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Molluscan biostratigraphy and paleomagnetism of Campanian strata, Queen Charlotte Islands, British Columbia: implications for Pacific coast North America biochronology

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Abstract

A previously uncollected fauna of ammonites, bivalves, and other mollusks, associated with radiolarian microfossils, has been newly recognized near Lawn Hill on the east coast of central Queen Charlotte Islands, British Columbia. The regional biostratigraphic zonation indicates that the Lawn Hill fauna is correlative with the *Nostoceras hornbyense* zonule of the *Pachydiscus suciaensis* ammonite biozone, recognized in the Nanaimo Group of southeast Vancouver Island. The *Nostoceras hornbyense Zone* (new) is herein proposed for strata of Pacific coast Canada containing the zonal index. Several molluscan taxa present in the Lawn Hill section are new to British Columbia and the ammonite fauna suggests that the *Nostoceras hornbyense* Zone is late Campanian in age, supported by radiolarian taxa present in the section. Strata sampled in the Lawn Hill section preserve reversed-polarity magnetization, considered likely correlative with Chron 32r. The presence of the *Nostoceras hornbyense* Zone on Queen Charlotte Islands is the first recognition of this zone in Canada north of central Vancouver Island and represents the youngest Cretaceous known in this region. Campanian radiolarians identified from the Lawn Hill section are also the first recognized from the Pacific coast of Canada.

1. Introduction

Cretaceous strata are distributed widely across Queen Charlotte Islands, British Columbia (Haggart, 1991, 2004), with major outcrop belts found in the Langara Island to White Point region on the northwest coast, and in the Skidegate Inlet and Cumshewa Inlet areas of the central part of the islands (Fig. 1). Cretaceous strata are inferred to be distributed also in the offshore regions adjacent to Queen Charlotte Islands and collectively, these deposits accumulated in the Hecate basin (Hunt, 1958; Haggart, 1993; Mossop et al., 2004), inferred to have developed in a fore-arc setting westward of an active magmatic arc (Haggart, 1991, 1993; Higgs, 1991; Thompson et al., 1991; Lewis et al., 1991; Lyatsky and Haggart, 1993).

The Hecate basin accumulated on a varied topography of older Mesozoic and Paleozoic(?) sedimentary, volcanic, and plutonic rocks collectively assigned to the Insular belt. This feature is one of several morphogeological provinces of the Canadian Cordilleran region and includes the offshore island systems of western British Columbia and Alaska, including the island systems of Queen Charlotte Islands and Vancouver Island in British Columbia, and parts of the southeastern Alaska archipelago (Fig. 1).

The principal geological components of the Insular belt are the Wrangellia and Alexander terranes, the former well developed on Queen Charlotte Islands, the latter in southeast Alaska. The Baja British Columbia (“Baja BC”) hypothesis proposes large-magnitude northwest translation of, at minimum, the Wrangellia terrane of the Insular belt relative to the North American craton during Late Cretaceous and Early Tertiary time. The hypothesis remains controversial (Mahoney et al., 2000; Enkin, 2006) as the paleomagnetic data upon which it is based (i.e., Bogue et al., 1995; Ague and Brandon, 1996; Irving et al., 1996; Ward et al., 1997; Housen and Beck, 1999; Enkin et al., 2001, 2003; Haskin et al., 2003; Housen et al., 2003; Bogue and Gromme, 2004; but see Stamatakis et al., 2001 and others) are methodologically sound yet seemingly contradicted by numerous geological and paleobiogeographical inferences (i.e., Mahoney et al., 1999; Butler et al., 2001a,b, 2006; Kodama and Ward, 2001; but see Miller et al., 2006).
We present herein new paleontological and paleomagnetic data from Upper Cretaceous (Campanian to lowermost Maastrichtian?) strata of Queen Charlotte Islands. The faunal data establish for the first time the presence of upper Campanian strata on Queen Charlotte Islands, with correlatives exposed in southern Alaska and on Vancouver Island and associated islands of southwestern British Columbia, some 650 km south of Queen Charlotte Islands. In addition, while the paleomagnetic data are considered of insufficient quality and number to establish a paleolatitude suitable for paleogeographic analysis, recovery of reversed-polarity magnetization in calcareous concretions sampled in the section is considered most likely correlative with Chron 32r (ca. 71–73 Ma).

Fig. 1. Location map of Queen Charlotte Islands, British Columbia, showing location of Cretaceous (Campanian) outlier at Lawn Hill. Area of Cretaceous Hecate basin indicated in grey in inset. AT – Alexander terrane, WT – Wrangellia terrane. Note inferred paleo-high separating Cretaceous Hecate and Nanaimo basins of west coast Canada.
2. Regional geological setting

Wrangellia terrane hosts sedimentary basins of various ages built on a distinctive and characteristic Upper Triassic massive volcanic succession (basalts of the Karmutsen Formation and equivalents), possibly erupted onto pre-existing oceanic basement (Jones et al., 1977). On Queen Charlotte Islands, these oceanic basalts are succeeded by fringing reef carbonates and deeper water calcareous clastic facies of the Upper Triassic to lowermost Jurassic Kunga Group (Fig. 2) (see Lewis et al., 1991). Overlying, Lower Jurassic clastic-rich sedimentary strata of the Maude Group preserve extensive active arc volcanic and associated epiclastic deposits at some distance from active volcanic activity. By Middle to Late Jurassic time, the locus of magmatism occupied the Queen Charlotte Islands region; Yakoun and Moresby groups preserve extensive active arc volcanic and associated epiclastic rocks, respectively, in geographic and temporal association with widespread plutonism. Middle to Late Jurassic magmatic activity may reflect the initiation of subduction in the region (Lewis and Ross, 1988; Thompson et al., 1991; Lewis et al., 1991).

The Cretaceous stratigraphic succession of Queen Charlotte Islands records a prolonged period of basin subsidence and sediment accumulation in a stable tectonic setting (Haggart, 1991, 1993; Lewis et al., 1991). Continuous deposition initiated in Valanginian time and continued unabated until the Campanian. Cretaceous strata are dominantly shelf-related clastic deposits, with minor, geographically-restricted shallow-marine to subaerial (?) Upper Cretaceous volcanic rocks and deeper-water, slope turbidite facies (Haggart, 1991). Calcareous concretions are found at numerous levels in the stratigraphic succession; these often contain well-preserved fossil materials, especially in Santonian and Campanian deposits.

Correlation of Cretaceous successions of Queen Charlotte Islands has relied principally on ammonites and other molluscan fossil groups (McLearn, 1972; Jeletzky, 1970a, 1977; Haggart, 1991, 1995; Haggart and Higgs, 1989), although recent studies of radiolarian faunas (Haggart and Carter, 1993; Carter and Haggart, 2006) have demonstrated the correlation potential of this fossil group, especially for poorly-fossiliferous deep-water strata of the islands.

Paleogene plutonic rocks are distributed widely on Queen Charlotte Islands (Haggart, 2004) and may document final amalgamation of Wrangellia terrane with North America (Lewis et al., 1991), although this is by no means established. Subsequently, the Mio–Pliocene Masset Formation represents widespread volcanic activity that accompanied regional extension, and initiated Queen Charlotte Islands’ modern trans-tensional setting (Hickson, 1991).

3. Lithostratigraphy

The stratigraphic succession at Lawn Hill is exposed in a geographically-restricted (~ 250 m long) outcrop in the intertidal region on the east coast of Graham Island, Queen Charlotte Islands (Fig. 1; NTS 103G/05: Lawnhill 1:50,000-scale topographic map). The Lawn Hill outcrop is an outlier of Cretaceous rocks on the east side of the Sandspit fault (Fig. 1) and comprises the easternmost outcrop of the informally named Tarundl formation (Haggart, 2002), the youngest unit of the Lower-Upper Cretaceous Queen Charlotte Group (Haggart, 1991) found on Queen Charlotte Islands (Fig. 2). The Tarundl formation has limited geographic distribution across central Queen Charlotte Islands and includes strata from Santonian through Campanian (Haggart and Higgs, 1989; Haggart, 1991, 2002, 2004).

The Cretaceous strata at Lawn Hill dip gently to the south and include approximately 60 m of silty mudstone and muddy siltstone hosting calcareous concretions (Fig. 3). The exposures are not continuous and are generally covered with cobbles and small boulders, the arrangement of which varies from year to year, depending on storm activity. Section thickness was determined using a metal tape and accounting for stratigraphic dip. The base of the section, on the north side of the outcrop, is not seen and is presumed to be faulted. Similarly, the top of the section is cut off by feeder dikes to Neogene volcanic deposits which are inferred to unconformably overlie the Cretaceous strata at Lawn Hill, based on adjacent exposures on Graham Island just above the intertidal zone (Haggart, 2004). The Cretaceous strata are homogeneous in composition and lack distinctive marker beds. Fossils are common throughout the section, both in the matrix as well as in large (~ 0.5–1 m) and elongate calcareous concretions, and include molluscs, crustaceans, and wood. Fossils are generally fragmentary, both in the matrix and in concretions, but visually-uncompacted. Early diagenetic concretions are sometimes marked by doubly-deformed shale laminae draping both concretion tops and bottoms.

The Lawn Hill Cretaceous strata are faulted locally and contorted on a sub-outcrop scale. Regionally, the Sandspit fault, striking approximately 140° azimuth, crosses the shoreline of Graham Island approximately 10 km south of the Lawn Hill exposure (Sutherland Brown, 1968; Haggart, 2004). Multiple splays of this
regional-scale fault separate exposures of older, Jurassic and Cretaceous rocks on the west from dominantly Miocene volcani- clastic strata to the east. Recognizable movement on the Sandspit fault is primarily east side-down, with throw of hundreds to thousands of meters (Sutherland Brown, 1968; Yorath and Chase, 1981). As a possible consequence of its hanging-wall block affinity, the Tarundl formation exposure at Lawn Hill appears to have escaped the thermochemical alteration that pervasively affects Cretaceous strata in the footwall block (Haggart and Verosub, 1994).

In addition, Mesozoic organic-rich strata exposed on Queen Charlotte Islands are generally overmature (Vellutini and Bustin, 1991) and most Jurassic and Cretaceous fossil materials from Queen Charlotte Islands are altered to black calcite, reflecting thermal alteration effects likely associated with Jurassic or Eocene pluton emplacement. Local replacement of shell aragonite by (Mg, Fe)-rich chlorite at many localities suggests penetrative chemical mobilization and mineral replacement by fluids passing through widespread Upper Triassic Karmutsen Formation basalts (Haggart and Bustin, 1999). This diagenetic alteration could have accompanied post-Eocene extension and exhumation along low-angle normal faults: Eocene and Oligocene volcanic stocks tilt consistently by \( \pm 11-16^\circ \) to the north (Lewis and Ross, 1991; Wynne et al., 1992; Irving et al., 2000). Significantly, Cretaceous exposures at Lawn Hill appear to be geographically distant from surface exposures of the Karmutsen Formation, and Tarundl formation strata do not show evidence of the chlorite replacement typical elsewhere on Queen Charlotte Islands.

Fossils found in the Tarundl formation at Lawn Hill preserve original aragonite shell material and display iridescent lustre, often (but not always) characteristic of organic macromolecules incorporated systematically into a biomineralized shell matrix. Since the near-surface structural inversion of aragonite to calcite proceeds at low temperature (< 100°C), and since fluid exchange alters shell matrix proteins and destroys iridescence, aragonitic, iridescent fossils are recognized as markers of locally and regionally unaltered outcrops suitable for study in areas of otherwise remagnetized sedimentary (Filmer and Kirschvink, 1989; Ward et al., 1997).

Despite this rule-of-thumb, the “biomineral alteration” test is not a paleomagnetic field test that provides a direct constraint on the character of remanent magnetization, and normal-polarity viscous (partial thermal) remanent overprints plague similarly low-grade sedimentary rocks of similar lithology throughout the Insular superterrane (e.g. Enkin et al., 2001; Kim and Kodama, 2004).

### 4. Molluscan biostratigraphy

Representative examples of the Lawn Hill Cretaceous fauna are shown in Figs. 4 and 5 and the stratigraphic distribution of important taxa is summarized in Fig. 3. Although the molluscan fauna is not especially diverse, it does contain important

![Stratigraphic section of Tarundl formation exposed at Lawn Hill, Graham Island, Queen Charlotte Islands, showing levels of fossil collections and paleomagnetic sampling.](#)

**Fig. 3.** Stratigraphic section of Tarundl formation exposed at Lawn Hill, Graham Island, Queen Charlotte Islands, showing levels of fossil collections and paleomagnetic sampling. Fossil locality details available from senior author or Chief of Paleontology, Geological Survey of Canada, Calgary, Alberta. PM = Paleomag Sample [No.], m = meters above base of section.
biostratigraphic and biogeographic elements. The section at Lawn Hill was previously considered to represent the lower Campanian Submortoniceras chicoense Zone, based on a poorly-preserved ammonite fragment identified as Submortoniceras chicoense (Trask, 1856) (Haggart, 1995). However, new collections of better-preserved fossil materials have subsequently shown that this specimen is better assigned to the ammonite Pachydiscus suciaensis (Meek, 1862) (Fig. 5A, B). In addition, a number of additional ammonite taxa are now known from the Lawn Hill site, including Damesites sp. cf. sugata (Forbes, 1846) (Fig. 4G–I), Gaudryceras demmanense Whiteaves, 1901 (Fig. 4A–C), Anagaudryceras politissimum (Kossmat, 1895) (Fig. 4F), Neophylloceras sp., Nostoceras hornbyense (Whiteaves, 1895) (Fig. 5C, D), Diplomoceras sp. cf. tenusulcatus (Forbes, 1846) (Fig. 5E), Solenoceras sp. cf. mexicanum Anderson, 1958 (Fig. 4J), Zelandites sp. (Fig. 4D, E), and Baculites sp. cf. occidentalis Meek, 1862 (Fig. 5F). Also found in the section are the bivalves Cordiceramus? sp. (Fig. 5H) and Inoceramus sp. cf. vancouverensis Shumard, 1859 (Fig. 5G).

Fig. 4. Fossils from the Tarundl formation at Lawn Hill, Queen Charlotte Islands; all fossils are coated with ammonium chloride before photography. A–C. Gaudryceras denmanense Whiteaves, 1901; A, B. GSC No. 132348, GSC Loc. C-304212; A. Latex peel of external mold of inner part of umbilicus, right flank; B. Lateral view of right flank; C. GSC No. 132349, GSC Loc. C-304212 (cf. Gaudryceras tenuinotatum Yabe, 1902); D, E. Zelandites sp. juv.; GSC No. 132350, GSC Loc. C-304212; F. Anagaudryceras politissimum (Kossmat, 1895); GSC No. 132351, GSC Loc. C-304212; G–I. Damesites sp. cf. sugata (Forbes, 1846); GSC No. 132352, GSC Loc. C-304212; Figure G shows flank of outer whorl, figures H and I show the inner whorl; J. Solenoceras sp. cf. mexicanum Anderson, 1958; GSC No. 132353, GSC Loc. C-304209.
5. Paleomagnetism

Twenty-seven oriented paleomagnetic sample cores were drilled in twenty-five distinct concretions belonging to seven stratigraphic levels spaced through ~sixty meters of exposed section. All samples underwent low alternating-field and progressive thermal demagnetization in a low-field (<10 nT) shielded furnace, and progressively decaying remanence was measured on a three-axis SQUID magnetometer with ambient field shielded to a background level of generally less than 100 nT and less than 5 nT in the machine's sense region. Paleo- and rock-magnetic measurements were collected using an automated sample-changing system (Kirschvink et al., 2008) and magnetization directions were analyzed using least-squares analysis (Kirschvink, 1980) in the software program Paleomag (Jones, 2002).

For a powdered, representative sample, acquisition of isothermal remanent magnetization (IRM) effectively saturates between 200 and 300 mT, and alternating field (AF) demagnetization of saturation IRM indicates a median coercivity of approximately 40 mT; together, these parameters suggest the presence of detrital magnetite, titanomagnetite, and/or biogenic magnetite (Fig. 6). AF demagnetization of anhysteretic remanent magnetization (ARM) reduces saturation IRM to zero at a marginally higher field strength than AF of IRM, suggesting the presence of single-domain crystals capable of retaining primary magnetizations against low thermal- and viscous-demagnetizing effects for significant periods of time (Cisowski, 1981).

In directional experiments, AF demagnetization up to 10 mT in 1.0 mT to 1.25 mT steps removes low-coercivity components usually accounting for 25–50 % of net natural remanent intensity. Post-AF magnetization is generally ~5 × 10^-9 Am². Samples were thermally demagnetized in closely-spaced steps from 100 °C until they became unstable, generally between 340 °C and 425 °C, and rarely to ~550 °C. These elevated unblocking temperatures are also consistent with magnetite and/or titanomagnetite as the magnetization carrier, unstable during thermal demagnetization during calcination reactions.
6. Discussion

6.1. Zonal assignment

Most of the Lawn Hill molluscan taxa are known from other localities along the Pacific coast of North America. *Nostoceras hornbyense* is found commonly in exposures of the upper Nanaimo Group of British Columbia, especially at Hornby Island where it is associated with *Baculites occidentalis*, *Didymoceras vancouverense*, and *Phlyoplocyrtaceras forbesianum* (Ward, 1978); examples are also known from southern Alaska (Jones, 1963). *Anagaudryceras politissimum* and *Damesites sugata* are also found in the upper Nanaimo Group, commonly in association with *Pachydiscus suicensis* (Haggart, 1989). The diplomoceratid ammonite *Solenoceras mexicanum* is known from the Rosario Formation of Baja California (Anderson, 1958), but, to date, representatives of the genus have not been recognized north of California (although the southern Alaskan specimen referred to *Pseudoxybeloceras*? sp. indet. by Jones 1963 (pl. 16, fig. 9) is likely referable to the genus). The Lawn Hill specimen compared herein with *S. mexicanum* is of smaller size than the illustrated Baja examples, although it exhibits similar morphology. The bivalve *Inoceramus vancouverensis* is a common component of Campanian assemblages of the Nanaimo Group and has also been recognized in the Campanian of California (Matsumoto, 1960).

The ammonite specimen GSC (Geological Survey of Canada) No. 132349, herein assigned to *Gaudryceras demanenense* (Fig. 4C), bears strong resemblance to material figured by Jones (1963, pl. 9, pl. 10, figs. 1–3) as *Gaudryceras tenuiliratum* Yabe; the strong and dense ribbing in the intermediate growth-stage stands in contrast to that of typical examples of *G. demanenense* (cf. Usher, 1952, pl. 4, figs. 1–2; Haggart, 1989, pl. 8.3, fig. 1). Earlier work on gaudryceratids of the Nanaimo Group led Haggart (1989) to synonymize Jones' materials within *G. demanenense*. The present coarsely ribbed specimen, found at the same level as more smoothly-ornamented forms readily assigned to *G. demanenense*, thus illustrates the variability found within single populations of Upper Cretaceous gaudryceratids and may have implications for taxonomic assignments of gaudryceratids in other regions, as well as the specific composition of the genus.

Based on the presence of *Pachydiscus suicensis*, the strata at Lawn Hill are broadly referable to the *Pachydiscus suicensis* Zone of western Canada. Jeletzky (1970a,b) established the *Pachydiscus suicensis* Zone for fossiliferous Upper Cretaceous strata of the Pacific slope of Canada containing the zonal index and other taxa, including the heteromorph *Nostoceras hornbyense*. The *Pachydiscus suicensis* Zone is well developed in the Nanaimo Group of Vancouver Island where it has been interpreted previously to have a late Campanian to possibly early Maastrichtian age (Jeletzky, 1970b; Ward, 1978; Haggart, 1995; ~77–71 Ma); the zone has not been recognized elsewhere in British Columbia prior to this report. Ward (1978, table 1) furthermore suggested that strata of the *P. suicensis* Zone on Vancouver Island and adjacent regions containing the heteromorph *Nostoceras hornbyense* and other ammonite taxa comprise a local zonule within the upper part of the *P. suicensis* Zone. *Nostoceras hornbyense* and *Pachydiscus suicensis* both occur in the Lawn Hill section at GSC Loc. 304209, approximately 4 meters above the base of the section (Fig. 3); neither taxon is recognized higher in the stratigraphic section at Lawn Hill.

Based on the new recognition of the *Nostoceras hornbyense* fauna on Queen Charlotte Islands, and the previous identification of *N. hornbyense* in southern Alaska (Jones, 1963), we propose that the *N. hornbyense* zonule be elevated to the status of a formal faunal zone for the Pacific coast region of western Canada, stratigraphically succeeding the *Pachydiscus suicensis* Zone (Fig. 8); the stratigraphic section at Lawn Hill is thus assigned to
the new Nostoceras hornbyense Zone. The base of the new faunal zone on Queen Charlotte Islands is located ca. 4 meters above the base of the exposed section at Lawn Hill (ca. UTM Grid Reference 306475E, 5923050N, Zone 9; NAD 27), at the first occurrence in the section of \textit{N. hornbyense}. The upper limit of the zone is not seen, but continues to the top of the exposed section (ca. UTM Grid Reference 306450E, 5922800N, Zone 9; NAD 27), which is cut by a Neogene dike.

The Nostoceras hornbyense Zone is the youngest ammonite faunal zone recognized to date in the Cretaceous of Pacific coast Canada. Exposures of the zone on Hornby Island (Fig. 1) constitute the stratigraphically-highest fossiliferous strata within the Northumberland Formation of the Nanaimo Group. Higher Nanaimo Group strata of the Spray Formation on Hornby Island are inferred also to be Late Cretaceous in age (Jeletzky, 1970b; Ward, 1978), but, to date, these submarine-fan deposits have not produced diagnostic faunal elements.
The N. hornbyense Zone of western Canada is also broadly
correlative with the Pachydiscus kamishakensis Zone of southern
Alaska (Jones, 1963), which has been assigned to the uppermost
Campanian to lowermost Maastrichtian (Jones, 1963) and contains
similar taxonomic components, including N. hornbyense.

6.2. Age

The age of the Pachydiscus suciaensis Zone, including strata of the new Nostoceras hornbyense Zone, was previously interpreted as latest Campanian to earliest Maastrichtian (Jeletzky, 1970b), based on foraminiferal data from the well exposed succession of the upper Nanaimo Group on Hornby Island (McGugan, 1979); this interpretation for the age of the zone has been followed subsequently by most workers (e.g. Ward, 1978; Haggart, 1989; England and Hiscott, 1992; Mustard, 1994). Although precise correlation of the North Pacific Upper Cretaceous sequences with European international stratotypes is problematic, due to limited numbers of shared taxa and long ranges of a number of species, several of the ammonite taxa present in the Nostoceras hornbyense Zone at Lawn Hill have a restricted stratigraphic range and, we argue, serve to establish a late Campanian age for the zone (~ 75–70 Ma).

Haggart (1989) showed that Gaudycria davenirense is restricted to strata of late Campanian age in the upper part of the Nanaimo Group of the Vancouver Island area. In addition, the diplomoceratid ammonite Solenoceras has been collected from the Campanian succession. Examples of this group are rare from west coast of North America, but are common in middle and, especially upper Campanian succession. The age for the Lawn Hill Tarundl formation section suggested by Ward (1978) and that favored here. Absolute ages after Ogg et al. (2004). Sant. – Santonian.

<table>
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<td>N. hornbyense</td>
<td>Nostoceras hornbyense</td>
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<td>Camp.</td>
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<td>Pachydiscus suciaensis</td>
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<td>Hoplitoplacenticeras cf. pacificum</td>
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<td>Sant.</td>
<td>83.5</td>
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Fig. 8. Campanian-Maastrichtian molluscan biostratigraphic zonation for western Canada proposed by Ward (1978) and that favored here. Absolute ages after Ogg et al. (2004). Sant. – Santonian.

Based on the evidence presented above, the radiolarian assemblage from Lawn Hill is probably late Campanian in age and illustrates the wide distribution of radiolarians in Panthalassa during the Late Cretaceous.

The age for the Lawn Hill Tarundl formation section suggested by radiolarians thus supports the age assignment based on molluscs. The late Campanian age indicated by molluscs and radiolarians also supports placement of the Lawn Hill section within one of the short reversed subchrons within or adjacent to Chon C32 (Ogg et al., 2004). We prefer correlation of the Lawn Hill section with the stratigraphically-highest of these subchrons as the age of the Nostoceras hornbyense Zone at Lawn Hill is assigned to the high Campanian.

Given their late Campanian age, the Tarundl formation exposures at Lawn Hill represent the youngest Cretaceous strata known on Queen Charlotte Islands. Indeed, the next older Cretaceous fauna known from Queen Charlotte Islands, also from the Tarundl formation but exposed in the western Skidegate Inlet area, is of late Santonian to early Campanian age (Haggart and Higgs, 1989).
7. Conclusions

We have recognized the *Nostoceras hornbyense* zonule of the *Pachydiscus suciaensis* Zone of the west coast North American Upper Cretaceous in strata on Queen Charlotte Islands, British Columbia. A stratigraphic section exposed in the intertidal region at Lawn Hill, on the east coast of the islands, includes both *N. hornbyense* and *P. suciaensis*, as well as a diverse assemblage of ammonites and ino-
ceramids that are assigned a late Campanian age. Radiolarians associated with the mollusc fossils also support a late Campanian age. Calcareous concretions found in the section exhibit reversed-
polarity magnetization which we correlate with Chron 32r.

The *N. hornbyense* Zonule of the *P. suciaensis* Zone was estab-
lished by Ward (1978), based on limited exposures in the Nanaimo
Group of southwestern British Columbia. Based on the new data demonstrating that *N. hornbyense* is more widely distributed along the west coast of North America than previously considered, we have proposed that this zonule be raised to zonal status. So far as known, the *N. hornbyense* Zone is restricted to the upper Cam-
panian along the west coast of North America, as diagnostic fossils of the lower Maastrichtian, such as *Pachydiscus neubergicus* and its equivalents, have yet to be found in association with the zonal index. As well, the highest fossiliferous exposures of the North-
umberland Formation at Hornby Island, British Columbia, which are rich with *N. hornbyense*, can be correlated with the uppermost Campanian, rather than the lower Maastrichtian as postulated previously (McGugan in Jeletzky 1970b); however, stratigraphically-higher strata on Hornby Island (Geoffrey, Spray, and
Gabriola formations), which are poor in macrofossils, may include Maastrichtian rocks.

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Appendix. Fossil localities

Data from Geological Survey of Canada Paleontological Database, Vancouver, British Columbia. All fossil localities are those of Geological Survey of Canada (GSC) and are located on NTS Topographic Map 103G/05 (Lawnhill).

GSC Loc. C-304210. 306475E, 5923025N; 4.2 m above base of exposed stratigraphic section; Coll. J.W. Haggart, 1998.
GSC Loc. C-304212. 306475E, 5923025N; 8.5 m above base of exposed stratigraphic section; Coll. J.W. Haggart, 1998.
GSC Loc. C-304213. 306475E, 5923025N; 42.0 m above base of exposed stratigraphic section; Coll. J.W. Haggart, 1998.
GSC Loc. C-304214. 306475E, 5923025N; 49.5 m above base of exposed stratigraphic section; Coll. J.W. Haggart, 1998.
GSC Loc. C-210839. 53°25.43′N, 131°54.77′W; near top of exposed stratigraphic section; Coll. E.S. Carter, 1993.