Fossils from the late-Cretaceous on Gabriola Island

Nick Doe

Anyone who knows I have made a mistake, or would like more information, please contact me. I have many more pictures of the fossils than are shown here.

These are notes on fossils that friends, neighbours, and Jenni Gehlbach and I, have found on Gabriola Island, BC, Canada.

We walk the beach on the south side of the island every day; however, we are not paleontologists, nor are we fossil collectors; so, these notes are not an exhaustive record of every fossil that has ever been observed on the island.

The fossils on Gabriola fall into two very different groups. Those from:

—the late Cretaceous; and those from
—the late Pleistocene and early Holocene.

This note discusses only the former. Ice-age fossils on Gabriola —the bones of woolly mammoths and whales, and marine shellfish—are discussed elsewhere.

Background geology

A non-technical introduction to Gabriola geology, with references can be found here.

The island's rocks are part of a syncline, a ∪-shaped fold, created in the Eocene, with an axis that runs the length of the island, roughly east–west. The rocks exposed on the beaches along the long south and north sides are furthest away from the syncline axis, and so are the oldest rocks on the island.

The rocks on the south side at False Narrows and east of there, and on the north side along Whalebone, are exposures of the same formation.

All four formations on Gabriola are marine sedimentary rocks belonging to the late-Cretaceous Nanaimo Group. There are no Paleogene or Neogene rocks on the island. Whatever rocks there may have been here of that age were removed during the many glaciations of the Pleistocene.

From oldest to youngest, the formations are:

—Northumberland Formation, mainly mudrock with siltstone, mudstone, and sandstone interlayers. Late Campanian. The Northumberland Formation north of Gabriola is sometimes still called the *Lambert Formation*, a nomenclature dating back to the days when there was some doubt as to whether the Nanaimo and Comox Basins were the same;

—Geoffrey Formation, gritty sandstone and conglomerate. Late Campanian-early Maastrichtian;

—Spray Formation, mainly mudrock. Early Maastrichtian. The Spray Formation has less exposure on beaches than the older Northumberland Formation;

—Gabriola Formation, mainly sandstone. Maastrichtian, possibly to late Maastrichtian. This is the youngest formation in the whole Nanaimo Group. Gabriola Formation sandstone is so devoid of recognizable fossils that it is difficult to accurately date. Who knows? there might even be a K/T (K-Pg) boundary here. http://www.nickdoe.ca/pdfs/Webp294c.pdf

Exposures of these four formations also occur on other islands, notably Hornby and Denman.

The cement for the sedimentary rocks on Gabriola is clay. Common cementing minerals such as *calcite*, *quartzite*, *zeolite*, iron oxides and sulphides (*limonite*, *hematite*, *pyrite*, *marcasite*), when present, are present only in concretions, weathering rinds, case-hardened sandstone surfaces, and metasomatically-altered shear zones.

By "mudrock" in the following, I mean lithified clay, about half of which on Gabriola consists of clay minerals and half of comminuted quartz and feldspar.

Locally, "mudrock" is almost invariably called "shale" even when it shows no sign of lamination. I often do the same out of habit.

Bouma sequences in the shale on Gabriola are quite common. Look here for notes.

The mineralogical evidence is that the sediments were not greatly weathered before being deposited. Although the paleo-geography of the late-Cretaceous Nanaimo Basin is uncertain, the picture appears to be of sediments being washed by mountain streams into rivers which transported them fairly quickly into a warm anaerobic, low-energy, marine environment. The feldspar content of the rocks is correspondingly high—the sandstone sometimes qualifies as a *feldspathic wacke*—and the *biotite* and *amphibole* in the rock weather rapidly on exposure to the modern atmosphere.

Background paleontology

Vancouver and Gulf Islands fossils are described in Rolf Ludvigsen & Graham Beard's book, *West Coast Fossils—A Guide to the Ancient Life of Vancouver Island*, Harbour Publishing, 1997. IMHO it's worth getting the 2nd edition of this, even if you already have the first.

It has to be said that Gabriola is not a good place for fossil observers. Practically all fossils have suffered chemical diagenesis, usually to the point where they can't be identified. It is also virtually impossible to extract fossils from the shale as it is so crumbly, a result of oxidation and dehydration in the sun. Once exposed to the elements, weathering often destroys fossils fairly quickly.

There is little evidence of the Northumberland Formation on Gabriola being an environment of great biodiversity—apart from bivalves and brachiopods; there is seldom anything to be found, particularly on the beaches between False Narrows and the Cemetery. I'm also not aware of any vertebrate fossils of late-Cretaceous age having been found here.

Many fossils of the Nanaimo Group north of Gabriola are found in concretions; but not on Gabriola. Calcareous concretions abound both in the sandstone, particularly the sandstone of the Gabriola Formation, but even the largest of these usually reveals only unrecognizable fragments of organic material. Commonly, only hydrochloric acid or aggregates of tiny crystals just visible to the naked eye indicate local concentration of *calcite* within these concretions.

Concretions also occur in the mudrock, but they are usually so weakly cemented that they are often mistakenly assumed to be the result of spherical weathering. Look here for notes on this. In the Northumberland Formation, the cement for mudrock concretions appears to be *calcite*, but John Packard (M.Sc. Oregon State University, 1972) in his investigation of what he called "pseudoconcretions" in Spray Formation mudstone found by X-ray analysis, the cement to be *marcasite*. I've seen these concretions in Leboeuf Bay on the north side of the island where they are highly visible in contrast to the weakly cemented textures that I am familiar with on the south side of the island; I have not investigated further.

Above: Concretions in sandstone on Gabriola can be very big. This one is from the Twin Beaches Peninsula (Gabriola Formation).

It is fairly common in the literature to make no distinction between "concretions" and "calcareous nodules" or just "nodules". On Gabriola, this is a serious mistake.

Above: Even large concretions—this one is 2-feet across—when split open reveal nothing more than a small featureless calcareous-chlorite nodule in the centre. The source for this one, which is on display at the Gabriola Museum is not known, but similar ones can be found on the Twin Beaches Peninsula.

Concretions, defined as I use the term, are composed of grains that are the same as those in the host rock. A sandstone "concretion" is still sandstone. What makes it different is the efficacy of the cement that binds the grains of sand together. For more on Gabriola's concretions look here.

Nodules, defined as I use the term, have a composition that is very different from that of the host rock. The minerals in nodules, in

Nodules on Gabriola have a uniform grey interior consisting mainly of clay and *calcite* with no sign of structure, yet alone a fossil. The vertical line in this picture is a hairline fracture that allowed the ingress of glacial meltwater. From the Northumberland Formation at the Cemetery site.

the present context, are minerals with a substantial contribution from decomposition of the soft tissue of the fossil and from chemical weathering of any shell.

The main host-rock component present in nodules on Gabriola is *chlorite* with only minor *quartz* and *plagioclase*. *Calcite* is commonly abundant, but some what-I-take-to-be brachiopod fossils contain *apatite*. For more on Gabriola's nodules see here.

The marine fossils on Gabriola are commonly in the form of nodules, not concretions. My interpretation of this is that the fossils were originally bottom dwellers that were buried alive when the area where they were living, some distance from a river estuary and its submarine fan, was inundated with silt and sand when a part of the fan collapsed, either as a result of an earthquake or over-accumulation of sediment. The subsequent decay of the buried-alive creatures often has consumed the shell creating an unrecognizable nodule.

On Gabriola, we have one site at the Community Cemetery however where a variation of this process has separated the shell from the soft body—possibly because the decaying soft body became riddled with gas and thus became sufficiently buoyant to leave the shell and rise through the overlying still-to-be-consolidated fine sediment—with the result that both shells and nodules co-exist within a short distance (< 0.5m) of one another.

The evidence for many nodules being inoceramids is quite persuasive:

—inoceramids fossils commonly occur *en masse* in a single bedding plane. This could only have been as a consequence of some catastrophic die-off;

—beds (pavements) of large calcareous shell-less nodules very occasionally contain a recognizable inoceramid shell fragment with an unusually small nodule. A simple explanation for this is that this particular specimen, unlike its neighbours, was already dead when the area was inundated;

—nodules and shells are observed together. Even when shells are very scarce, it is always possible to find, after a sometimes lengthy search, at least one example of a nodule with a small fragment of inoceramid shell attached to it or embedded in it;

—the nodules always have a flint-like, *calcite*-rich, structureless interior quite unlike concretions further north, but they frequently have wonderfully preserved trace fossils—ichnofossils and chondrites—on their surface. A simple explanation for this is the the decaying bodies of the buried inoceramids attracted many burrowing scavengers. When the rotted material was eventually dried out, the nodule swelled slightly in the manner of calcium sulphate (plaster of Paris) and thereby made a cast of the void in the mud containing the decaying or decayed material;

—the nodules commonly have features attached that were once hollow and filled with liquid. These appear to be siphons and feet.

The nodules on Gabriola have attracted iron and manganese deposits—they are quite heavy. I interpret this as being the result of their being immersed at various times during the Pleistocene in flowing, pressurized, anaerobic, mineral-rich, mildly acidic, sub-glacial meltwater. Because of the high pH of the nodules, there was a slow accumulation of precipitated iron and manganese oxides on their surfaces and on fracture planes within the nodules.

Gabriola Formation fossils in Pilot Bay?

The beach along the Twin Beaches Peninsula on Gabriola is very rich in large sandstone calcareous "cannon-ball" concretions, which is interesting because this sandstone belongs to the Gabriola Formation, which usually lacks any evidence of organic material.

However, the source of the organic material in these concretions appears to be not from the Gabriola Formation but from the Spray Formation that lies just beneath it.

The evidence, particularly in Pilot Bay, is that the sand that evolved into sandstone arrived in massive amounts in what might have been a relatively short-lived event, and that this inundation stirred up the mud of the Spray Formation and along with it, the bivalves? living on or near its surface.

Although fossils can be seen in the sandstone close to the boundary with the shale, they do not lie with any orientation that would suggest that this was their living orientation. The same fossils are relatively abundant in the upper layers of the shale where their orientation usually follows the bedding plane. A few concretions on this beach have been broken or eroded open enough for one of these fossils to be seen near the centre, and it is my conjecture that it is these upper-Spray-Formation fossils that account for the abundance of sandstone concretions.

Concretions, both free like these and still partially embedded, are common on the beach between Pilot and Taylor Bays. Although the cement of the concretions contains *calcite*, the concentration is not enough to make the sandstone impervious; hence, the honeycomb salt weathering.

Contacts between the Gabriola Formation (sandstone) and underlying Spray Formation (shale) on Gabriola are sharp unlike those reported at other locations (Mustard, GSC 481, pp.88–90). This is consistent with a major submarine-fan channel migration at the end of the Spray Formation deposition. Likely this was part of the regional progradation that resulted from uplift in the mainland mountains and from expansion of the watersheds of major rivers flowing westward into the Nanaimo Basin.

Pictures

All fossils unless noted otherwise are from the Nanaimo Group–Northumberland Formation on Gabriola (Cretaceous-upper Campanian). The stratigraphy at the sites is poor; the shale is capped with Pleistocene Vashon till and the lower contact with the De Courcy Formation is below sea level. If I had to guess, I would say the fossils are mostly from nearer the bottom of the Northumberland Formation than the top; there are reefs of De Courcy Formation silt/sandstone 200 metres from the shore in False Narrows that dip shallowly down under Gabriola while the contact with the Geoffrey Formation conglomerate (False Narrows bluffs) is over half a kilometre inland from this stretch of beach.

The list is short:

Ammonites:

Diplomoceras notabile
Gaudryceras denmanense
Gaudryceras aff. *venustum*
(previously Neophylloceras ramosum)
Nostroceras hornbyense
Pachydiscus suciaensis and *P. sp.*
Anapachydiscus sp.?
Unidentified *sp.*

Bivalves:

Inoceramous sp. (large)

http://www.nickdoe.ca/pdfs/Webp225c.pdf.

I habitually identify these as *Inoceramous vancouverensis* because this is what I was told they were early on in my study of them. However, having read the type description (Shumard), I doubt this is right. I'd be glad to have an expert opinion on this.

Unidentified *sp*. mainly in Pilot Bay.

Brachiopods:

Lingula sp.
http://www.nickdoe.ca/pdfs/Webp288c.pdf.

Plant fossils:

Petrified log (*unidentifiable species*).
Coalified vegetation in Gabriola Formation sandstone (*unidentifiable species*).

Ichnofossils

Ammonites

1. *Gaudryceras denmanense*

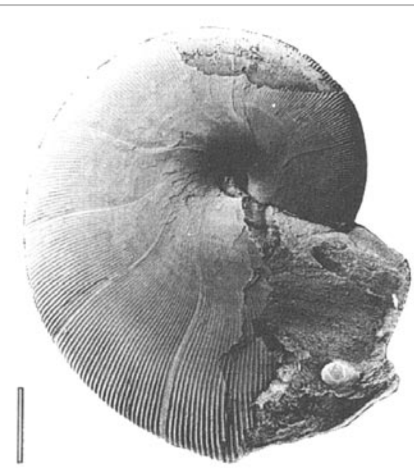
2. *Gaudryceras* aff. *venustum* [1] (Originally identified as *Neophylloceras ramosum*)

Thought to be *Phylloceras*, but not an expert opinion—about 200 mm diameter; pictures below from Ludvigsen & Beard, p.129. Probably *Gaudryceras sp.*

Second specimen near-by

Although these might be zoophycos trace fossils, I doubt it. At least one had a probably-associated nodule close by which is typical of ammonite fossils on Gabriola.

They also only occur in isolation.



[1] Comment thanks to Jim Haggart. See Haggart J., 1990; GSC Bull. 396, pl.8.3, figs.2,3.

Following is just a guess as to species based solely on suture pattern.

Above: *Phylloceras*. Cambridge Guide to Minerals & Fossils, 1999, p.251

3. *Nostroceras hornbyense*

This is not a second specimen; it's a cast of the one shown above.

Found on beach at False Narrows (Northumberland Fm.). There's a more recent find on Whalebone Beach at the end of this file (pp.45–46). Same rock formation.

4. *Pachydiscus suciaensis.* and *P. sp.*

P. suciaensis is suspected in some cases just on the basis of size.

5. Possibly *Pachydiscus suciaensis* but also possibly an *Anapachydiscus. sp.*

This remarkably well-preserved ammonite with beautiful suture patterns was found on Whalebone Beach (late Campanian) by Sheila Haniszweska. It might be *P. suciaensis*, but if so, it is smaller than usual and quite uncharacteristically has both halves reasonably well preserved—very commonly only the lower halves of *P. suciaensis* specimens are found.

Centimetre scale (mm graduations) bottom left corner

6. Unidentified *spp.*

Above: Note the surviving nodules. Possibly the fossilized ammonite soft tissue (it was buried alive?).

Below: Another ghostly remnant with possible 3-D coiled form spiralling into the centre. This one might have been a heteromorph. 28-mm coin.

Inoceramids (references File: 225c and File: 226c)

This one is showing the inner pearly nacreous layer of the lower valve.

Typical bed of "ginger root" nodules. The rosy surfaces are common; inside, they are flint-grey, occasionally with patches of minute *calcite* crystals that sparkle in the sun. Very large beds like this occur in the Northumberland Formation on Denman Island.

This large nodule—fossilized body of an inoceramid with siphon? on the left—found by Hans (Mickey) Pfeiffer in the Northumberland Formation and donated to the Gabriola Museum. The body is 24 × 29 cm wide; and the siphon is 24 cm long with an elliptical cross-section 11 × 7 cm. The nodule weighs 40 lb.

Added May 30, 2020, in response to Facebook postings.

Here's a photograph of a bed of nodules on Denman Island. That these beds form this way is an indication that these inoceramids lived in a close-packed community on the surface—the chemical decomposition has merged them together— and that they all died together. A long search in these beds located inoceramid shells embedded in the beds in an orientation consistent with these few individuals having been dead and their shells emptied before the catastrophy hit.

I suspect that the ruddy/orangey colouration of the nodules is mainly due to traces of an iron mineral, perhaps *lepidocrocite*. There might also be lesser amounts of a manganese mineral, which would likely be brown. This colouration is also common in the brachiopod fossils. ◊

A rare example of a foot? still attached to a nodule with shell. The bend where the foot left the shell is nearly always broken off.

Left: Fossilized inoceramid feet? At the cemetery site on Gabriola and along False Narrows, these are almost always found embedded in the shale is an upright position.

They have rounded bottoms, where there is no sign of the central core feature, which suggests they are feet rather than open-ended siphons. At other sites, feet are absent or very hard to find.

Above: A common configuration of shells and "ginger root" nodules with the nodules separate and slightly above the shells. It is common for nodules to be overlain by a thin layer of siltstone or very fine sandstone, a remnant perhaps of the deposit of sediment that buried the inoceramids so deeply that they were unable to dig themselves out.

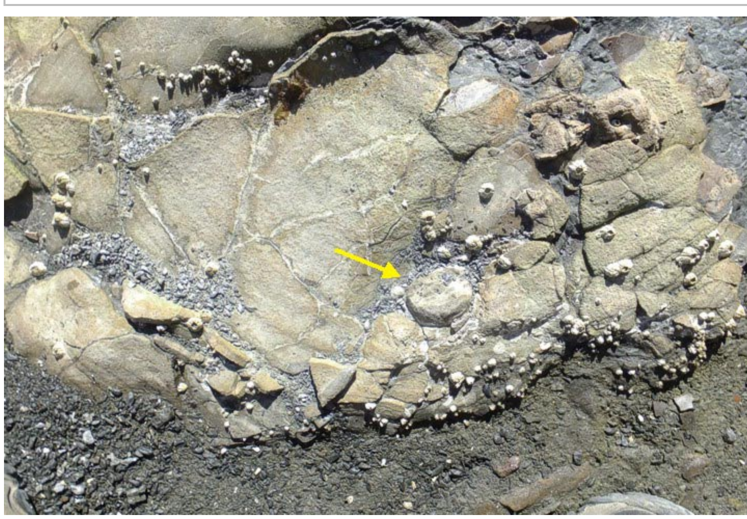
Below: Another uncommon example of a foot and a surviving shell together.

Above: An uncommon combination of a nodule (below) and inoceramid shell (above). Finding this at the outset of the observations would have saved a lot of time—usually the shells and nodules are separate. Full credit for the discovery of the shell:nodule association should go to Jenni Gehlbach.

An even more uncommon combination of nodules (orange coloured) and ~~inoceramid~~ ammonite shell, leaving no doubt as to their relationship. About 0.2 m long.

Note the peculiar circular feature on the top right side of the shell. It appears to be a feature protruding through the shell, but is this a feature of the living animal, or one that has developed after burial? Although not common, such features always appear in similar positions on the shell (photo below) ruling out the possibility that they are the work of scavengers.

Photograph above by Megan Adam on Whalebone Beach.



Isolated "feet" are common in the inoceramid bed at Cemetery Beach, but not elsewhere.

One of the odd things about the inoceramids on Gabriola's beaches is that you almost never see any juvenile ones. The following pictures are of a very rare clump of Northumberland Formation mudstone (False Narrows) containing a number of smaller bivalves (shells and nodules), one of which was clearly either a young inoceramid, or one of a different and smaller species. Its associated "foot", the only such structure visible in the clump, was only 2–3 mm in diameter in contrast to the usual several centimetres.

Mudstone like this usually crumbles within a few days when exposed to the air, but in this case the *calcite* concentration in the clump is sufficiently high to hold it together.

Shell fragment and "foot" of a small inoceramid. Millimetre scale in the bottom lefthand corner.


22 23 24 25 26 27 28 29 30

This particular nodule was a puzzle at first glance. It is from Whalebone Beach, Northumberland Formation, (courtesy Sheila Haniszewska). It's heavy, and looks and feels like a typical surf-polished basalt pebble, perhaps with surficial bivalve attachment scars. The clue that it is not in fact basalt is that the "scars" are etched into the stone, something a bivalve couldn't do, even shallowly, if the stone were truly igneous. It is in fact a polished *chlorite–calcite* nodule with a high concentration of *calcite*. The "scars" are fragments of inoceramid shell embedded in the stone with characteristic prisms of *calcite* deposited perpendicular to what-was-once their surfaces.

Unidentified bivalves? in Pilot Bay

These occur in both the shale of the Spray Formation and the sandstone of the Gabriola Formation just above the boundary between the two formations. The evidence is that these creatures lived on or near the surface of the mud until they were buried under a massive influx of sand. Some of the creatures ended up in the sand, where they subsequently formed the nodular core of sandstone concretions.

None of the fossils have the asbestos-like fibrous shells of inoceramids.

Bivalves? calcite rich-nodules, here in sandstone just above the shale. These lens-shaped nodules are common at the sandstone-shale boundary. The largest here is 12 cm across. In the shale, the nodules are parallel with the bedding planes, even when severely folded as shown below. In the massive sandstone they are scattered, sometimes in piles.

Above: A large concretion still embedded in the bedrock near Pilot Bay (Gabriola Formation). It has been split, revealing lens-shaped *calcite* nodules up to 12 cm wide at its centre.

Below: Calcite-rich nodules of the Pilot Bay fossils.

Brachiopods

No preserved shells have been found. For details see here. The orange material appears to be clay.

Lingula sp.? Fossil tubes (pedicles) are common at the east Brickyard site.

Brachiopod? nodules embedded in shale. Size 10 boot for scale. There are no signs of inoceramids at this site just east of Brickyard Beach.

Chemical analysis showed them to be richer in phosphorous than carbon.

Chemistry (brachiopod? nodule)

Numbers are % wt., ppm (10^{-3} ‰), or ratio of atoms.
C/Ca<<1 =Ca as silicate; C/Ca≈1 =Ca as *calcite*, C/Ca>>1 =*calcite* and free carbon
3P/5Ca<<1 =Ca not as *apatite*; 3P/5Ca≈1 =*apatite*, 3P/5Ca>>1 =very rare.

	False Narrows Beach	Cemetery Beach
	nodule	host shale
	27-GAB/NOR A403430	14-GAB/NOR A305008
SiO_2	23.2	51.0
TiO_2	0.2	0.7
Al_2O_3	7.8	17.3
MgO	1.9	2.4
CaO	13.6	1.7
Fe_2O_3	13.4	8.2
MnO	11.1	2.0
Na_2O	1.5	1.5
K_2O	1.1	2.3
P_2O_5	9.7	0.1
other	0.5	0.2
LOI	15.7	12.2
SUM	99.7%	99.6%
CO_2	2.9	6.6
S	0.1	0.3
C/Ca ratio	0.27	5.09
3P/5Ca ratio	0.95	0.10
ppm		
Ba	2915	1014
Cr	34	89
Nb	5	5
Ni	69	94
Sc	18	18
Sr	1161	184
Y	390	25
Zr	46	94

Plant fossils

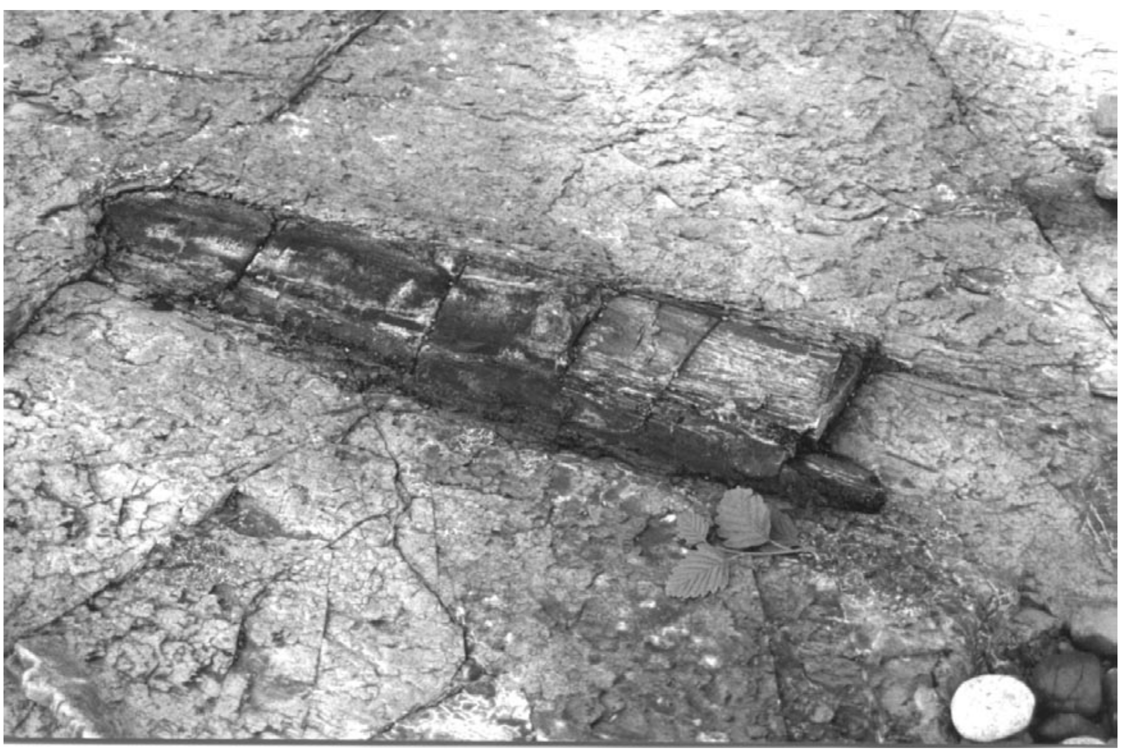
Above: Coalified vegetation; Maastrichtian Gabriola Formation (pencil for scale).

Well-drillers have come across considerably thicker deposits than this, but always in a limited area, consistent with it having been waterlogged wood.

No microscopic fossil research has been done that I am aware of on Gabriola's "coal".

Petrified log in shale. Campanian.
D = 25.5 cm max. observed, but 17.6 cm after correction for flattening.

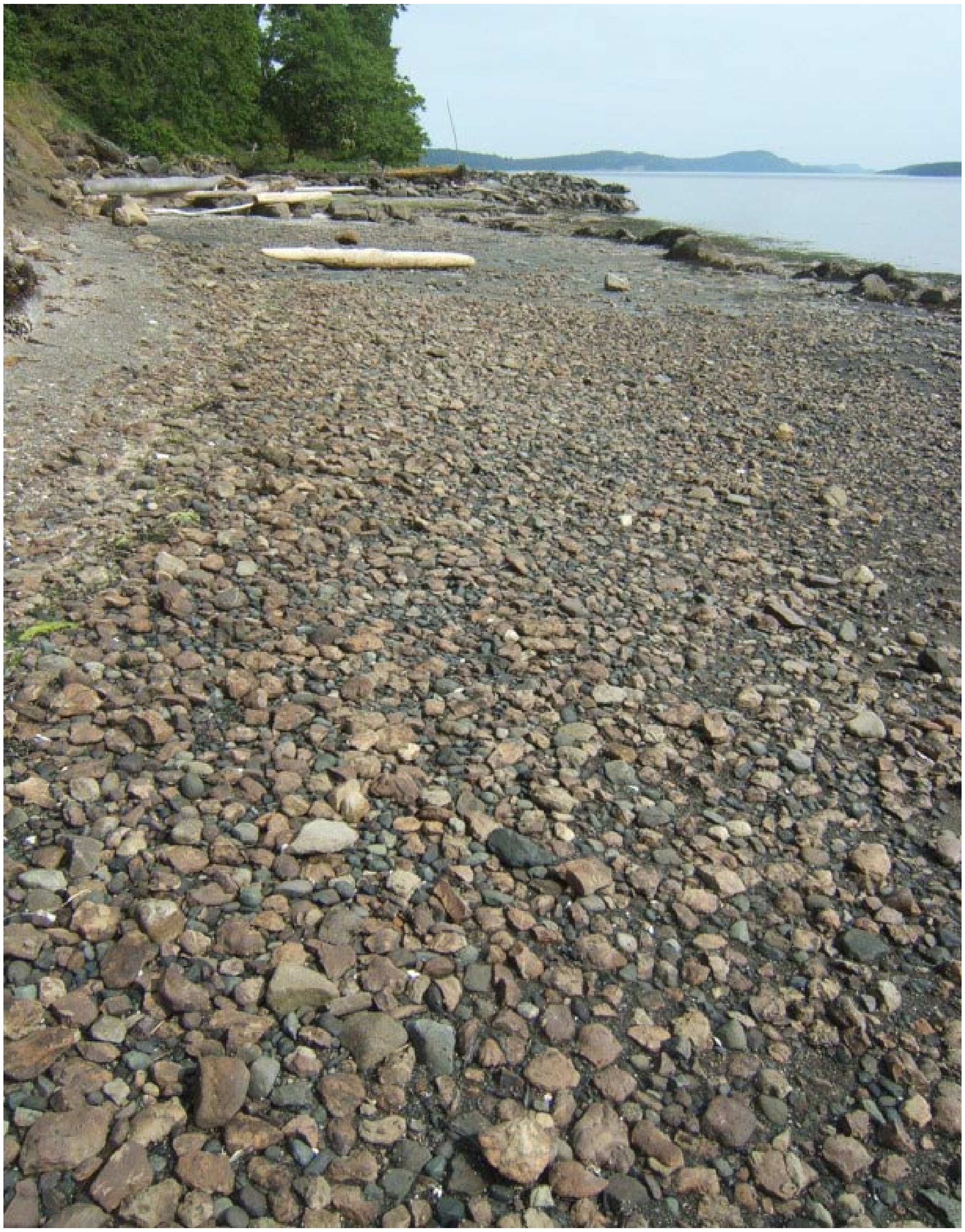
If this *were* to be the DBH (diameter at breast height), the tree *might* have been *ca.* 15 m tall.



Trace fossils (ichnofossils) (reference File: 226c)

Inoceramid nodules

Cemetery Beach, Gabriola. Practically all of the brown rocks in this picture are inoceramid nodules, many of which have trace fossils on their surface. The nodules are all that remains of the eroded shale bluff to the left. The shale itself is quickly broken down to sand-sized particles and removed in winter storms that move up from the SE seen here in the distance.



One geologist visiting the island in the 1800s suggested these nodules might be useful for manufacturing hydraulic cement.

The interiors of these nodules are a featureless "flint" of *calcite* and *chlorite*; they are not concretions in that they are not just well-cemented clasts of the host mudrock. The preservation of the surface features is probably due to the presence of *calcium sulphate*, (plaster of Paris), which has made a cast of the suface of the buried decaying soft tissue of the inoceramids. The orange coating is rich in iron and manganese deposited on the relatively high-pH nodules from slightly acidic meltwater at the end of the ice age.

Some of the ichnofossils show tiny, but long and very narrow structures, sometimes identified as plant material on account of their occasional dendritic (treelike) structure; however, the "branches" of these structures too under the microscope can be seen to have once been hollow and fit the description of chondrites.

Trace fossils not related to inoceramids

An isolated group of burrows? About 80 mm long and 10 mm wide. Flat. No *calcite*.

Petrographic reports of inoceramid nodules

Hand sample report—Sample 06-GAB/NOR

Note: This sample was taken from near the Community Cemetery site on Gabriola and is a slice of a supposed inoceramid foot? found embedded upright in the shale with its rounded end at the bottom. This sample was unusual in that instead of one central core, it had two of unequal size. This is uncommon, but probably of little significance beyond demonstrating that the central core is an artefact of compaction-lithification. It is unlikely to be a remnant anatomical feature. Slices with one central core are common at this site. It is also not unusual to find at other sites on Gabriola smaller, disc, fossil nodules with a central core,sometimes eroded away leaving a hole, that are not inoceramids.

Nodules from shale deposits (Northumberland Formation, Nanaimo Group) on Gabriola Island, known to contain calcium, iron, and manganese, and apparently the result of mineralization of voids in the original mud (presumably prior to compaction and lithification). They have little of no internal structure; yet their outer surface is very commonly coated with the casts of thalassinoides burrows.

The hand specimen [50 mm diameter] is dark greenish-grey, very fine-grained, with a suggestion of an outer rim (paler coloured) and containing two circular features in the core [one about 4 mm and the other 2 mm], both rimmed by fine sulphides. Offcut very weakly magnetic and strong reaction to cold dilute HCl, but virtually no stain for K-feldspar.

Chemistry

Numbers are % wt., ppm (10^{-3} ‰), or ratio of atoms.
C/Ca<<1 =Ca as silicate; C/Ca≈1 =Ca as *calcite*, C/Ca>>1 =*calcite* and free carbon
3P/5Ca<<1 =Ca not as *apatite*; 3P/5Ca≈1 =*apatite*, 3P/5Ca>>1 =very rare.

	Cemetery Beach	Cemetery Beach	Spring Beach	Cemetery Beach	Easthom Road
	nodule	foot	nodule	host shale	Spray shale
	01-GAB/NOR A302906	16-GAB/NOR A305008	17-GAB/NOR A305008	14-GAB/NOR A305008	15-GAB/NOR A305008
SiO_2	12.4	11.8	13.7	51.0	55.0
TiO_2	0.2	0.2	0.2	0.7	0.6
Al_2O_3	4.0	3.5	4.7	17.3	16.1
MgO	2.1	1.7	2.8	2.4	3.0
CaO	23.9	29.2	21.6	1.7	3.1
Fe_2O_3	14.3	8.1	19.8	8.2	6.3
MnO	11.4	11.7	3.5	2.0	0.1
Na_2O	0.6	0.7	0.6	1.5	2.2
K_2O	0.4	0.5	0.5	2.3	1.9
P_2O_5	5.8	9.6	6.2	0.1	0.1
other	0.2	0.2	0.2	0.2	0.1
LOI	24.1	22.6	26.2	12.2	11.0
SUM	99.4%	99.8%	100.0%	99.6%	99.5%
CO_2	26.0	24.7	26.2	6.6	1.8
S	1.3	1.4	0.2	0.3	0.5
C/Ca ratio	1.39	1.08	1.55	5.09	0.71
3P/5Ca ratio	0.32	0.43	0.38	0.10	0.04
	ppm				
Ba	705	979	819	1014	659
Cr	14	41	21	89	48
Nb	5	5	10	5	5
Ni	77	51	10	94	32
Sc	9	7	11	18	12
Sr	683	1006	670	184	494
Y	185	169	110	25	22
Zr	32	33	47	94	118

Sample 01-GAB/NOR was a "ginger-root" nodule including the weathered rusty surface. The elemental concentration of phosphorous is around 2.5% which is consistent with the nodule being dried clam meat. The phosphorous in the nodule *may* (a supposition only) have been been derived from support structures in the gills of the bivalves.

Sample 16-GAB/NOR was a disc-shaped segment of a "foot" embedded upright in the shale. It was from the same site as 01 but not the same specimen. Note the close match of the chemistry with the nodule.

Sample 17-GAB/NOR was a "ginger-root" nodule including the weathered rusty surface from Spring Beach. At this site there are no inoceramid shells or "feet". Only by searching on several occasions was a nodule found here with an embedded fragment of inoceramid shell. Note the close match of the chemistry with the Cemetery Beach nodule. The manganese:iron ratio is lower, but the total manganese+iron content is about the same.

Sample 14-GAB/NOR was of the shale at Cemetery Beach. This shale has a steely-blue and rust-coloured stains along hairline fracture planes. These stains are presumed to be iron and manganese rich.

Sample 15-GAB/SPY was of the shale along Easthom Road. This shale is from the Spray Formation and lacks inoceramids fossils and steely-blue and rust-coloured stains. Note the lack of manganese.

Thin section—Sample 06-GAB/NOR Notes by *Craig H.B. Leitch, Saltspring Island BC.*

Modal mineralogy in polished thin section is approximately:

carbonate (mainly calcite?)	80%
chlorite	15%
pyrite (partly after marcasite?)	3-5%
quartz	<1%
plagioclase	<1%
K-feldspar	trace
biotite	trace
magnetite	trace

The chlorite group is:
$[Mg,Fe,Mn,Ni,Zn]^{2+}{}_{12-x}\,[Al,Fe,Cr,Mn]^{3+}{}_{x}\,[Si_{8-x},Al_{x}]^{+32-x}\,O_{20}\,(OH)_{16}$; $x \approx 1–3$

The nodule appears to be composed almost entirely of carbonate and chlorite with variable amounts of sulphides; there are only traces of quartz. The bulk of the slide consists of very fine-grained carbonate in a matrix of chlorite, with significant, locally patchy, concentrations of sulphide.

Carbonate, likely mainly calcite to judge by the reaction to cold dilute HCl in the hand specimen, forms minute, rounded subhedra mostly <5 μm in diameter but commonly in aggregates with a suggestion of spherulitic structure, about 15–20 μm in diameter.

Chlorite is interstitial to the carbonate, locally forming a matrix to it, and composed of subhedral flakes, mostly <15 μm in diameter, in places aggregating to as much as 100 μm across. The optical properties (pale greenish-brown, no pleochrosim, near-zero to length slow birefringence) suggest an iron-rich variety, with Fe:Fe+Mg ratio possibly about 0.5–0.6.

Sulphides appear to be mostly pyrite, forming minute subhedra mainly <25 μm in diameter, in places aggregating to 50 μm, with a hint of relic framboidal texture.

Rare quartz forms small subhedral crystals or possibly detrital grains mostly <40 µm in diameter, locally concentrated in patches with coarser-grained carbonate (subhedra up to 100 µm in diameter).

Paler-coloured zones around the internal circular (axial) structures appear to be enriched in carbonate and depleted in chlorite; the weathered? zone around the margin may be similar but is not cut in this section. These axial features show concentric but not radial structure; inside the zone of carbonate enrichment is a 2–3 mm zone of chlorite (and sulphide) enrichment, succeeded inward by an amygdular concentration of coarse, clear calcite (bladed subhedra up to 1.5 mm long with a radial texture) separated from the surrounding rock by a rim of sulphide that appears to be mainly pyrite, in aggregates up to 1 mm long of subhedral cubic crystals <100 µm in diameter (anisotropism in bladed crystals is not strong enough to confirm marcasite, although it is possible that the pyrite has replaced former marcasite) and fine-grained (<100 µm) subhedral carbonate.

The rim locally is up to 1.75 mm thick, and contains euhedral feldspar crystals (that do not look detrital) up to 0.35 mm long. Most of these appear to be plagioclase, but one K-feldpar crystal was indicated by yellow stain in the etched offcut.

Rare euhedral flakes of brown biotite are also present in this zone, and a few euhedral crystals of magnetite up to 100 µm in diameter may explain the magnetism detected in the hand specimen. Within the core of the axial features, there is a very thin (< 100 µm) zone of framboidal pyrite.

The internal structure is limited to the areas around the two axial features, and appears to be concentric rather than radial, suggesting that the bulk of the nodule precipitation occurred throughout rather than progressively from the core to the rim.

There was no indication of pyrolusite in the sample.

Unidentified species in Taylor Bay

The Bob Phelps discoveries, June 30, 2016.

Location is the north shore of the inner part of Taylor Bay. Possibly the Spray Formation at its contact with the overlying Gabriola Formation (sharp), or, Steve Earle suggestion, upper part of a mudstone intertongue of the mainly-sandstone Gabriola Formation.

Anthropod ?

1 metre long;

about 10 cm wide at the “head” (left end seen from seaward side);

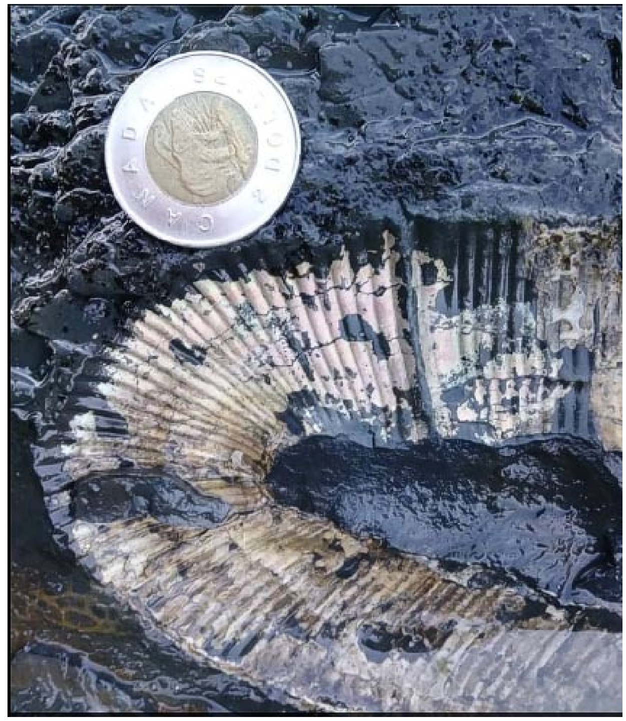
no calcite detected.

Pictures below left to right.

At the same location, lying loose on the beach, but almost certainly from the same level. Inoceramid (calcite rich)? Part of a heteromorph ammonite (2.5 in.)?

Diplomoceras notabile on Whalebone beach

The David Nicholson discovery, posted on FaceBook (Life on Gabriola) January 23, 2019 at 9:56 pm. Very nicely observed and photographed. Coin diameter is 28 mm. A heteromorph ammonite, *Diplomoceras notabile* (Whiteaves), known locally on Hornby Island and a few other locations but never before on Gabriola. (personal communication Jim Haggart)



Above: A related *Diplomoceras* sp. from Hornby Island.

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