Contributions Series 1, 538 p., 45 photo pls., 23 illustration pls.

Braman, D.R., 2018. Terrestrial palynostratigraphy of the Upper Cretaceous (Santonian) to lowermost Paleocene of southern Alberta, Canada. Palynology 42, 102–147.

Braman, D.R., Koppelhus, E.B., 2005. Campanian palynomorphs. In: Currie, P.J., Koppelhus, E.B. (Eds.), Dinosaur Provincial Park. Indiana University Press, Baltimore, 423 p.

Braman, D.R., Sweet, A.R., 2012. Biostratigraphically useful Late Cretaceous–Paleocene terrestrial palynomorphs from the Canadian Western Interior Sedimentary Basin. Palynology 36, 8–35.

Budrin, V.S., 1969. A Paleopalynologic description of the key Upper Cretaceous section in the Nayba River Basin, Southern Sakhalin. Doklady Akademiya Nauk SSSR 186, 650- 652.

Burger, D., 1993. Early and middle Cretaceous angiosperm pollen grains from Australia. Review of Palaeobotany and Palynology 78, 183–234.

Cant, D.J., Stockmal, G.S., 1989. The Alberta foreland basin: relationship between stratigraphy and Cordilleran terrane-accretion events. Canadian Journal of Earth Sciences 26, 1964–1975.

Cathyl-Bickford, G., 1993. Geology and petrography of the Wellington Seam, Nanaimo Coalfield, Vancouver Island. Doctoral dissertation, University of British Columbia, 420 p.

Cathyl-Bickford, G., 2001. Lithostratigraphy of the Comox and Trent River formations in the Comox Coalfield, Vancouver Island (92F/7, 10, 11, 14). B.C. Ministry of Energy, Mines and Petroleum Resources, GeoFile 2001-1, 29 p.

Cecil, M.R., Rusmore, M.E., Gehrels, G.E., Woodsworth, G.J., Stowell, H.H., Yokelson, I.N., Chisom, C., Trautman, M., and Homan, E., 2018. Along-Strike variation in the magmatic tempo of the Coast Mountains Batholith, British Columbia, and implications for processes controlling episodicity in arcs. Geochemistry, Geophysics, Geosystems, 4274–4289.

Choi, D.K., 1984. A new Eocene triporjectate pollen genus from the Canadian Arctic, *Novemprojectus*. Review of Palaeobotany and Palynology 43, 337–341.

Clapp, C.H., 1912a. Note on the geology of the Comox and Suquash coal fields. Geological Survey of Canada, Summary Report 1911, 105–117.

Clapp, C.H., 1912b. Geology of Nanaimo sheet, Nanaimo Coal Field, Vancouver Island, British Columbia. Geological Survey of Canada, Summary Report 1911, 91–105.

Clapp, C.H., 1914. Geology of the Nanaimo map area. Geological Survey of Canada, Memoir 51, 135 p.

Clapp, C.H., Cooke, H.C., 1917. Sooke and Duncan map-areas, Vancouver Island. Geological Survey of Canada, Memoir 96, 445 p.

Cookson, I.C., 1950. Fossil pollen grains of proteaceous type from Tertiary deposits in Australia. Australian Journal of Biological Sciences 3, 166–177.

Cookson, I.C., 1960. Upper Mesozoic microplankton from Australia and New Guinea. Palaeontology 2, 243–261, pls. 37–39.

Corral, J.-C., Pueyo, E.L., Berreteaga, A., Rodríguez-Pintó, A., Sánchez, E., Pereda-Suberbiola, X., 2016. Magnetostratigraphy and lithostratigraphy of the Laño vertebrate-site: Implications in the uppermost Cretaceous chronostratigraphy of the Basque-Cantabrian Region. Cretaceous Research 57, 473–489.

Costa, L.I., Davey, R.J., 1992. Dinoflagellate cysts of the Cretaceous System. In: Powell, A.J. (Ed.), A stratigraphic index of dinoflagellate cysts; British Micropaleontological Society Series. Chapman & Hall, London, pp. 99–154.

Coutts, D. S., Matthews, W. A., Englert, R. G., Brooks, M. D., Boivin, M.-P., Hubbard, S. M., 2020. Along-strike variations in sediment provenance within the Nanaimo basin reveal mechanisms of forearc basin sediment influx events. Lithosphere 12, 180–197.

Couper, R.A., 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. New Zealand Geological Survey, Paleontological Bulletin 22, 77 p.

Crane, P.R., Stockey, R.A., 1987. *Betula* leaves and reproductive structures from the middle Eocene of British Columbia, Canada. Canadian Journal of Botany 65, 2490–500.

Crickmay, C.H., Pocock, S.A., 1963. Cretaceous of Vancouver, British Columbia, Canada. American Association of Petroleum Geologists, Bulletin 47, 1928–1942.

Davey, R.J., 1975. A dinoflagellate cyst assemblage from the Late Cretaceous of Ghana. Proceedings of the 5th West African Colloquium on Micropaleontology, Series 7, 150–173.

Davey R.J., Verdier J.-P., 1973. An investigation of microplankton assemblages from latest Albian (Vraconian) sediments. Revista Española de Micropaleontología 5, 173–212.

Dawson, G.M., 1887. Report on a geological examination of the northern part of Vancouver Island and adjacent coasts. Geological Survey of Canada, Annual Report 1886 2, Part B, 107 p.

Dawson, G.M., 1890. Notes on the Cretaceous of the British Columbia region—the Nanaimo Group. American Journal of Science 39, 180–183.

Demchuk, T.D., 1990. Palynostratigraphic zonation of Paleocene strata in the central and south-central Alberta plains. Canadian Journal of Earth Sciences 27, 1263–1269.

Dettmann, M.E., Jarzen, D.M., 1996. Pollen of proteaceous-type from latest Cretaceous sediments, southeastern Australia. Alcheringa 20, 103–160.

Dodsworth, P., 2000. Trans-Atlantic dinoflagellate cyst stratigraphy across the Cenomanian–Turonian (Cretaceous) Stage boundary. Journal of Micropalaeontology 19, 69–84.

Drugg, W. S., 1967. Palynology of the upper Moreno Formation (Late Cretaceous-Paleocene), Escarpado Canyon, California. Palaeontographica, Abteilung B 140, 1–71, 9 pls.

Dutta, S.K., Sah, S.C.D., 1970. Palynostratigraphy of the Tertiary sedimentary formations of Assam. 5. Stratigraphy and palynology of south Shillong Plateau. Palaeontographica, Abteilung B 131, 1–72.

Duxbury, S., 1980. Barremian phytoplankton from Speeton, east Yorkshire. Palaeontographica, Abteilung B 173, 107–146, 13 pls.

Duxbury, S., 1983. A study of dinoflagellate cysts and acritarchs from the Lower Greensand (Aptian to lower Albian) of the Isle of Wight, southern England. Palaeontographica, Abteilung B 186, 18–80, 10 pls.

Eberth, D.A., Braman, D.R., 2012. A revised stratigraphy and depositional history for the Horseshoe Canyon Formation (Upper Cretaceous), southern Alberta plains. Canadian Journal of Earth Sciences 49, 1053–1086.

Eberth, D.A., Braman, D.R., Tokaryk, T.T., 1990. Stratigraphy, sedimentology and vertebrate paleontology of the Judith River Formation (Campanian) near Muddy Lake, west-central Saskatchewan. Bulletin of Canadian Petroleum Geology 38, 387–406.

Edwards, K.J., 1981. The separation of *Corylus* and *Myrica* pollen in modern and fossil samples. Pollen et Spores 23, 205–218.

Elsik, W.C., 1968. Palynology of a Paleocene Rockdale lignite, Milam County, Texas, II. Morphology and taxonomy. Pollen et Spores 10, 599–664.

England, T.D.J., 1989. Late Cretaceous to Paleogene evolution of the Georgia Basin, southwestern British Columbia. PhD thesis, Memorial University, 430 p.

England, T.D.J., Bustin, R.M., 1998. Architecture of the Georgia Basin southwestern British Columbia. Bulletin of Canadian Petroleum Geology 46, 288–320.

Erdtman, G., 1966. Pollen morphology and plant taxonomy. 1. Angiosperms: An introduction to palynology. New York, Hafner, 553 p.

Feist-Burkhardt, S., Monteil, E., 1997. Kystes de dinoflagellés du stratotype du Bajocien (Calvados, Normandie, France). Bulletin du Centre de Recherches Elf Exploration Production 21, 31–105. (in French)

Felix, C. J., Burbridge, P.E.P., 1973. A Maestrichtian age microflora from Arctic Canada. Geoscience and Man 7, 1–29.

Fensome, R.A., Williams, G.L., 2019. Dinoflagellate cyst palyatlas. Geological Survey of Canada, Open File 8408, 277 p.

Fensome, R.A., Williams, G.L., Wood, S.E.L., Riding, J.B., 2019a. A review of the areoligeracean dinoflagellate cyst *Cyclonephelium* and morphologically similar genera. Palynology 43, 1–71.

Fensome, R.A., Williams, G.L., MacRae, R.A., 2019b. The Lentin and Williams index of fossil dinoflagellates 2019 edition. American Association of Stratigraphic Palynologists, Contribution Series 50, 1173 p.

Fensome, R.A., Crux, J.A., Gard, G., MacRae, R.A., Williams, G.L., Thomas, F.C., Fiorini, F., Wach, G., 2008. The last 100 million years on the Scotian Margin, offshore eastern Canada: an event-stratigraphic scheme emphasizing biostratigraphic data. Atlantic Geology 44, 93–126.

Foucher J.C., Robaszynski F., 1977. Microplancton des silex du Bassin de Mons (Belgique) (dinoflagellés Crétacés et Daniens). Annales de Paléontologie 63, 19–58. (in French)

Frederiksen, N.O., 1987. Tectonic and paleogeographic setting of a new latest Cretaceous floristic province in North America. Palaios 2, 533–542.

Frederiksen, N.O., 1990. Pollen zonation and correlation of Maastrichtian marine beds and associated strata, Ocean Point Dinosaur locality, North Slope, Alaska. In: Hoffman, A.C. (Project coordinator), Evolution of sedimentary basins. United States Geological Survey, Bulletin1990, E1–E24.

Frederiksen, N.O., Christopher, R.A., 1978. Taxonomy and biostratigraphy of Late Cretaceous and Paleogene triatriate pollen from South Carolina. Palynology 2, 113–145.

Gale, A.S., Mutterlose, J., Batenburg, S. with Gradstein, F.M., Agterberg, F.P., Ogg, J.G., Petrizzo, M.R., 2020. Chapter 27: The Cretaceous Period. In: Gradstein, F.M., Ogg, J.G., Schmitz, M.D., Ogg, G. (Eds.), The Geological Time Scale, Book Volume 2, Part III. Geological Periods Phanerozoic, pp. 1023–1086.

Galloway, J.M., Sweet, A.R., Pugh, A., Schröder-Adams, C.J., Swindles, G.T., Haggart, J.W., Embry, A.F., 2012. Correlating mid-Cretaceous strata in the Canadian High Arctic using palynology. Palynology 36, 277–302.

Galloway, J.M., Fensome, R.A., Swindles, G.T., Hadlari, T., Fath, J., Schröder-Adams, C., Herrle, J.O., Pugh, A., 2022. Exploring the role of High Arctic large igneous province volcanism on Early Cretaceous Arctic forests. Cretaceous Research 129, 105022.

Gehrels, G.E., Valencia, V.A., Ruiz, J., 2008. Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation-multicollector-inductively coupled plasma-mass spectrometry. Geochemistry Geophysics Geosystems 9, 13.

Girotto, K., Dashtgard, S.E., Huang, C., Jones, M.T., Kent, B.A.P., Gibson, H.D., Cathyl-Huhn, G. Tectono-stratigraphic model for the early evolution of the Late Cretaceous Nanaimo Group: Georgia Basin, British Columbia, Canada. Basin Research, *in review*.

Góczán, F., Groot, J.J., Krutzsch, W., Pacltová, B., 1967. Die Gattungen des “Stemma Normapolles Pflug 1953b” (Angiospermae): Neubeschreibungen und Revision europäischer Formen (Oberkreide bis Eozän). Paläontologische Abhandlungen, Abteilung B, Paläobotanik 2, 427–633. (in German)

Gradstein, F. Ogg, J.G., Schmitz, M., Ogg, G.M., 2012. The Geologic Time Scale 2012, 1st Edition. Science Direct, 1144 pp.

Greene, A.R., Scoates, J.S., Weis, D., Katvala, E.C., Israel, S., Nixon, G.T., 2010. The architecture of oceanic plateaus revealed by the volcanic stratigraphy of the accreted Wrangellia oceanic plateau. Geosphere 6, 47–73.

Habib, D., Drugg, W.S., 1983. Dinoflagellate age of Middle Jurassic–Early Cretaceous sediments in the Blake-Bahama Basin. In: Sheridan, R.E., Gradstein, F.M., et al. (Eds.), Deep Sea Drilling Project, Initial Reports 76, pp. 623–638.

Haggart, J.W., 1984. Upper Cretaceous (Santonian–Campanian) ammonite and inoceramid biostratigraphy of the Chico Formation, California. Cretaceous Research 5, 225–241.

Haggart, J.W., 1989. New and revised ammonites from the Upper Cretaceous Nanaimo Group of British Columbia and Washington State: Contributions to Canadian Paleontology, Geological Survey of Canada, Bulletin 396, 181–221.

Haggart, J.W., 1991a. A new assessment of the age of the basal Nanaimo Group, Gulf Islands, British Columbia. In: Current Research, Part E. Geological Survey of Canada, Paper 91-1E, pp. 77–82.

Haggart, J.W., 1991b. Biostratigraphy of the Upper Cretaceous Nanaimo Group, Gulf Islands, British Columbia. In: Smith, P.L. (Ed.), A field guide to the paleontology of southwestern Canada. The First Canadian Paleontology Conference. University of British Columbia, Vancouver, pp. 222–257.

Haggart, J.W., 1994. Turonian (Upper Cretaceous) strata and biochronology of southern Gulf Islands, British Columbia. Geological Survey of Canada, Current Research, 1994-A, 159–164.

Haggart, J.W., Graham, R., 2018. The crinoid *Marsupites* in the Upper Cretaceous Nanaimo Group, British Columbia: Resolution of the Santonian–Campanian boundary in the North Pacific province. Cretaceous Research 87, 277–295.

Haggart, J.W., Tipper, H.W., 1994. New results in Jura-Cretaceous stratigraphy, northern Vancouver Island, British Columbia. Geological Survey of Canada, Current Research 1994-E, 59–66.

Haggart, J.W., Ward, P.D., 1984. Late Cretaceous (Santonian–Campanian) stratigraphy of the northern Sacramento Valley, California. Geological Society of America, Bulletin 95, 618–627.

Haggart, J.W., Ward, P.D., Orr, W., 2005. Turonian (Upper Cretaceous) lithostratigraphy and biochronology, southern Gulf Islands, British Columbia, and northern San Juan Islands, Washington State. Canadian Journal of Earth Sciences 42, 2001–2020.

Haggart, J.W., Ward, P.D., Raub, T.D., Carter, E.S., Kirschvink, J.L., 2009. Molluscan biostratigraphy and paleomagnetism of Campanian strata, Queen Charlotte Islands, British Columbia: implications for Pacific coast North America biochronology 30, 939–951.

Haggart, J.W., Graham, R., Beard, G., 2011. Field Trip 2. The Upper Cretaceous of the Nanaimo–Courtenay region of Vancouver Island. In: Haggart, J.W., Smith, P.L. (Eds.), Field Trips to Harrison Lake and Vancouver Island, British Columbia. 21st Canadian Paleontology Conference, Field Trip Guidebook No. 16, pp. 31–62.

Hamblin, A.P., 2012. Upper Cretaceous Nanaimo Group of Vancouver Island as a potential bedrock aquifer zone: summary of previous literature and concepts. Geological Survey of Canada, Open File 7265, 20 p.

Harding, I.C., Smith, G.A., Riding, J.B., Wimbledon, W.A.P., 2011. Inter-regional correlation of Jurassic/Cretaceous boundary strata based on the Tithonian–Valanginian dinoflagellate cyst biostratigraphy of the Volga Basin, western Russia. Review of Palaeobotany and Palynology 167, 82–116.

He Chengquan, 1991. Late Cretaceous–early Tertiary microphytoplankton from the western Tarim Basin in southern Xinjiang, China. Nanjing Institute of Geology and Palaeontology, Academia Sinica, 235 p., 65 pls. (In Chinese with English summary)

He Chenquan, Cheng Jinhui, Zhu Youhua, 2005. Middle to Late Jurassic marine dinoflagellates from Haixi, Hoh Xil. In: Sha Jingeng, Wang Qifei, Lu Huinan (Eds.), Micropalaeontology of the Qiangtang Basin. Beijing, Science Press, pp. 42–74, 245–250. (in Chinese with English summary)

Head, M.J., 1997. Thermophilic dinoflagellate assemblages from the mid Pliocene of eastern England. Journal of Paleontology 71, 165–193.

Heilmann-Clausen, C., Thomsen, E., 1995. Barremian–Aptian dinoflagellates and calcareous nannofossils in the Ahlum 1 Borehole and the Otto Gott Clay pit, Sarstedt, Lower Saxony Basin, Germany. Geologisches Jahrbuch, Reihe A 141, 257–365, 1–20 pls.

Helby, R., McMinn, A., 1992. A preliminary report of Early Cretaceous dinocyst floras from Site 765, Argo Abyssal Plain, northwest Australia. Proceedings of the Ocean Drilling Program, Scientific Results 123, 407–420.

Heusser, L.E., 1983. Palynology and paleoecology of postglacial sediments in an anoxic basin, Saanich Inlet, British Columbia. Canadian Journal of Earth Sciences 20, 873–885.

Hickey, L.J., West, R.M., Dawson, M.R., Choi, D.K., 1983. Arctic terrestrial biota: Paleomagnetic evidence of age disparity with mid-northern latitudes during the Late Cretaceous and Early Tertiary. Science 221, 1153–1156.

Hopkins, W.S., 1973. Some preliminary palynological conclusions on the Albian and Upper Cretaceous strata of Amund and Ellef Ringnes Islands, District of Franklin. In: Blackadar, R.G. (Ed.), Report of activities, Part B: November 1971 to March 1972. Geological Survey of Canada, Paper 73-1B, 179–180.

Huang, C., Dashtgard, S. E., Haggart, J. W., Girotto, K., 2022. Synthesis of chronostratigraphic data and methods in the Georgia Basin, Canada, with implications for convergent-margin basin chronology. Earth-Science Reviews, 104076.

Huang, C., Dashtgard, S.E., Kent, B.A., Gibson, H.D., Matthews, W.A., 2019. Resolving the architecture and early evolution of a forearc basin (Georgia Basin, Canada) using detrital zircon. Scientific Reports 9, 1–12.

Hultberg, S.U., Malmgren, B.A., Skarby, A., 1984. Fourier shape analysis of Upper Cretaceous Normapolles from southern Sweden. Taxonomic implications. Grana 23, 97–107.

Irving, E., 1985. Whence British Columbia? Nature 314, 673–674.

Jaramillo, C.A., Dilcher, D.L., 2001. Middle Paleogene palynology of Central Columbia, South America: A study of pollen and spores from tropical latitudes. Palaeontographica, Abteilung B 258, 87–213, 23 pls.

Jansonius, J., Hills, L.V., 1976. Genera File of Fossil Spores. Special Publication Department of Geology, University of Calgary, Calgary, AB.

Jansonius, J., Hills, L.V., Hartkopf-Fröder, C., 1998. Genera File of Fossil Spores, Supplement 12. Special Publication, Department of Geology and Geophysics, University of Calgary, Calgary, AB.

Jarzen, D.M., 1982. Angiosperm pollen—keys to the understanding of Cretaceous and Tertiary flowering plants. Proceedings of the 3rd North American Paleontological Convention 1, 263–263.

Jarzen, D.M., Norris, G., 1975. Evolutionary significance and botanical relationships of Cretaceous angiosperm pollen in the western Canadian interior. Geoscience and Man 11, 47–60.

Jeletzky, J.A., 1969. Mesozoic and Tertiary stratigraphy of northern Vancouver Island (92E, L, 102 I). In Blackadar, R.G. (Ed.), Report of Activities, Part A: April to October, 1968. Geological Survey of Canada, Paper 69-1, Part A, pp. 126–134.

Jeletzky, J.A., 1970. Biochronology. In: Muller J.E., Jeletzky, J.A. Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia. Geological Survey of Canada, Paper 69-25. pp. 35–58.

Jeletzky, J. A., 1976. Mesozoic and ?Tertiary rocks of Quatsino Sound, Vancouver Island, British Columbia. Geological Survey of Canada*,* Bulletin 242, 243 p., 4 sheets.

Jerzykiewicz, T., Sweet, A.R., 1988. Sedimentological and palynological evidence of regional climatic changes in the Campanian to Paleocene sediments of the Rocky Mountain Foothills, Canada. Sedimentary Geology, 29–76.

Johnstone, P.D., Mustard, P.S., MacEachern, J.A., 2006. The basal unconformity of the Nanaimo Group, southwestern British Columbia: a Late Cretaceous storm-swept rocky shoreline. Canadian Journal of Earth Sciences 43, 1165–1181.

Jonsson, C.H., Hebda, R.J., 2015. Macroflora, paleogeography, and paleoecology of the Upper Cretaceous (Turonian?–Santonian) Saanich Member of the Comox Formation, Saanich Peninsula, British Columbia, Canada. Canadian Journal of Earth Sciences 52, 519–536.

Kashif, M., Yingchang Cao, Guanghui Yuan, Asif, M., Rehman, F., Shehzad, K., Ullah, M.F., Mustafa, G., 2020. Sedimentology of Shahejie Formation, Bohai Bay Basin: a case study of Es1 member in Nanpu Sag. Carbonates and Evaporites 35, article 52.

Katnick, D.C., Mustard, P.S., 2003. Geology of Denman and Hornby islands, British Columbia: implications for Nanaimo basin evolution and formal definition of the Geoffrey and Spray formations, Upper Cretaceous Nanaimo Group. Canadian Journal of Earth Sciences 40, 375–393.

Kennedy, W.J., Summesberger, H., 2000. Additional Ammonites from the Upper Campanian (Upper Cretaceous) of the Gschliefgraben (Ultrahelvetic; Austria). Annalen des Naturhistorischen Museums in Wien, Serie A, für Mineralogie und Petrographie, Geologie und Paläontologie, Anthropologie und Prähistorie 102, 85–107.

Kennedy, W.J., Hansotte, M., Bilotte, M., Burnett, J., 1992. Ammonites and nannofossils from the Campanian of Nalzen (Ariège, France). Geobios 25, 263–278.

Kent, B.A.P., Dashtgard, S.E., Huang, C., MacEachern, J.A., Gibson, H.D., Cathyl-Huhn, G., 2020. Initiation and early evolution of a forearc basin: Georgia Basin, Canada. Basin Research 32, 163–185.

Kenyon, C., Cathyl-Bickford, C.G., Hoffman, G., 1992. Quinsam and Chute Creek coal deposits (NTS 92F/13, 14)., British Columbia Geological Survey, Paper 1991-3. British Columbia Ministry of Energy, Mines, and Petroleum Resources, Victoria, B.C. 90 p., 2 figs.

Kerr, J.W., 1974. Geology of Bathurst Island Group and Byam Martin Island, Arctic Canada. Geological Survey of Canada, Memoir 378, 1–152.

Krutzsch, W., 1961. Zum typus von “*Pollenitese pompeckji* R. Pot., 1931a” und von “*Trudopollis subhhercynicus* Krutzsch 1954a”. Geologie 10, 94–96.

Küchler, T., 2000. *Scaphites hippocrepis* (DeKay) IV, a new chronological subspecies from the lower–upper Campanian (Upper Cretaceous) boundary interval of northern Spain. Acta Geologica Polonica 50, 161–167.

Leahy, G.D., Lerbekmo, J.F., 1995. Macrofossil magnetobiostratigraphy for the upper Santonian-Lower Campanian interval in the Western Interior of North America: comparisons with European stage boundaries and planktonic foraminiferal zonal boundaries. Canadian Journal of Earth Sciences 32, 247–26.

Leereveld, H., 1995. Dinoflagellate cysts from the Lower Cretaceous Rio Argos succession (southeast Spain). Laboratory of Palaeobotany and Palynology, Contributions Series 2. PhD thesis, Utrecht University, Utrecht, The Netherlands, 175 p.

Leereveld, H., 1997. Upper Tithonian–Valanginian (Upper Jurassic–Lower Cretaceous) dinoflagellate cyst stratigraphy of the western Mediterranean. Cretaceous Research 18, 385–420.

Leffingwell, H.A., 1971. Palynology of the Lance (Late Cretaceous) and Fort Union (Paleocene) Formations of the type Lance area, Wyoming. Geological Society of America Special Paper 127, 1–64.

Leopold, E.B., 1969. Late Cenozoic palynology. In: Tschudy, R.H., Scott R.A. (Eds.), Aspects of palynology. John Wiley & Sons, New York, pp. 377–438.

Lerbekmo, J.F., Braman, D.R., 2005. Magnetostratigraphic and palynostratigraphic correlation of late Campanian to early Maastrichtian strata of the Bearpaw and Horseshoe Canyon formations between the CPOG Strathmore corehole and the Red Deer Valley section, Alberta, Canada. Bulletin of Canadian Petroleum Geology 53, 154–164.

Lerbekmo, J.F., Sweet, A.R., 2008. Magnetobiostratigraphy of the continental Paleocene upper Coalspur and Paskapoo formations near Hinton, Alberta. Bulletin of Canadian Petroleum Geology 56, 118–146.

Lupia, R., 1999. Discordant morphological disparity and taxonomic diversity during the Cretaceous angiosperm radiation: North American pollen record. Paleobiology 25, 1–28.

Mahoney, J.B., Mustard, P.S., Haggart, J.W., Friedman, R.M., Fanning, C.M., McNicoll, V.J., 1999. Archean zircons in Cretaceous strata of the western Canadian Cordillera: The "Baja B.C." hypothesis fails a "crucial test". Geology 27, 195–198.

Mahoney, J. B., Haggart, J. W., Grove, M., Kimbrough, D. L., Isava, V., Link, P. K., Pecha, M. E., Fanning, C. M., 2021. Evolution of the Late Cretaceous Nanaimo Basin, British Columbia, Canada: Definitive provenance links to northern latitudes. Geosphere 17, 2197–2233.

Mao Shaozhi, Norris, G., 1988. Late Cretaceous—early Tertiary dinoflagellates and acritarchs from the Kashi area, Tarim Basin, Xinjiang Province, China. Royal Ontario Museum, Life Sciences Division, Contributions 150, 1–93, 16 pls.

Markevich, V.S., Bugdaeva, Y.V., 1999. Flora and correlation of layers with dinosaur fossil remains in the Russian Far East. Geology of the Pacific Ocean 14, 977–990.

Markevich, V.S., Bugdaeva, E.V., Bolotsky, Y.L., 2010. Palynoflora of the Gil'chin and Dim dinosaur localities (the Zeya–Bureya Basin, Russian Far East). Russian Journal of Pacific Geology 4, 502–509.

Martin, A.R.H., 1973. Reappraisal of some palynomorphs of supposed proteaceous affinity. I. The genus *Beaupreaidites* Cookson ex Couper and the species *Proteacidites hakeoides* Couper. In: Glover, J.E., Playford, G. (Eds.), Mesozoic and Cainozoic palynology: Essays in honour of Isabel Cookson. Stratigraphic, palaeoecological, and palaeobotanical aspects of spore-pollen floras. Geological Society of Australia Special Publication 4, 73–78.

Martin, A.R.H., Harris, W.K., 1974. Reappraisal of some palynomorphs of supposed proteaceaous affinity: The genus *Proteacidites* Cookson ex Couper. Grana 14, 108–113.

Masure, E., Rauscher, R., Dejax, J., Schuler, M., Ferre, B., 1998. Cretaceous–Paleocene palynology from the Cote D'ivoire-Ghana Transform Margin, sites 959, 960, 961, and 962. Proceedings of the Ocean Drilling Program, Scientific Results 159, 253–276.

Matsumoto, T., Popenoe, W.P., 1960. Upper Cretaceous ammonites of California, Part 2. Memoirs of the Faculty of Science, Kyushu University, Series D, Geology, Special Volume 1, 172 p.

Matsuoka, K., Bujak, J.P., Shimazaki, T., 1987. Late Cenozoic dinoflagellate cyst biostratigraphy from the west coast of northern Japan. Micropaleontology 33, 214–229.

Matthews, W.A., Guest, B., Coutts, D., Bain, H., Hubbard, S.M., 2017. Detrital zircons from the Nanaimo Basin, Vancouver Island, British Columbia: An independent test of Late Cretaceous to Cenozoic northward translation. Tectonics, 854–876.

McGugan, A., 1962. Upper Cretaceous foraminiferal zones, Vancouver Island, British Columbia, Canada. Journal of the Alberta Society of Petroleum Geologists 10, 585–592.

McGugan, A., 1979. Biostratigraphy and paleoecology of Upper Cretaceous (Campanian and Maestrichtian) Foraminifera from the upper Lambert, Northumberland, and Spray formations, Gulf Islands, British Columbia, Canada. Canadian Journal of Earth Sciences 16, 2263–2274.

McIntyre, D.J., 1974. Palynology of an Upper Cretaceous section, Horton River, District of Mackenzie, N.W.T. Geological Survey of Canada, Paper 74-14, 57 p., 24 pls.

McIntyre, D.J., Ricketts, B.D., 1989. New palynological data from Cornwall Arch, Cornwall and Amund Ringnes Islands, District of Franklin, NWT. In: Current Research, Part G: Frontier Geoscience Program, Arctic Canada). Geological Survey of Canada, Paper 89-1G, 199–202.

McIver, E.E., 1994. An early *Chamaecyparis* (Cupressaceae) from the Late Cretaceous of Vancouver Island, British Columbia. Canadian Journal of Botany 72, 1787–1796.

McIver, E.E., Sweet, A.R., Basinger, J.F., 1991. Sixty-five-million-year-old flowers bearing pollen of the extinct triprojectate complex—a Cretaceous-Tertiary boundary survivor. Review of Palaeobotany and Palynology 70, 77–88.

McLachlan, S.M.S., 2021. *Phelodinium fensomei* sp. nov.: A protoperidineacean dinoflagellate cyst from the lower Paleocene (Danian) of the Oyster Bay Formation, Vancouver Island, Canada. Palynology 46, 1–11.

McLachlan, S.M.S., Haggart, J.W., 2018. Reassessment of the late Campanian (Late Cretaceous) heteromorph ammonite fauna from Hornby Island, British Columbia, with implications for the taxonomy of the Diplomoceratidae and Nostoceratidae. Journal of Systematic Palaeontology 16, 1247–1299.

McLachlan, S.M.S., Pospelova, V., 2021. Dinoflagellate cyst-based paleoenvironmental reconstructions and phytoplankton paleoecology across the Cretaceous–Paleogene (K/Pg) boundary interval, Vancouver Island, British Columbia, Canada. Cretaceous Research 126, article 104878.

McLachlan, S.M.S., Pospelova, V., Hebda, R.J., 2018. Dinoflagellate cysts from the upper Campanian (Upper Cretaceous) of Hornby Island, British Columbia, Canada, with implications for Nanaimo Group biostratigraphy and paleoenvironmental reconstructions. Marine Micropaleontology 145, 1–20.

McLachlan, S.M.S., Pospelova, V., Hebda, R.J., 2019. Areoligeracean dinoflagellate cysts from the upper Campanian (Upper Cretaceous) of Hornby Island, British Columbia, Canada. Palynology 43, 669–689.

McLachlan, S.M.S., Pospelova, V., Humphrey, E.H., 2021. Vesiculation in the dinoflagellate cyst *Cannosphaeropsis franciscana* Damassa, 1979 across the K/Pg boundary (Vancouver Island, Canada) with implications for spiniferate gonyaulacacean taxonomy and ecophenotypy. Review of Palaeobotany and Palynology, 292, article 104452.

McLeroy, C.A.C., 1970. Upper Cretaceous (Campanian–Maastrichtian) angiosperm pollen from the western San Joaquin Valley, California. Unpublished PhD thesis, Stanford, California, Stanford University, 382 p.

McLeroy, C.A.C., 1971. Late Cretaceous angiosperm pollen from the western San Joaquin Valley, California. Geoscience and Man 3, 95, 96.

Memom, H.R., 1983. Exclusion of North American *Proteacidites* species from the Southern Hemisphere Proteaceae. Sind University Research Journal (Science Series) 15, 73–84.

Mikhailov, N.P., 1951. Ammonity verkhnego mela yuzhnoi chasti yevropeiskoi chasti SSSR i ich stratigraficheskoye znachenie [The ammonites of the Upper Cretaceous of the southern regions of the European part of the USSR and their stratigraphic value]. Akademiya Nauk SSSR, Trudy Instituta Geologicheskikh Nauk 129, Geological Series 50, 143 p. (in Russian)

Miki, A., 1977. Late Cretaceous pollen and spore floras of northern Japan: composition and interpretation. Journal of the Faculty of Science Hokkaido University, Series IV, Geology and Mineralogy, 399–436.

Mingzhen Zhang, Baoxia Du, Zhixiong Wu, Longhui Dou, Abduljan Zhumahun, Dunzhu Jiaoba, Peihong Jin, Zhen Du, Sen Wang, Yanqing Xia, 2022. Dinoflagellate cyst biostratigraphy of initial Neotethys transgression deposits from the Cenomanian and Turonian in the Tarim Basin, western China. Marine and Petroleum Geology 138, 105531.

Monger, J.W.H., Price, R.A., 2002. The Canadian Cordillera: Geology and tectonic evolution. Canadian Society of Exploration Geophysicists Recorder 27, 17–36.

Monger, J.W.H., Price, R.A., Tempelman-Kluit, D.J., 1982. Tectonic accretion and the origin of the two major metamorphic and plutonic welts in the Canadian Cordillera. Geology 10, 70–75.

Montgomery, P., Hailwood, E.A., Gale, A.S., Burnett, J.A., 1998. The magnetostratigraphy of Coniacian–late Campanian chalk sequences in southern England. Earth and Planetary Science Letters 156, 209–224.

Msaky, E., 2011. Middle Jurassic–earliest Late Cretaceous palynofloras, coastal Tanzania. Part two. Palaeontographica, Abteilung B 286, 1–99, 15 pls.

Muller, J., 1981. Fossil pollen records of extant angiosperms. Botanical Review 47, 1–142.

Muller, J.E., 1977. Geology of Vancouver Island; Field trip 7: Guidebook. Geological Association of Canada / Mineralogical Association of Canada Joint Annual Meeting, Vancouver, B.C., 53 p.

Muller, J.E., Jeletzky, J.A., 1970. Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia. Geological Survey of Canada, Paper 69-25, 77 p.

Muller, J.E., Cameron, B.E.B., Northcote, K.E., 1981. Geology and mineral deposits of Nootka Sound map-area (92E) Vancouver Island, British Columbia. Geological Survey of Canada, Paper 80-16, 53 p.

Muller, J.E., Northcote, K.E., Carlisle, D., 1973. Geology and mineral deposits of Alert Bay and Cape Scott map areas, Vancouver Island, British Columbia. Geological Survey of Canada, Open File 170, 100 p., 1 sheet.

Muller, J.E., Northcote, K. E., Carlisle. D., 1974. Geology and mineral deposits of Alert Bay-Cape Scott map area, Vancouver Island, British Columbia. Geological Survey of Canada, Paper 74-8, 86 p., 2 sheets.

Muller, S.W., Schneck, H.G., 1943. Standard of Cretaceous System. American Association of Petroleum Geologists, Bulletin 27, 262–278.

Mustard, P.S., 1994. The Upper Cretaceous Nanaimo Group, Georgia Basin. Geological Survey of Canada, Bulletin 491, 27–95.

Mustard, P.S., Monger, J.W.H., 1991. Upper Cretaceous–Tertiary Georgia Basin: Forearc or foreland. Abstracts with Program, Geological Association of Canada Annual Meeting, 16, A88.

Mustard, P.S., Rouse, G.E., 1991. Sedimentary outliers of the eastern Georgia Basin margin, British Columbia. In: Current Research, Part A. Geological Survey of Canada, Paper 91-1A, pp. 229–240.

Mustard, P.S., Parrish, R.R., McNicoll, V., 1995. Provenance of the Upper Cretaceous Nanaimo Group, British Columbia: evidence from U-Pb analyses of detrital zircons. Stratigraphic Development in Foreland Basins, SEPM Special Publication 52, 65–76.

Newman, K.R., 1969. Palynology of interflow sediments from the Standard Oil Company of California Rattlesnake Hills No. 1 Well, Benton County, Washington. Columbia River Basalt Symposium, 2nd Proceedings, 201–207.

Newman, K.R., 1986. Stratigraphic palynology of Cretaceous-Paleocene boundary rocks, San Juan Basin, Colorado and Mexico. American Association of Stratigraphic Palynologists, 18th Annual Meeting, Program with Abstracts 10, 255.

Nagy, E., 1965. The microplankton occurring in the Neogene of the Mecsek Mountains. Acta Botanica, Academiae Scientiarum Hungaricae 11, 197–216, pls. 1–6.

Nichols, D.J., 1973. North American and European species of *Momipites* ("*Engelhardtia*") and related genera. Geoscience and Man 7, 103–117.

Nichols, D.J., 2002. Palynology and palynostratigraphy of the Hell Creek Formation in North Dakota: A microfossil record of plants at the end of Cretaceous time. In: Hartman, J.H., Johnson, K.R., Nichols, D.J. (Eds.), The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the northern Great Plains: An integrated continental record of the end of the Cretaceous. Geological Society of America, Special Paper 361, 395–456.

Nichols, D.J., Brown, J.L., 1992. Palynostratigraphy of the Tullock Member (lower Paleocene) of the Fort Union Formation in the Powder River Basin, Montana and Wyoming. United States Geological Survey, Bulletin 1917-F, 35 p.

Nichols, D.J., Jacobson, S.R., 1982. Palynostratigraphic framework for the Cretaceous (Albian–Maestrichtian) of the overthrust belt of Utah and Wyoming. Palynology 6, 119–147.

Nichols, D.J., Ott, H.L., 1978. Biostratigraphy and evolution of the *Momipites–Caryapollenites* lineage in the early Tertiary in the Wind River Basin, Wyoming. Palynology 2, 93–112.

Nichols, D.J., Matsukawa, M., Ito, M., 2010. The geological age and phytogeographic significance of some metamorphosed palynomorphs from the Omichidani Formation, Japan. Palynology 34, 157–163.

Nikitenko, B., Pestchevitskaya, E.B., Lebedeva, N.K., Ilyina, V.I., 2008. Micropalaeontological and palynological analyses across the Jurassic-Cretaceous boundary on Nordvik Peninsula, northeast Siberia, Newsletters in Stratigraphy 42, 181–222.

Norris, G., Miall, A.D., 1984. Arctic biostratigraphic heterochroneity. Science 224, 174–175.

Norris, G., Jarzen, D.M., Awai-Thorne, B.V., 1975. Evolution of the Cretaceous terrestrial palynoflora in western Canada. In: W.G.E. Caldwell (Ed.), The Cretaceous System in the Western Interior of North America. Geological Association of Canada, Special Paper 13, 333–364.

Norton, N.J., Hall, J.W., 1969. Palynology of the Upper Cretaceous and lower Tertiary in the type locality of the Hell Creek Formation, Montana, U.S.A. Palaeontographica, Abteilung B 125, 1–64.

Obradovich, J.D., 1993. A Cretaceous time scale. In: Caldwell, W.G.E., Kauffman, E.G. (Eds.), Evolution of the Western Interior Basin. Geological Association of Canada, Special Paper 39, pp. 379–396.

Obradovich, J.D., Cobban, W.A., 1975. A time-scale for the Late Cretaceous of the Western Interior of North America. In: Caldwell, W.G.E. (Ed.), The Cretaceous System in the Western Interior of North America, pp. 31–54.

Oleinik, E.S., 1975. Nekotorye novye i kharakternye vidy peridinei iz isfarinsko-khanabadskikh sloev (verkhnii eotsen) Tadzhikistana [Some new and characteristic species of dinoflagellate cyst from the Isfara-Khanabad layers (Upper Eocene) of Tajikistan]. In: Voprosy Paleontologii Tadzhikistana. Donish, Dushanbe, Tadzhikistan, pp. 224–243. (in Russian)

Oltz, D.F., Jr., 1969. Numerical analyses of palynological data from Cretaceous and early Tertiary sediments in east central Montana. Palaeontographica, Abteilung B 128, 90–166.

Oltz, D.F., Jr., 1971. Cluster analyses of Late Cretaceous–early Tertiary pollen and spore data. Micropaleontology 17, 221–232.

Panova, L.A., 1964. Lower Cretaceous spore-pollen complexes of Central Asia. In: Pokrovskaya, I.M., Stelmak, N.K. (Eds.), Atlas of Lower Cretaceous spore-pollen complexes of some regions of the USSR. Trudy Vsesoyuznogo nauchno-issledovatel'skogo Geologo-razvedochnogo instituta n.s. 30, 575 p.

Payenberg, T.H.D., Braman, D.R., Davis, D.W., Miall, A.D., 2002. Litho- and chronostratigraphic relationships of the Santonian–Campanian Milk River Formation in southern Alberta and Eagle Formation in Montana utilising stratigraphy, U-Pb geochronology, and palynology. Canadian Journal of Earth Sciences 39, 1553–1577.

Pearson, D.L., 1984. Pollen/Spore colour standard. Phillips Petroleum Company Exploration Projects Section, 4 p.

Peyrot, D., 2011. Late Cretaceous (late Cenomanian–early Turonian) dinoflagellate cysts from the Castilian Platform, northern Spain. Palynology 35, 267–300.

Pflug, H.D., 1953. Origin and development of the angiosperm pollen in Earth history [Zur Entstehung und Entwicklung des angiospermiden Pollens in der Erdgeschichte]. Palaeontographica, Abteilung B 95, 61–171. (in German)

Pocknall, D.T., Crosbie, Y.M., 1988. Pollen morphology of *Beauprea* (Proteaceae): Modern and fossil. Review of Palaeobotany and Palynology 53, 305–327.

Polette, F., Batten, D.J., 2017. Fundamental reassessment of the taxonomy of five Normapolles pollen genera. Review of Palaeobotany and Palynology 243, 47–91.

Popenoe, W.P., Imlay, R.W., Murphy, M.A., 1960. Correlation of the Cretaceous formations of the Pacific Coast (United States and northwestern Mexico). Geological Society of America, Bulletin 71, 1491–1540.

Pöthe de Baldis, E.D., Ramos, V., 1983. Dinoflagelados del Aptiano inferior de Río Fósiles, Lago San Martin, Provincia de Santa Cruz, Argentina. Revista Española de Micropaleontología 15, 427–446, pls. 1–4. (in Spanish)

Potonié, R., 1934. Zur Mikrobotanik der Kohlen und ihrer Verwandten: Zur Morphologie der fossilen Pollen und Sporen. Preußische Geologische Landesanstalt, 24 p. (in German)

Potonié, R., 1960. Synoposis der Gattungen der Sporae dispersae: III. Tiel [Synopsis of the genera of the sporae dispersae. Part 3] Nachträge Sporites. Fortsetzung Pollenites mit Generalregister zu Teil I–II, Beihefte zum Geologischen Jahrbuch, 189 p. (in German)

Poulsen, N.E., 1998. Upper Bajocian to Callovian (Jurassic) dinoflagellate cysts from central Poland, Acta Geologica Polonica 48, 237–245.

Raine, J.I, Mildenhall, D.C., Kennedy, E.M., 2011. New Zealand fossil spores and pollen: an illustrated catalogue. 4th edition. GNS Science miscellaneous series no. 4. http://data.gns.cri.nz/sporepollen/index.htm

Richardson, J., 1872. Report on the coal fields of the east coast of Vancouver Island. Geological Survey of Canada, Report of Progress 1871–1872, pt. 3, 73–100.

Ridgeway, K.D., Trop, J.M., Sweet, A.R., 1997. Thurst-top formation along a suture zone, Cantwell Basin, Alaska Range. Implication for development of the Denali fault system. Geological Society of America, Bulletin 109, 505–523.

Riding, J.B., 2019. The literature on Triassic, Jurassic and earliest Cretaceous dinoflagellate cysts: Supplement 3. Palynology 43, 104–150.

Riding, J.B., Thomas, J.E., 1992. Dinoflagellate cysts of the Jurassic System. In: Powell, A.J. (Ed.), A stratigraphic index of dinoflagellate cysts. British Micropaleontological Society Publications Series, Chapman and Hall, London, 7–97.

Rothwell, G.W., Stockey, R.A., 2013. Evolution and phylogeny of gnetophytes: Evidence from the anatomically preserved seed cone *Protoephedrites eamesii* gen. et sp. nov. and the seeds of several bennettitalean species. International Journal of Plant Science 174, 511–529.

Rouse, G.E., 1957. The application of a new nomenclatural approach to Upper Cretaceous plant microfossils from Western Canada. Canadian Journal of Botany 8, 349–375.

Rouse, G.E., 1962. Plant microfossils from the Burrard Formation of western British Columbia. Micropaleontology 8, 187–218.

Rouse, G.E., 1967. A Late Cretaceous plant assemblage from east-central British Columbia: I, fossil leaves. Canadian Journal of Earth Sciences 4, 1185–1197.

Rouse, G.E., Srivastava, S.K., 1972. Palynological zonation of Cretaceous and early Tertiary rocks of the Bonnet Plume Formation Northeastern Yukon. Canadian Journal of Earth Sciences 9, 1163–1179.

Rouse, G.E., Hopkins, W.S., Piel, K.M., 1970. Palynology of some Late Cretaceous and early Tertiary deposits in British Columbia and adjacent Alberta. In: Kosanke, R.M., Cross, A.T. (Eds.), Symposium on palynology of the Late Cretaceous and early Tertiary, San Francisco, California, 1966. Geological Society of America, Special Paper 127, 213–246.

Rouse, G.E., Lesack, K.A., White, J.M., 1990. Palynology of Cretaceous and Tertiary Strata of Georgia Basin, southwestern British Columbia Research, Part F, Frontier Geoscience Program, Cordilleran and Offshore Basins, British Columbia / Recherches En Cours, Partie F, Programme Geoscientifique Des Regions Pionnieres, Bassins De La Cordillere Et Extracotiers, Colombie – Britannique. Geological Survey of Canada, Paper 90-1F, 157 p.

Rouse, G.E., Matthews, W.H., Blunden, R.H., 1975. The Lions Gate Member: a new Late Cretaceous sedimentary subdivision in the Vancouver area of British Columbia. Canadian Journal of Earth Sciences 12, 464–471.

Schiøler, P., Brinkhuis, H., Roncaglia, L., Wilson, G.J., 1997. Dinoflagellate biostratigraphy and sequence stratigraphy of the Type Maastrichtian (Upper Cretaceous), ENCI Quarry, The Netherlands. Marine Micropaleontology 31, 65–95.

Sedova, M.A., 1964. Lower Cretaceous spore-pollen complexes of South Primorsk-Suchansk Coal Fields, In: Pokrovskaya, I.M., Stelmak, N.K. (Eds.), Atlas of Lower Cretaceous spore-pollen complexes of some regions of USSR. Trudy Vsesoyuznogo nauchno-issledovatel'skogo Geologo-razvedochnogo instituta n.s. 30, 575 p. (in Russian)

Sims, H.J., Herendeen, P.S., Lupia, R., Christopher, R.A., Crane, P.R., 1999. Fossil flowers with Normapolles pollen from the Upper Cretaceous of southeastern North America. Review of Palaeobotany and Palynology 106, 131–151.

Singh, C., 1971. Lower Cretaceous microfloras of the Peace River Area, northwestern Alberta. Research Council of Alberta, Bulletin 28, 299 p.

Skarby, A., 1968. *Extratriporopollenites* (Pflug) emend. from the Upper Cretaceous of Scania, Sweden. Stockholm Contributions in Geology 16, 60 p.

Skupien, P., 2004. Albian non-calcareous dinoflagellates of the western Carpathians, Slovak. Geological Magazine 10, 203–214.

Skuratenko, A.V., 1966. Turonskie sporovo-ply'tsevye kompleksy nekotorykh raionov zapadnoi Sibiri [Turonian spore and pollen assemblages of some regions of west Siberia]. In: 2nd International Conference on Palynology, Utrecht, 1966: Akadaymiya Nauk SSSR Palinologiia Sibiri, 84–89, pls. 1, 2. (in Russian)

Sliter, W.V., 1973. Upper Cretaceous foraminifers from the Vancouver Island area, British Columbia, Canada. Journal of Foraminiferal Research 3, 167–186.

Sluijs, A., Brinkhuis, H., Williams, G.L., Fensome, R.A., 2009. Taxonomic revision of some Cretaceous–Cenozoic spiny organic-walled peridiniacean dinoflagellate cysts. Review of Palaeobotany and Palynology 154, 34–53, pls. 1–6.

Snead, R.B., 1969. Microfloral diagnosis of the Cretaceous-Tertiary boundary, central Alberta. Research Council of Alberta, Bulletin 25, 1–148.

Spicer, R.A., Wolfe, J.A., Nichols, D.J., 1987. Alaskan Cretaceous-Tertiary floras and Arctic origins. Paleobiology 13, 73–83.

Srivastava, S.K., 1966. Upper Cretaceous microflora (Maestrichtian) from Scollard, Alberta, Canada. Pollen et Spores 8, 497–552.

Srivastava, S.K., 1967. Upper Cretaceous palynology: A review. Botanical Review 33, 260–288.

Srivastava, S.K., 1968. Ephedralean pollen from the Upper Cretaceous Edmonton Formation of Alberta (Canada) and their paleoecological significance. Canadian Journal of Botany 2, 211–221.

Srivastava, S.K., 1969a. Some angiosperm pollen from the Edmonton Formation (Maestrichtian), Alberta, Canada. J. Sen Memorial Volume; J. Sen Memorial Volume Committee and Botanical Society of Bengal, Calcutta, India, 47–67, 2 pls.

Srivastava SK. 1969b. Assorted angiosperm pollen from the Edmonton Formation (Maestrichtian), Alberta, Canada. Canadian Journal of Botany 47, 975–989.

Srivastava, S.K., 1969c. Upper Cretaceous proteaceous pollen from the Edmonton Formation, Alberta (Canada) and their paleoecologic significance. Canadian Journal of Botany 47, 1571–1578.

Srivastava, S.K., 1972. Taxonomic notes on pollen genera *Callistopollenites*, *Tricoborites*, and *Carpinipites*. Canadian Journal of Botany 50, 9–12.

Srivastava, S.K., 1975. Maastrichtian microspore assemblages from the interbasaltic lignites of Mull, Scotland. Palaeontographica, Abteilung B 150, 125–156.

Srivastava, S.K., 1978. Cretaceous spore-pollen floras. Biological Memoirs 3, 130 p.

Srivastava, S.K., 1981a. Evolution of Upper Cretaceous phytogeoprovinces and their pollen flora. Review of Palaeobotany and Palynology 35, 155–173.

Srivastava, S.K., 1981b. Fossil pollen genus *Kurtzipites* Anderson. Journal of Paleontology 55, 868–879.

Srivastava, S.K., Braman, D.R., 2013. The palynostratigraphy of the Edmonton Group (Upper Cretaceous) of Alberta, Canada. Palynology 37, 1–27.

Stanley, E.A., 1965. Upper Cretaceous and Paleocene plant microfossils and Paleocene dinoflagellates and hystricosphaerids from northwestern South Dakota. Bulletin of American Paleontology 49, 175–384.

Stanely, E.A., 1966. Problems of reworked pollen and spores in marine sediments. Marine Geology 4, 397–408.

Stanley, E.A., 1970. The stratigraphical, biogeographical, paleoautecological and evolutionary significance of the fossil pollen Group Triprojectacites. Bulletin of the Georgia Academy of Science 28, 1–44.

Stover, L.E., Brinkhuis, H., Damassa, S.P., de Verteuil, L., Helby, R.J., Monteil, E., Partridge, A.D, Powell, A.J., Riding, J.B, Smelror, M., Williams, G.L., 1996. Mesozoic–Tertiary dinoflagellates, acritarchs and prasinophytes. In: Jansonius, J., McGregor, D.C. (Eds.), Palynology: Principles and Applications. American Association of Stratigraphic Palynologists Foundation, pp. 641–750.

Sutherland Brown, A., 1968. Geology of the Queen Charlotte Islands, British Columbia. British Columbia Department of Mines and Petroleum Resources, Bulletin 54, 226 p.

Sweet, A.R., 1978. Palynology of the lower part, type section, Tent Island Formation, Yukon Territory. In: Current Research, Part B. Geological Survey of Canada, Paper 78-1B, pp. 31–37.

Sweet, A.R., 2005. Applied research report on four Tertiary samples from Appian Way plant locality, east coast of Vancouver Island near Campbell River (Map Area 92F/14, UTM Zone 10U 343800mE, 5531000mN). Geological Survey of Canada, Paleontological Report 02-ARS-2005, 6 p.

Sweet, A.R., Braman, D.R., 2001. Cretaceous–Tertiary palynofloral perturbations and extinctions within the *Aquilapollenites* phytogeographic province. Canadian Journal of Earth Sciences 38, 249–269.

Sweet, A.R., Braman, D.R., Lerbekmo, J.F., 1990, Palynofloral response to K/T boundary events; A transitory interruption within a dynamic system. In: Sharpton, V.L., Ward, P.D. (Eds.), Global catastrophes in Earth history: An interdisciplinary conference on impacts, volcanism, and mass mortality. Geological Society of America, Special Paper 247, pp. 457–469.

Takahashi, K., 1974. Palynology of the upper Aptian Tanohata Formation of the Miyako Group, northeast Japan. Pollen et Spores 16, 535–564.

Thiergart, F., 1950. Pollenfloren aus den Tertiaren Braunkohlen vom Niederrhein. Geologisches Jahrbuch, Reihe A 65, 81–106. (in German)

Torricelli, S., Rosa Amore, M., 2003. Dinoflagellate cysts and calcareous nannofossils from the Upper Cretaceous Saraceno Formation (Calabria, Italy): Implications about the history of the Liguride Complex. Rivista Italiana di Paleontologia e Stratigrafia 109, 499–516.

Traverse, A., 1988. Paleopalynology. Unwin Hyman, London, xxiii + 600 p.

Traverse, A., 2007. Paleopalynology. 2nd Edition, Springer, Dordrecht, The Netherlands, xviii + 813 p.

Tschudy, R.H., 1971. Two new fossil pollen genera from Upper Campanian, (Cretaceous), rocks of Montana. United States Geological Survey, Professional Paper 750, 53–61.

Tschudy, R.H., 1973. Palynology of the Upper Cenomanian (Cretaceous) Judith River Formation, north-central Montana. United States Geological Survey, Professional Paper 770, 1–42.

Tschudy, R.H., 1976. Palynology of Crevasse Canyon and Menefee Formations of San Juan Basin, New Mexico. In: Shomaker, J.W., Stone, W.J. (Eds.), Guidebook to coal geology of northwest New Mexico. New Mexico Bureau of Mines and Mineral Resources Circular 154, 48–58.

Tschudy, R.H., 1981. Geographic distribution and dispersal of Normapolles genera in North America. Review of Palaeobotany and Palynology 35, 283–314.

Tschudy, R.H., Pillmore, C.L., Orth, C.J., Gilmore, J.S., Knight, J.D., 1984. Disruption of the terrestrial plant ecosystems at the Cretaceous-Tertiary boundary, Western Interior. Science 225, 1030–1032.

Usher, J.L., 1952. Ammonite faunas of the Upper Cretaceous rocks of Vancouver Island, British Columbia. Geological Survey of Canada, Bulletin 21, 182 p.

Vallati, P., 2002. Biostratigraphy of Cretaceous non-marine sequences in Patagonia. In: European Meeting on the Paleontology and Stratigraphy of Latin America 3, 2002. Expanded Abstracts, Toulouse, pp. 124–127.

Vallati, P., 2013. Paleotropical pollen grains from the Neuquén Group, Patagonia, Argentina. Carnets de Géologie [Notebooks on Geology) – Letter 2013/05 (CG2013_L05).

Vajda, V., McLoughlin, S., 2007. Extinction and recovery patterns of the vegetation across the Cretaceous-Palaeogene boundary—a tool for unravelling the causes of the end-Permian mass extinction. Review of Palaeobotany and Palynology 144, 99–112.

Vajda, V., Raine, J.I., 2003. Pollen and spores in marine Cretaceous/Tertiary boundary sediments at mid-Waipara River, North Canterbury, New Zealand. New Zealand Journal of Geology and Geophysics 46, 255–273.

Van Itterbeck, J., Markevich, V.S., Codrea, V., 2005. Palynostratigraphy of the Maastrichtian dinosaur and mammal sites of the Râul Mare and Barbat valleys (Haþeg Basin, Romania). Geological Carpathica 56, 137–147.

Ward, P.D., 1978. Revisions to the stratigraphy and biochronology of the Upper Cretaceous Nanaimo Group, British Columbia and Washington State. Canadian Journal of Earth Sciences 15, 405–423.

Ward, P.D., Haggart, J.W., 1981. The Upper Cretaceous (Campanian) ammonite and inoceramid bivalve succession at Sand Creek, Colusa County, California, and its implications for establishment of an Upper Cretaceous Great Valley Sequence ammonite zonation. Newsletters on Stratigraphy 10, 140–147.

Ward, P.D., Stanley, K.O., 1982. The Haslam Formation: a late Santonian–early Campanian forearc basin deposit in the Insular Belt of southwestern British Columbia and adjacent Washington. Journal of Sedimentary Petrology 52, 975–990.

Ward, P.D., Haggart, J.W., Mitchell, R., Kirschvink, J.L., Tobin, T., 2012. Integration of macrofossil biostratigraphy and magnetostratigraphy for the Pacific coast Upper Cretaceous (Campanian–Maastrichtian) of North America and implications for correlation with the Western Interior and Tethys. Geological Society of America, Bulletin 124, 957–974.

Wetzel, W., 1966. Charakteristik des marinen Planktons und Pseudo-planktons der Amaltheen-Schichten Deutschlands und Lotharingens. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 124, 313–326, pls. 30–31. (in German)

White, J.M., 2006. Palynodata Datafile: 2006 version. Geological Survey of Canada, Open File 5793, 2008, 1 CD-ROM.

Whiteaves, J.F., 1889. On some Cretaceous fossils from British Columbia, the Northwest Territory and Manitoba. Geological Survey of Canada, Contributions to Canadian Palaeontology 1, 151–196.

Williams, G.L., Stover, L.E., Kidson, E.J., 1993. Morphology and stratigraphic ranges of selected Mesozoic–Cenozoic dinoflagellate taxa in the Northern Hemisphere. Geological Survey of Canada, Paper 92, 1–140.

Willumsen, P.S., 2012. Three new species of dinoflagellate cyst from Cretaceous-Paleogene (K-Pg) boundary sections at mid-Waipara River and Fairfield Quarry, South Island, New Zealand. Palynology 36, 48–62.

Wodehouse, R.P., 1933. Tertiary pollen—II. The oil shales of the Eocene Green River formation. Bulletin of the Torrey Botanical Club, 479–524.

Wolfe, J.A., 1976. Stratigraphic distribution of some pollen types from the Campanian and lower Maestrichtian rocks (Upper Cretaceous) of the middle Atlantic states. United States Geological Survey, Professional Paper 977, 18 p.

Wood, S.E.L., Riding, J.B., Fensome, R.A., Williams, G.L., 2016. A review of the *Sentusidinium* complex of dinoflagellate cysts. Review of Palaeobotany and Palynology 234, 61–93.

Worobiec, G., Worobiec, E., Erdei, B., 2020. Fossil callimothalloid fungi: Revised taxonomy, modern equivalents and palaeoecology. Fungal Biology 124, 835–844.

Wheeler, J.O., Hoffman, P.F., Card, K.D., Davidson, A., Sanford, B.V., Okulitch, A.V., Roest, W.R., 1996. Geological map of Canada. Geological Survey of Canada, Map 1860A, scale 1:5000000.

Yi, S., Yi, S., Batten, D.J., Yun, H., Park, S.-J., 2003. Cretaceous and Cenozoic non-marine deposits of the northern southern Yellow Sea Basin, offshore western Korea: palynostratigraphy and palaeoenvironments. Palaeogeography, Palaeoclimatology, Palaeoecology 191, 15–44.

Yorath, C.J., Sutherland Brown, A., Massey, N.W.D., 1999. LITHOPROBE, southern Vancouver Island, British Columbia. Geological Survey of Canada, Bulletin 498, 145 p.

Zhang Yi-Yong, 1993. Late Cretaceous palynofloras of China [In Chinese with English summary]. Acta Micropalaeontologica Sinica (Weiti Gushengwu Xuebao) 10, 131–157.