

Geology of Coats Marsh area, Gabriola Island, BC—a summary

Definitions of terms in italics as used in [File 690](#) (<http://nickdoe.ca/pdfs/Webp690.pdf>)

area specifically one of the six areas identified in the first pages of [File 690](#).

lake see *marsh*.

marsh specifically the body of open water in Coats Marsh RP, but generally a shallow-water wetland, flooded year round and without trees. Some times identified as “the lake” here and in the Coats Marsh field notes, even though the wetland is technically too shallow to be classified as such.

region all six of the *areas* identified in the first pages of [File 690](#).

subsurface in the context of Gabriola hydrology, water flow (runoff) just a few metres at the most below the surface. Not groundwater.

Bedrock

The bedrock of the *region* is sandstone of the Maastrichtian-age Gabriola Formation of the Nanaimo Group. Outcrops are confined to a few threadbare patches on trails where it appears with a smooth case-hardened dark surface, and to small borrow pits where it appears as sandy-coloured channery that result from spalling. Sandstone bedrock surfaces that have only recently been directly exposed to sun and rain sometimes show glacial striae and there is an example of this at the western end of the South Boulevard in the 707 SW [*area* 6].

The late-Cretaceous Nanaimo Group bedrock was subject to folding in the Eocene and is as a result heavily fractured. Most of these fractures are sub-parallel, bedding-plane perpendicular, linked horizontally only by occasional joints and by thin laminated fine-grained interbeds, and are relatively deep. It is these fractures that form aquifers on Gabriola.

An important addition to the Eocene fractures are fractures in the sandstone that are a result of deformation during the Pleistocene (ice ages) and subsequent post-glacial relaxation. These fractures are close to the surface, seldom more than five metres down.

The quasi-orthogonal geometry of these two sets of fractures plays a major role in determining the flow of surface water, *subsurface* water, and groundwater in the *region*. (Ref. 3, Ref. 9)

Regolith and Soil

All of the pre-glacial regolith and soil on the island was removed during the last glaciation (the Fraser Glaciation) with the possible exception of local pockets of well-sorted (fluvial), stone-free, Quadra Sand. What we have now is either till; post-glacial sediments left by meltwater and the retreating sea; alluvium that is the product of recent weathering and erosion of glacial drift or the bedrock; black organic soil; or even practically no soil at all.

During the Fraser Glaciation, glaciers moved over Gabriola from three different directions at three different times. The initial onslaught of ice was from the Kennedy Lake region on Vancouver Island; however, it has left little evidence of its presence on Gabriola.

The second onslaught was by the massive glacier that moved down the Strait of Georgia from the northwest. This brought with it lodgement till from Vancouver Island containing abundant angular to sub-rounded stones of basalt, often with flat faces, practically all of them now with a

deceptive pale weathering rind or are greenish due to chloritization, not uncommonly scattered with small white quartz amygdules very thinly ringed with probably greenish pumpellyite and intruded with stringers of quartz or quartz-plagioclase. The till also contains occasional quartz diorite, granodiorite, and diorite, all of which is well-weathered and hornblende-rich compared to the plutonic rocks from the mainland. Also-rans include argillite and remnants of quartz or aplite veins in basalt including rare white pebbles of water-rounded silica, bits of silica-plagioclase-coated fracture planes and vugs, dallasite, and silica-cemented breccia.

The third phase of the glaciation was from Howe Sound and the Coast Mountains when ice from the mainland icecap moved across the strait and across Vancouver Island to the open Pacific. It was this glaciation that brought erratic boulders to the *region*, some weighing tens of tonnes. Most are either granodiorite, tonalite (quartz diorite), diorite, or any of the similar plutonic rocks, only lightly-weathered and relatively rich in biotite, or are dacite, a fine-grained volcanic equivalent. Also from the mainland are a variety of metasomatic and contact metamorphic rocks, commonly green due to the presence of chlorite, amphiboles, clinozoisite, or epidote; and extrusive volcanic rocks such as andesite. Granite is absent.

Lag gravel remnants of the Strait of Georgia lodgement till along with minor ablation till are often seen embedded in stretches of the heavily-compacted dirt trails throughout the *region*. Trails underlain by lodgement till, which was compressed so much it is practically impermeable, become very muddy and puddly in winter. Although sandstone fragments in this gravel may have originally been in lodgement till, it is more likely, when present in copious amounts in sandy soil with igneous stones few or absent, that they are the result of post-glacial bedrock weathering (oxidation of mafics, frost) and erosion (rain and human activity).

The degree of re-working of till is dependant to some extent on the elevation of the land above sea level (AMSL). Fossil sites on Gabriola have indicated a highstand sea level of more than 104 metres AMSL (Ref. 5, Site 4), but less than 110 metres AMSL (Ref. 5, Site 3), which, interestingly, is a contour that cuts right across Coats Marsh East [*area 2*] as shown in the following soil type map from Kenny (Ref. 4). The sea evidently became ice-free at its highstand, the melting accelerated by undermelting, while ice above the highstand under a thermal blanket of ablation till remained as an icecap the subsequent slow melting of which created great flows of meltwater and various glaciofluvial accumulations of well-sorted sediments in depressions at lower elevations.

A thorough and impressively detailed survey of Gabriola soils can be found at Ref. 4, the map from which is partly reproduced here. Originally commissioned by Agriculture Canada, its focus is inevitably on the pedological rather than the geological aspects of the soil, and the geology is a little imprecise and is out-of-date as are some of the natural vegetation notes; but nevertheless, it remains a valuable reference especially since it was based on actual ground surveys, not interpretations of aerial or satellite images. It is to be noted that the gleysols in Coats Marsh RP are said to be very rare in the Gulf Islands. (Ref. 10A, p.28)

The Coats Marsh RP Management Plan has reports on soils at five study sites made by the Nature Trust (TNT) of BC. (Ref. 1A, pp.12–15) Unfortunately all five sites had soils described as being of morainal (glacial deposited) origins, which doesn't adequately describe the pedological diversity and consequent ecological diversity of the *region*. The 707 CP Management Plan (Ref. 2, p.22) has a very brief summary of data from Kenny (Ref. 4) relevant to the whole of the existing park.

Hydrogeology

See [Ref. 9](#) for a detailed account of the hydrogeology of Coats Marsh and its environs.

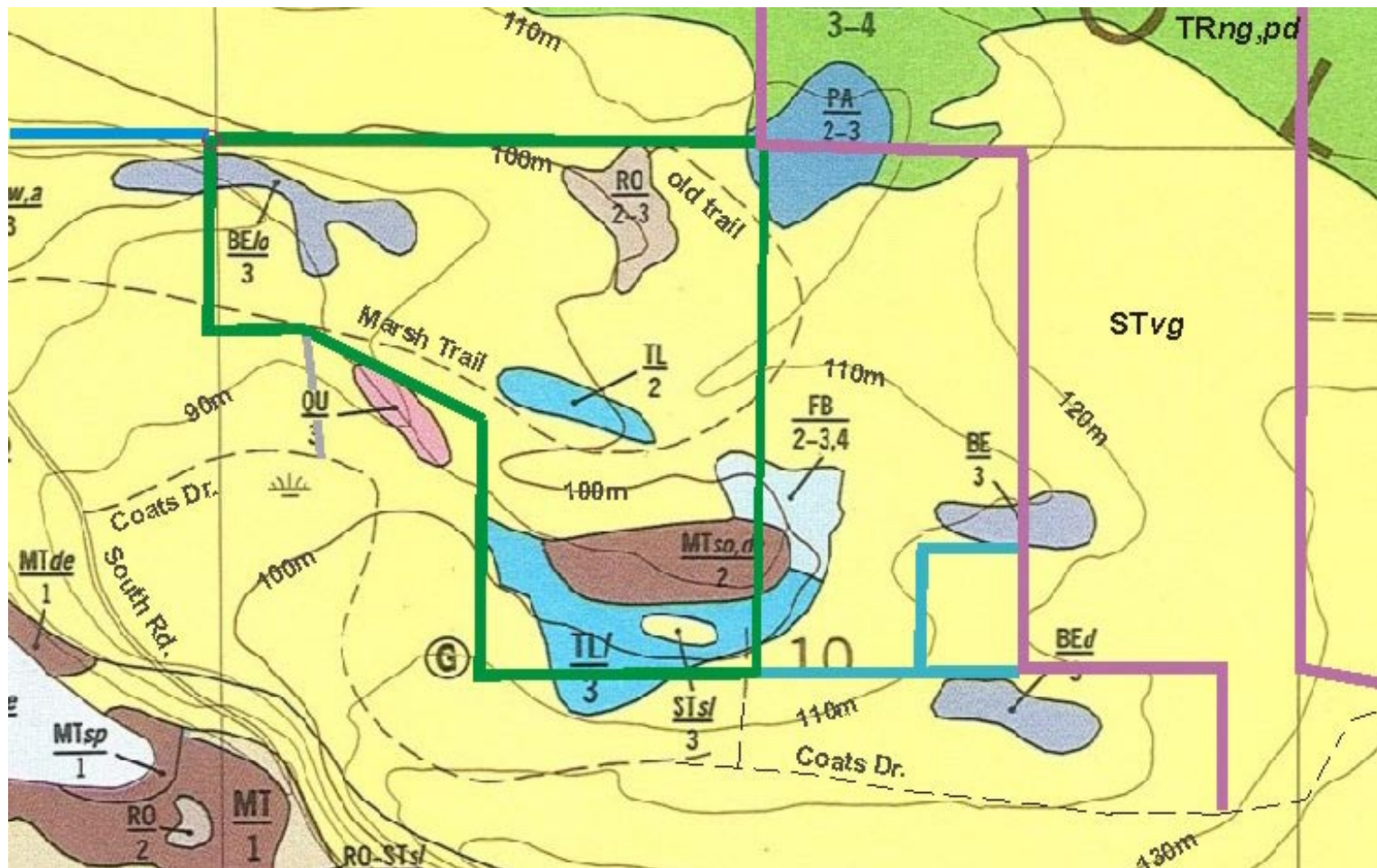
In summary, the “lake” in the park (technically a shallow-water wetland but commonly called a lake) is a “puddle” in that it retains water that collects in the depression in winter, and this water remains throughout the summer during which water is lost through evaporation and the transpiration of vegetation but is only added to by light summer rain. There are no springs feeding the lake although when East Path Creek is flooding, some local flow in the delta is subsurface, possibly following rotted-out tree roots, emerging from underground at the shoreline of the late-Pleistocene meltwater lake. Addendum Jan. 2020, Ref. 9.


The lake only manages to retain water so efficiently because its bed is a thick layer of clay which is so impermeable as to completely seal it and prevent any seepage into the fractured sandstone bedrock below. This clay is the result of a weathering of an accumulation of glacial flour rich in feldspars that gathered there during the great melt of ice at the end of the last ice age; ice which was so thick that its melting took hundreds of years.

Augering into this clay has revealed what geologists call dropstones; these are plutonic rock fragments most likely brought here by a glacier from the Coast Mountains and which were deposited in the glacial flour by melting icebergs. The longevity of the lake is further evidenced by layers of diatomaceous earth beneath the modern sediments. Radio carbon dating of, not these, but similar layers on Gabriola, indicate that they formed during what is known as the “hypothermal”, a climatic period after the end of the last age which lasted for several thousand years during which the climate was warmer and drier than it is now, and during which there were probably no extensive forests on Gabriola.

Over time of course, the lake was gradually filled with sediment. It may have been dredged out by early settlers, but this is not known for sure. Its nature was changed in the 1930s when the sandstone ridge at the western end of the lake was blasted out and the then existing water drained away by farmers. This drainage channel is now blocked by the weir at the western end.

Nearly all of the water that replenishes the lake every winter comes from land to the east and northeast, primarily from seasonal wetlands in the so-called NE Arm, probably part of the post-glacial lake system but now dry in summer, and East Path Creek, [Ref. 11](#), which only runs in winter. Any surplus water drains into Coats Marsh Creek and eventually Hoggan Lake and the ocean.



Soil types. BE (purple) = Brigantine; FB (light blue) = Fairbridge; MT (brown) = Metchosin; PA (blue) = Parksville; QU (pink) = Qualicum; RO (grey) = rock; ST (yellow) = Saturna; TL (turquoise) = Tolmie; TR (green) = Trincomali
d = deep; *de* = diatomaceous earth; *l* = shallow lithic; *lo* = loam cap; *ng* = no gravel; *pd* = poorly drained;
sl = very shallow; *so* = shallow organic; *sp* = peat; *vg* = very gravelly; G = gravel pit (now zoned RR); 10 = Sec.10;
 = marsh or swamp (now zoned RR); soil type underline slope (1 = level, 2 = nearly level, 3 = very gentle, 4 = gentle).

The following is my personal very simplified and brief summary of data in Ref. 4 and should not be taken as being authoritative. The source must be consulted and cited for details.

species = now absent, species/species = now only occasional or rare.

RO: shallow soil (<0.1m) over bedrock. Mosses, grasses, flowers, ~~stonecrop~~, scattered dwarf Douglas-fir, and arbutus.

STvg, sl: thin (<1.0m) loose sandy loam, well-drained, becoming stoney with depth, over sandstone bedrock. Douglas-fir, scattered arbutus, and some grand fir, salal, bracken, and dull Oregon-grape. (*Brunisol sombric, orthic*)

QU: gravelly sandy loam, deeper than Saturna (**ST**) soil (<1.5m), well drained. Douglas-fir, grand fir, scattered arbutus, ~~shore pine~~, stunted salal, and bracken. (*Brunisol dystric, orthic*)

TRng, pd: glaciofluvial sandy loam, similar to Qualicum (**QU**) soil but with less gravel at the surface over compact (lodgement) till, imperfectly drained. No marine component. Douglas-fir, some grand fir, scattered arbutus, salal, bracken, and dull Oregon-grape. (*Brunisol dystric, gleyed*)

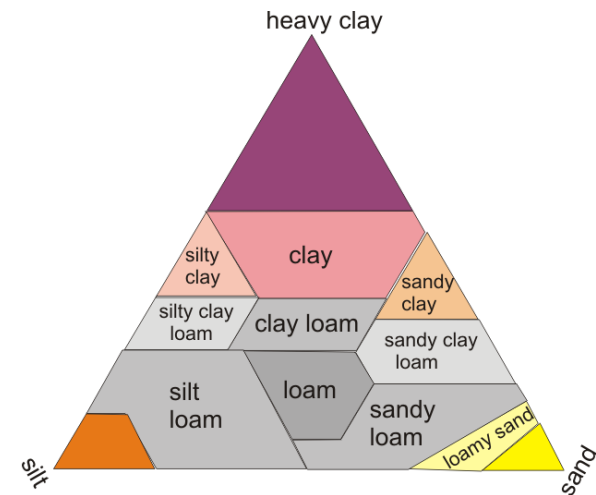
BE, d, lo: deep glaciofluvial to fluvial deposits, well sorted, loamy sand to sandy loam over loam, imperfectly drained, broadly similar to the more weathered Parksville (**PA**), Tolmie (**TL**), and Fairbridge (**FB**) soils. Too high AMSL to be marine in some cases. Cedar/~~cedar~~, alder, Douglas-fir, sword fern, salal, and bracken. (*Brunisol dystric, gleyed*)

PA: soil with a silty clay loam base, poorly drained. Cedar/~~cedar~~, alder, ~~hardhack~~, and willow. (*Gleysol humic, orthic*)

TL, l: deep (>1.0m) silty clay loam textured with loamy sand phases (l), poorly drained, ref. authors say marine but I think glaciofluvial outwash, stone free, (drop stones in gleysol, Ref.5, Site 4, says marine undermelt till, but elevation AMSL a little too high for that). Ref. 1, p.12 suggests TL (no l) soil may have been an aeolian dune. I think this highly unlikely; a Quadra Sand component possibly. Cedar, alder, maple, salmonberry, sword fern, sedges, horsetail/~~horsetail~~, bracken, ~~skunk cabbage~~. (*Gleysol humic, orthic*)

FB: deep (>1.5m) silt loam to silty clay, stone-free, wet, similar in origin to Tolmie (**TL**) soil but more weathered to clay, imperfectly drained. Alder, ~~cedar~~, Douglas-fir, maple, sword fern, salal, nettles, and bracken. (*Luvisol gray, gleyed brunisolic*)

MTso, de: organic (sedge and woody), very poorly drained, not investigated >2m by ref. authors, but underlain by gleysol (**FB**?), see text. The slope class 2 indicates the “lake” was drained at the time of the survey. Sedges, grasses, rushes, scattered willow, and ~~hardhack~~/~~hardhack~~. (*Humisol typic*)



Gallery

Identifying what, and where, well-weathered and eroded rocks are, and are from, without breaking them open and subjecting them to petrographic and geochemical analysis is an almost impossible task. A “real” geologist would never attempt it. Expect mistakes! All the rocks are from Coats Marsh RP or close by unless stated otherwise.



Late-Cretaceous Gabriola Formation sandstone is bluish-grey, but is almost never seen unweathered outside of quarries. This one is at Twin Beaches. The first stage of weathering forms a sandy-coloured rind due to the oxidation of biotite and hornblende to form Fe^{3+} oxides, mainly hematite Fe_2O_3 . A second stage of weathering hydrates the surface of the rind to form a dark-brown almost black coloured goethite $\text{FeO}(\text{OH})$. Goethite is a very stable oxyhydroxide of iron.



The weathering rind of sandstone is very strong—the “rust” spot-welds grains, mainly feldspar and quartz, together. But this “case-hardening” also sets up compressive stress in the rind because of its differing thermal properties from the parent rock it’s attached to beneath it. When fractures do occur in the rind, it spalls and the compressive stress breaks it up into fragments called channery, much in the same way and for the same reason that tempered glass shatters (dicing fracturing).

Left: A visitors’ view of the sandstone bedrock. Rarely seen except along trails, this patch on the East Path in Coats Marsh East. Well-weathered at the surface with goethite cementation and spalled patches creating channery.



Above: Lag gravel embedded in the southern end of the Three Gates Trail. Probably mostly basalt with weathering rinds of various colours—orange, brown, greenish, black—resulting from the iron oxides and oxy-hydroxides derived from pyroxenes. Ref. 5A

Below: Lag gravel from the dry bed of Coats Marsh Creek. Most igneous stones are also probably basalt with a weathering rind that is light coloured due to the leaching of the alteration products of the basalt's iron-rich pyroxenes leaving plagioclase, probably anorthite, behind. These stones' interiors are the usual fine-grained grey of basalt or the greenish-grey of chloritized basalt.

The absence of any plutonic rock points to these being the remnants of the lodgement till of the glacier that moved down the Strait of Georgia from the northwest bringing with it an assortment of rocks from the east coast of Vancouver Island north of Nanaimo.

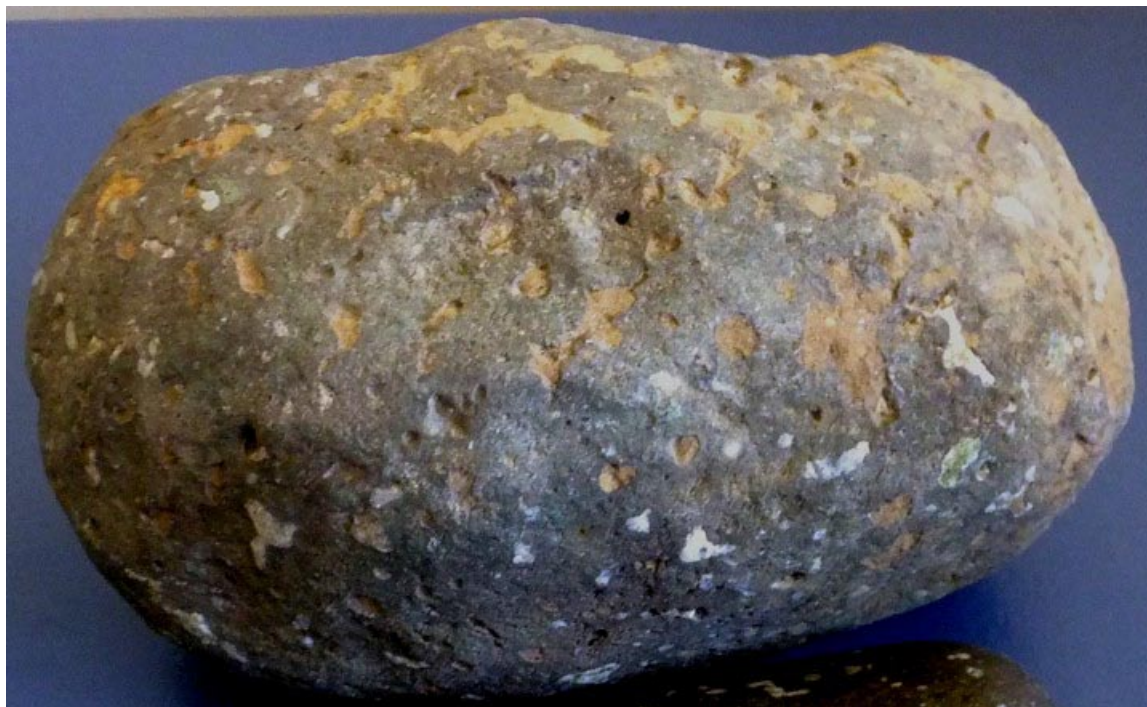


Above: Large erratic boulders in the park are commonly intrusive rocks, granodiorite, tonalite, or similar. While the surfaces are very weathered and covered with lichens, the rock just below them is fresh and the mafic minerals in it unweathered. This is possibly ablation till from the glacier that moved down Howe Sound from the Coast Mountain icecaps at the peak of the Fraser Glaciation.



Left: Chip of the erratic shown above. A granodiorite type felsic plutonic (intrusive) rock (granular with quartz, mainly plagioclase feldspars, biotite, hornblende, muscovite) extremely common in the Coast Plutonic Complex on the mainland..

Right: A very large erratic just across Coats Drive from the park, note the dog. A similar plutonic rock to those found within the park; a chip of it looks like quartz diorite. Boulders this size of this kind of rock are rare on the east coast of Vancouver Island.



Basalt stone with amygdules, gas cavities filled with minerals, in this case quartz. Fairly common. The orange stain is limonite, which frequently occurs on weathered mafic rocks.

Similar looking rocks, seen much less often in the park, are basalt porphyries or andesite in which the white specks are plagioclase phenocrysts.



Left: A few mafic stones in the till in the park have a powdery red coating rather than the usual orange.

Probably limonite with a high lepidocrocite content, an iron oxy-hydroxide related to goethite that some references say forms underwater, which possibly in this case would be ice-age meltwater.

Left: Left: Tonalite pebble weathered but otherwise unremarkable except for the abundance of stacked laths of hornblende and little biotite.

Left: Middle: Quartz. Chert? Very hard. There is some chert at Nanoose.

Left: Right: Argillite (non-fissile slate). Soft. Uncommon. Quite possibly from the Nanoose Peninsula where there are outcrops of the Sicker Group, though it is also found in the Gambier Group in Howe Sound.





Left above: Occasionally basalt pebbles in the till have stringers of quartz, which is interesting in that exactly the same is seen in Karmutsen Formation basalt bedrock at Neck Point just north of Nanaimo, *right above.* Too common to be absolutely sure of a connection though.



Left: Fragments of plutonic rock in the till in the park are, in contrast to the large erratics, well-weathered, sometimes to the point where most of the mafic minerals have gone leaving only a pitted white crust making it look like trondhemite. The hornblende crystal habit is commonly acicular, which is more usual in local Jurassic Vancouver Island Intrusives than much younger samples from the mainland.

Below: Plagioclase coated basalt revealed by a hammer.



Also-rans in the till—unusual specimens that are only discovered after lengthy searches—are commonly metamorphic whose composition is hard to impossible to determine in hand samples and, by themselves, are unlikely to give a clue as to their geographical origin. But they're interesting; it's not just sandstone you find here. The notes accompanying these pictures should not be taken on any account as being authoritative.



Left. The crust of what I took at first glance to be andesite, an extrusive volcanic rock common on the mainland. *Right.* But the unweathered interior however was black, with only a few phenocrysts of plagioclase. Under the microscope it appeared to be almost all amphibole, making the rock amphibolite. I suspect that the amphibole is actinolite not the far more common hornblende. The crystals are black and bladed in columnar aggregates like books of mica, randomly oriented like felt, occasionally with fine hair-like splinters that, when highly magnified, show some turquoise. Dusty with minute crystals of limonite. Maybe the result of hydrothermal alteration of basalt within the Gambier or Bowen Island Groups in Howe Sound, or metamorphosed remnants of intruded basalt from Nanoose.



Left. No not a flowerstone (basalt porphyry), they're rare on Gabriola. The white "phenocrysts" in places tinged green are aggregates of soft crystals with no discernible habit, possibly heulandite. The matrix is clay, whitish but loaded with tiny fragments of black amphibole and locally some pistachio-green microcrystals too small to identify. The surface is lightly scratched and pitted, the scratches running in all directions. The rock is heavy—see next.



Left: Similar to the previous rock with a stained mottled surface. The interior has a high concentration of clear concretionary quartz and coarse-grained milky plagioclase with sparse fine-grained mafic interstitial material, probably an amphibole. Biotite sparse or absent. Very little else. A hydrothermal quartz vein perhaps?

The rind of this sample is thin, white, and chalky.

This is only a small sample of stones to be found in the soil and till. They represent what might be loosely characterized as a disseminated *mélange*—rocks of differing sizes, lithologies, geographical origins, and ages going back over 300 million years from the Paleozoic to almost the present. ◇

References

- Ref. 1: Coats Marsh Regional Park — 2011–2021 Management Plan, RDN Recreation and Parks Department, August 29, 2011. Online at <https://www.rdn.bc.ca/2222>
- Ref. 1A: Coats Marsh Regional Park — 2011–2021 Management Plan, Appendix A, Ecological Features and Management Recommendations
- Ref. 2: 707 Community Park — 2010–2020 Management Plan, RDN Recreation and Parks Department, August 2010. Online at <https://www.rdn.bc.ca/cms.asp?wpID=2019>
- Ref. 3: Doe, Nick, Fractures in Gabriola Formation sandstone and their effect on aquifers, *SILT* 20, March 2017. Online at <https://nickdoe.ca/pdfs/Webp573.pdf>
- Ref. 4: E.A. Kenny et al., Soils of the Gulf Islands of British Columbia, vol. 4, Soils of Gabriola and lesser islands, Agriculture Canada, 1990. Online at http://www.env.gov.bc.ca/esd/distdata/ecosystems/Soils_Reports/bc43-4_report.pdf
- Ref. 5: Doe, Nick, Gabriola's glacial drift - 13, Ice-age fossil sites on Gabriola, *SILT* 8-13, January 2014. Online at <https://nickdoe.ca/pdfs/Webp533.pdf>
- Ref. 5A: Doe, Nick, So what colour is basalt?, *SILT* 3, March 2012. Online at <https://nickdoe.ca/pdfs/Webp510.pdf>
- Ref. 9: Doe, Nick, Hydrogeology of Coats Marsh, Gabriola Island, May 2015 plus 2019 and 2020 Addenda. Online at <https://nickdoe.ca/pdfs/Webp668.pdf>
- Ref. 10A: Terrestrial Ecosystem Mapping of the Coastal Douglas-Fir Biogeoclimatic Zone, June 2008. Online at <http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=15273>
- Ref. 11: Doe, Nick, Locations and names of wetlands and waterways on Gabriola. Online at <https://nickdoe.ca/pdfs/Webp661.pdf>